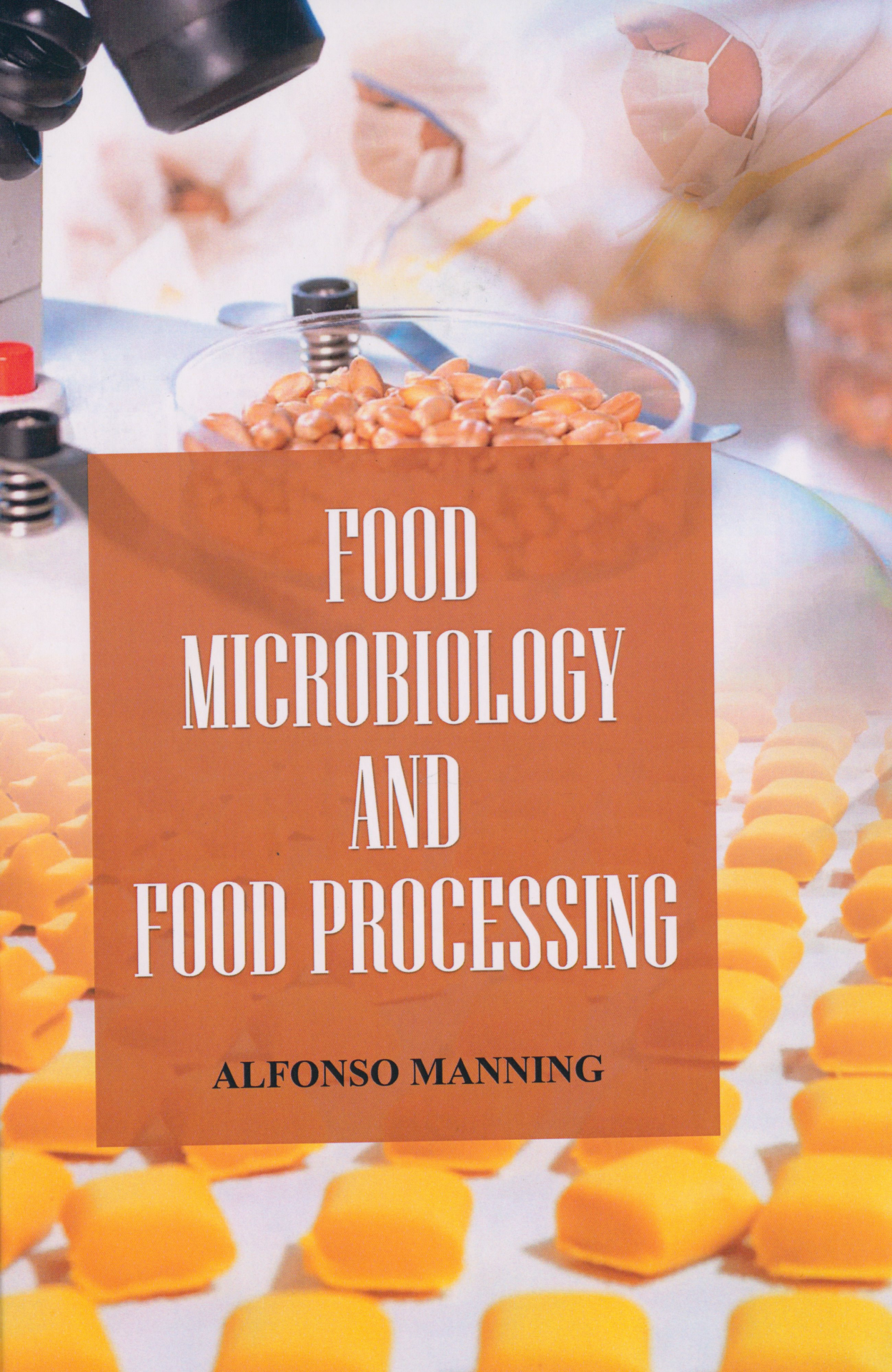


FOOD MICROBIOLOGY AND FOOD PROCESSING

ALFONSO MANNING

Food Microbiology and Food Processing

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Alfonso Manning

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PREFACE

The scope of food microbiology is vast and spreading very rapidly. The study of microorganisms which have both positive and negative effects on the quality and safety of raw and processed foods.

Microbiology is important to food safety, production, processing, preservation, and storage. Food microbiology students use a wide variety of modern technologies from fields including immunology, microbiology, and molecular biology. Microbes such as yeasts, molds, and bacteria are being used for the production of foods and food ingredients. Beneficial microbes are exploited in the fermentative production, processing, and preservation of many foods and beverages. Spoilage microorganisms cost food producers, processors, and consumers millions of dollars annually in lost products. Lost productivity resulting from illness caused by foodborne microorganisms is an enormous economic burden throughout the world. The study of food microbiology includes understanding not only the factors influencing the growth of microorganisms in food systems but also the means of controlling them.

Food processing, any of a variety of operations by which raw foodstuffs are made suitable for consumption, cooking, or storage. A brief treatment of food processing follows. For fuller treatment of storage methods, Food processing generally includes the basic preparation of foods, the alteration of a food product into another form (as in making preserves from fruit), and preservation and packaging techniques. A number of food-processing innovations have even resulted in new products, such as concentrated fruit juices, freeze-dried coffee, and instant foods. Foods and food supplements have also been processed from such hitherto untapped sources as oilseeds (chiefly protein-rich soybeans and cottonseeds); mutant varieties of crops; leaves, grasses, and aquatic plants; and highly nutritious fish meal and concentrates.

Food processing is the set of methods and techniques to transform raw ingredients into food for consumption by humans. The food processing industry utilizes these processes. Food processing often taken clean, harvested or slaughtered and butchered components and uses these to produce attractive and marketable food products. Similar process are used to produce animal feed.

This book will be proved as an useful reference to get first hand information of food microbiology for the people who are working in food-processing industries, state and local government agencies and in academic institutions.

– Alfonso Manning

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Scope of Microbiology

The advent of new technologies and growing recognition of the enormous degree of microbial diversity has revolutionized our understanding of microbiology as a discipline. Microbiology is moving into a new era that focuses less on specific organisms and more on the processes and mechanisms that link them. *Microbiology* embraces this new era by encompassing the discipline in its broadest sense. We take an integrated approach to microbiology, bridging fundamental research and its clinical, industrial and environmental applications to create a single information resource for all who share an interest in microbial life.

The highest-quality and perspectives highlighting important developments in our understanding of bacteria, archaea, viruses, fungi and protozoa, their interaction with their environments, how these organisms are harnessed in human endeavour and their impact on society. Also featured are timely summaries of significant research papers, as well as monthly updates on the latest developments in microbial genomics, post-genomic biology and infectious diseases. In line with our ongoing ambition to overcome the traditional barriers between bacteriology, virology, mycology and archaeal and protozoan biology, articles are tailored to appeal to microbiologists of every persuasion and at every level. The scope of the journal encompasses, but will not be limited to, the following fields pertaining to bacteria, archaea, viruses, fungi and protozoa:

- Biochemistry, physiology and molecular biology
- Genetics and genomics
- Ecology, evolution and biodiversity
- Cellular microbiology

- Environmental microbiology
- Pathogenesis and host defence
- Clinical and diagnostic microbiology
- Infectious diseases
- Antimicrobial therapies and vaccines
- Epidemiology and public health microbiology
- Applied and industrial microbiology
- Microbiology education
- Microbiology and society.

If a career involving microbes is in your future, you'll want to learn about the educational requirements and possibly find a mentor. You may not encounter any microbiologists in your everyday activities or even know of anyone who works as a microbiologist. But the efforts of thousands of these scientists to better understand our planet's microscopic inhabitants affect you in many ways every day.

Microbiologists' research helps keep your food from making you sick and your drinking water clean and safe.

They track down the culprits behind mysterious new illnesses and harness microbes' abilities to make medicines, industrial enzymes, food ingredients, and many other useful products. Microbiologists work behind the scenes in hospital labs to pinpoint the germ making you sick so your doctor can prescribe the right treatment, and they figure out the basic workings of infectious microbial cells so that drug makers can devise potent new medicines.

They solve environmental problems by using microbes in bioremediation, and they explore oceans, caves, deserts, and even Antarctica's ice to learn how microbes affect the workings of our planet.

You might expect to find microbiologists working at research universities or in the sprawling complexes of pharmaceutical companies. But microbiologists also work in the food industry, water treatment, agriculture, pollution control, biotechnology, energy development, museum preservation, and many other disciplines.

Microbiologists also find jobs in government agencies and labs, such as the National Institutes of Health and the Environmental Protection Agency.

Microbiologists can be found in a variety of settings, from the traditional laboratory to the woods.

Because there are so many different species of microbes out there and they do such very different things, no one microbiologist can study every kind of microorganism. Microbiologists and other scientists who study microbes usually focus on a particular microbe or research area.

Here are a few examples:

- Bacteriologists focus specifically on bacteria and how they help or hurt us.
- Virologists specialize in viruses and how they infect cells.
- Mycologists study fungi in particular.

- Protozoologists devote their efforts to protozoa.
- Epidemiologists investigate infectious disease outbreaks to learn what caused them and if we're facing a deadly new microbe.
- Immunologists study how the body defends itself against microbial invaders.

BENEFITS

While some fear microbes due to the association of some microbes with various human illnesses, many microbes are also responsible for numerous beneficial processes such as industrial fermentation (*e.g.* the production of alcohol, vinegar and dairy products), antibioticproduction and as vehicles for cloning in more complex organisms such as plants. Scientists have also exploited their knowledge of microbes to produce biotechnologically important enzymes such as Taq polymerase, reporter genes for use in other genetic systems and novel molecular biology techniques such as the yeast two-hybrid system.

Bacteria can be used for the industrial production of amino acids. Corynebacterium glutamicum is one of the most important bacterial species with an annual production of more than two million tons of amino acids, mainly L-glutamate and L-lysine.

A variety of biopolymers, such as polysaccharides, polyesters, and polyamides, are produced by microorganisms. Microorganisms are used for the biotechnological production of biopolymers with tailored properties suitable for high-value medical application such as tissue engineering and drug delivery. Microorganisms are used for the biosynthesis of xanthan, alginate, cellulose, cyanophycin, poly(gamma-glutamic acid), levan, hyaluronic acid, organic acids, oligosaccharides and polysaccharide, and polyhydroxyalkanoates. Microorganisms are beneficial for microbial biodegradation or bioremediation of domestic, agricultural and industrial wastes and subsurface pollution in soils, sediments and marine environments. The ability of each microorganism to degrade toxic waste depends on the nature of each contaminant. Since sites typically have multiple pollutant types, the most effective approach to microbial biodegradation is to use a mixture of bacterial and fungal species and strains, each specific to the biodegradation of one or more types of contaminants.

Symbiotic microbial communities are known to confer various benefits to their human and animal host's health including aiding digestion, production of beneficial vitamins and amino acids, and suppression of pathogenic microbes. Some benefit may be conferred by consuming fermented foods, probiotics (bacteria potentially beneficial to the digestive system) and/or prebiotics (substances consumed to promote the growth of probiotic microorganisms). The ways the microbiome influences human and animal health, as well as methods to influence the microbiome are active areas of research.

Research has suggested that microorganisms could be useful in the treatment of cancer. Various strains of non-pathogenic clostridia can infiltrate and replicate within solid tumors. Clostridial vectors can be safely administered and their potential to deliver therapeutic proteins has been demonstrated in a variety of preclinical models.

INTRODUCTION TO SCOPE OF MICROBIOLOGY

Definition: It is the study of living organisms of microscopic size, that include essentially bacteria, fungi, algae, protozoa and the infectious agents viruses.

THE DISCOVERY OF MICROORGANISMS

Roman philosopher Lucretius (about 98–55 B.C.) and the physician Girolamo Fracastoro (1478–1553) recommended that infection was caused by invisible living creatures. The first person to examine and explain microorganisms was the part-time microscopist Antony van Leeuwenhoek (1632–1723) of Holland. In 1673 Leeuwenhoek sent detailed findings to Royal Society of London. He called such minute organisms as animalcules. It is clear from that he observe both bacteria and protozoa. some important events that leads to the discovery of microbiology is summarized as follows.

a. In 1546, Fracastoro suggests that invisible organisms cause disease
b. During 1590–1608, Jansen develops first useful compound microscope
c. In 1676, Leeuwenhoek discovers "animalcules"

THE ARGUMENTS OVER SPONTANEOUS GENERATION

Statement of spontaneous generation: living organisms could develop from non-living matter. This outlook finally was confront by the Francesco Redi (1626–1697), who carried out a by a series of experiments on decaying meat and its capability to make maggots spontaneously. He placed meat in three containers. One flask was uncovered, a second flask was covered with paper, and the third flask was covered with a fine gauze that would exclude flies. Flies laid their eggs on the exposed meat and maggots developed. In other two container maggots were not produces. On gauze covered container maggots developed on the gauze. In 1748, John boiled mutton broth and then tightly close the flasks. In due course many of the flasks became hazy and contained microorganisms. He state that organic matter has a power to confer the properties of life on non-living matter.

After few years Lazzaro Spallanzani done same experiment with some improved design. He seals glass flasks that contained water and seeds. If the sealed flasks were placed in boiling water for 45 minutes then no growth took place as long as the flask is sealed. He projected that air carried microorganisms to the nutritional medium, but also remark that the external air might be required for growth of animals already in the medium. The supporters of spontaneous generation theory supporters argued that heating the air in sealed flasks destroyed its ability to support life.

Finally Louis Pasteur settle the the matter once and for all. Pasteur designed a swan neck flask which has variety of curves at neck region, while maintaining the ends of the necks open to the atmosphere. Pasteur then boiled the nutrient medium for a some minutes and then allowed it to cool. No growth took place even though the contents of

the flasks were uncovered to the air. He explains that no growth occurred because dust and germs had been entrapped on the walls of the curved necks. If necks is not swan shaped or they were broken, growth occurs. In this way the controversy around the spontaneous germination theory was resolved

Broadly accepted fields of microbiology

- *Bacteriology:* It is the study of *bacteria*
- *Mycology:* It is the study of *fungi,*
- *Phycology:* It is the study of *algae*
- *Protozoology:* It is the study of *protozoans*
- *Virology:* It is the study of viruses.

THE SCOPE AND APPLICATION OF MICROBIOLOGY

Microorganisms were the primary living organisms on our earth. They were omni present. They are more plentiful than any other kind of organism, and probably it represents the largest part from the earth's biomass. The whole ecosystem depends on their activities, and their activities influences the humans in many ways. Hence currently microbiology is a large area with many different specialization; it has a great impact on fields such as diagnostics, medicine, agricultural and food chemistry, ecology, genetics, molecular biology and biochemistry.

One can get the importance of microbiology in the twentieth century by analysing the award of nobel prize in physiology or medicine. More than 33 % of these were given to scientists working on microbiology aspect.

- *Medical microbiology:* It deals with the diseases of human being developed due to harmful effects of microbial pathogens.
- *Public health microbiology:* Here microbiologist tries to control the spread of communicable diseases in the society. Public health microbiologists often monitor community food establishments an water supplies to keep them safe and free from infectious diseases.
- *Agriculture microbiology:* Microbiologist tries to fight against the plant diseases that affect the important food crops, develop techniques to improve the soil fertility and crop yields. Development of biofertilizers and biopesticides are the recent examples.
- *Microbial Ecology:* It is closely related to agricultural microbiology. Microbial ecologist study the relationship between microorganism and their habitats. They are concerned with the contribution of microorganism and their habitats. It also concern with the effect of pollution on microbes.
- *Vaterinary microbiology:* This discipline deals with the pathogen of domestic livestocks and poultry. They control the spread of such diseases. They have the scope of establishing such live stock units.

- *Food Microbiology:* It deals with the food industry. Here microbiologist is responsible microbial aspects of the quality and control. They are responsible for maintain the hygienic environment in the production unit. Many products are there which are processed with the help of microorganism or they are fermentation product of microbial origin. In such units production microbiologist are required. Eg. Single cell protein, ensilage, cheese etc.
- *Dairy microbiology:* This includes microbiology of cream, physical and chemical testing of milk and dairy products and microbiological and physical and chemical properties of raw milk used for processing pasteurised milk.
- *Aero microbiology:* It deals with the study of atmospheric air and environment which includes pollutants as well as bacteria, bacterial spores, fungal spores and viruses etc.
- *Aquatic microbiology:* It deals with the study of microorganisms in aquatic environments.
- *Water and waste water microbiology (Sanitary microbiology):* It deals with the study related to treatment of drinking water supplies and sewage disposal.
- *Geo chemical microbiology:* It deals with the applied areas such as extraction of metal from the ores. Such process is also called bioleaching.
- *Industrial microbiology:* It concerned with the efficient use of microorganisms to produce economically important products and with the development of techniques used to prevent microbial destruction of economically important products formed by other ways. Pharmaceutical industries involving the microbial production of antibiotics, vitamins and aminoacids as well as microbial transformation of steroids. Production units for preparing vaccines and toxods. Production of therapeutics developed by recombinant DNA technology. Industries involved in the microbial production of organic acids and enzyme industries.

THE EARLY HISTORY OF MICROBIOLOGY

Microbiology is the study of microscopic life on Earth. Today Microbiology has numerous applications in disciplines such as medicine, health-care, environmental science, and food science.

As an independent science, modern Microbiology began in the 17th century with the invention of the microscope. The first microscopes were built by Robert Hooke and Antoine van Leeuwenhoek. Robert Hooke was an English scientist, and he was the first person to use the word cell after using his microscope to observe plant cells. In 1665, Robert Hooke published Micrographia in which he described many of his microscopic observations. Antoine van Leeuwenhoek was a scientist from the Netherlands, who also used his microscope to observe living cells. By using pond water samples, Antoine van Leeuwenhoek was able to document the appearances of microscopic organisms

that he viewed with his microscope. The co-invention of the microscope led to a burst of interest in the field of Microbiology. A direct application of the study of microbes is vaccination, which is the process by which artificial means are used to protect an individual from a specific disease. Modern vaccination began in 1796, when an English physician by the name of Edward Jenner demonstrated that people could be vaccinated against smallpox through exposure to cowpox. Cowpox is a disease in cows that is similar to smallpox in humans. Jenner had made the observation that milkmaids seldom suffered from smallpox. To test his hypothesis, Jenner injected cowpox particles into a young boy and then exposed him to smallpox. The child was protected from smallpox disease, and modern vaccination was born.

The origin of microscopic life was a subject of great debate in the early days of Microbiology. The accepted theory throughout the 17th century and into the 1800s was that of Spontaneous Generation.

This theory asserted that living things such as microbes and fruit flies came into existence from nothing. For example if the garbage was left in the street, flies and microbes could arise from nothing to feed on it. This theory was challenged and disproved by Louis Pasteur, a French microbiologist and chemist, in 1861. In a very famous experiment using nutrient broth in a flask, Pasteur demonstrated that the broth would become contaminated and appear cloudy only if it was exposed to air that already contained microbes.

Today the flask is on display in France at the Pasteur Museum in Dole. In addition to disproving the Theory of Spontaneous Generation, Pasteur created an anthrax vaccine and developed the process of pasteurization that is still used today to minimize bacterial growth in many food products.

In addition to his work on vaccines and food safety, Pasteur proposed the Germ Theory of Disease. This theory asserted that many human diseases were the result of infection with microbes, as opposed to other non-biological reasons. Pasteur's theory was proven by Robert Koch, a German physician and microbiologist in 1876. Koch demonstrated through experiments with mice, that the microbes taken from mice infected with a bacterium called Bacillus anthracis could be used to infect healthy mice. Bacillus anthracis is the causative agent of anthrax. The steps used by Koch to prove the Germ theory of disease are referred to as Koch's postulates. In addition to proving Pasteur's theory, Koch is also credited with the discovery of Mycobacterium tuberculosis in 1876, and with the development of the pure culture techniques that are still used today to cultivate many species of bacteria in the laboratory.

TYPES OF MICROORGANISMS

The major groups of microorganisms—namely bacteria, archaea, fungi (yeasts and molds), algae, protozoa, and viruses—are summarized below. Links to the more detailed articles on each of the major groups are provided.

BACTERIA (EUBACTERIA AND ARCHAEA)

Microbiology came into being largely through studies of bacteria. The experiments of Louis Pasteur in France, Robert Koch in Germany, and others in the late 1800s established the importance of microbes to humans. As stated in the Historical background section, the research of these scientists provided proof for the germ theory of disease and the germ theory of fermentation. It was in their laboratories that techniques were devised for the microscopic examination of specimens, culturing (growing) microbes in the laboratory, isolating pure cultures from mixed-culture populations, and many other laboratory manipulations. These techniques, originally used for studying bacteria, have been modified for the study of all microorganisms—hence the transition from bacteriology to microbiology.

The organisms that constitute the microbial world are characterized as either prokaryotes or eukaryotes; all bacteria are prokaryotic—that is, single-celled organisms without a membrane-bound nucleus. Their DNA (the genetic material of the cell), instead of being contained in the nucleus, exists as a long, folded thread with no specific location within the cell.

Until the late 1970s it was generally accepted that all bacteria are closely related in evolutionary development. This concept was challenged in 1977 by C.R. Woese and coinvestigators at the University of Illinois, whose research on ribosomal RNAfrom a broad spectrum of living organisms established that two groups of bacteria evolved by separate pathways from a common and ancient ancestral form. This discovery has resulted in the establishment of a new terminology to identify the major distinct groups of microbes—namely, the eubacteria (the traditional or "true" bacteria) and the archaea, bacteria that diverged from other bacteria at an early stage of evolution and are distinct from the eubacteria), and eukarya (the eukaryotes). The evolutionary relationships between various members of these three groups, however, have become uncertain, as comparisons between the DNA sequences of various microbes have revealed many puzzling similarities. As a result, the precise ancestry of today's microbes is very difficult to resolve. Even traits thought to be characteristic of distinct taxonomic groups have unexpectedly been observed in other microbes. For example, an anaerobic ammonia-oxidizer—the "missing link" in the global nitrogen cycle—was isolated for the first time in 1999. This bacterium (an aberrant member of the order Planctomycetales) was found to have internal structures similar to eukaryotes, a cell wall with archaean traits, and a form of reproduction (budding) similar to that of yeast cells.

Bacteria have a variety of shapes, including spheres, rods, and spirals. Individual cells generally range in width from 0.5 to 5 micrometres (îm; millionths of a metre). Although unicellular, bacteria often appear in pairs, chains, tetrads (groups of four), or clusters. Some have flagella, external whiplike structures that propel the organism through liquid media; some have capsule, an external coating of the cell; some produce spores—reproductive bodies that function much as seeds do among plants. One of the major characteristics of bacteria is their reaction to the Gram stain. Depending upon

the chemical and structural composition of the cell wall, some bacteria are gram-positive, taking on the stain's purple colour, whereas others are gram-negative.

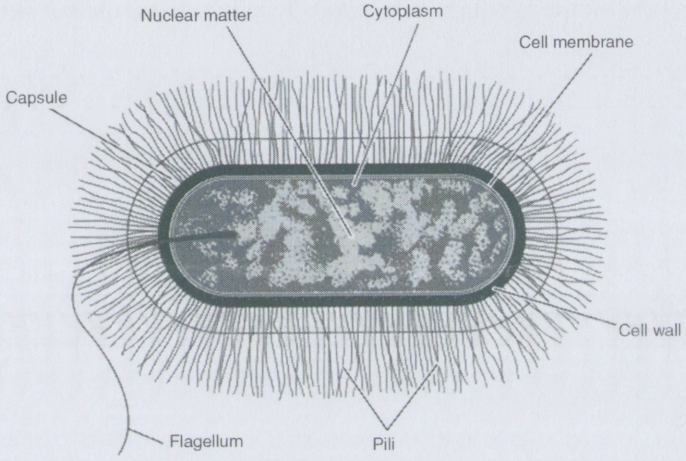


Fig. Schematic drawing of the structure of a generalized bacterium.

Through a microscope the archaea look much like eubacteria, but there are important differences in their chemical composition, biochemical activities, and environments. The cell walls of all eubacteria contain the chemical substance peptidoglycan, whereas the cell walls of archaeans lack this substance. Many archaeans are noted for their ability to survive unusually harsh surroundings, such as high levels of salt or acid or high temperatures. These microbes, called extremophiles, live in such places as salt flats, thermal pools, and deep-sea vents. Some are capable of a unique chemical activity—the production of methane gas from carbon dioxide and hydrogen. Methane-producing archaea live only in environments with no oxygen, such as swamp mud or the intestines of ruminants such as cattle and sheep. Collectively, this group of microorganisms exhibits tremendous diversity in the chemical changes that it brings to its environments.

ALGAE

The cells of eukaryotic microbes are similar to plant and animal cells in that their DNA is enclosed within a nuclear membrane, forming the nucleus. Eukaryotic microorganisms include algae, protozoa, and fungi. Collectively algae, protozoa, and some lower fungi are frequently referred to as protists (kingdom Protista, also called Protoctista); some are unicellular and others are multicellular.

Unlike bacteria, algae are eukaryotes and, like plants, contain the green pigment chlorophyll, carry out photosynthesis, and have rigid cell walls. They normally occur in moist soil and aquatic environments. These eukaryotes may be unicellular and microscopic in size or multicellular and up to 120 metres (nearly 400 feet) in length. Algae as a group also exhibit a variety of shapes. Single-celled species may be spherical, rod-shaped, club-shaped, or spindle-shaped. Some are motile. Algae that are multicellular appear in a variety of forms and degrees of complexity. Some are organized as filaments

of cells attached end to end; in some species these filaments intertwine into macroscopic, plantlike bodies. Algae also occur in colonies, some of which are simple aggregations of single cells, while others contain different cell types with special functions.

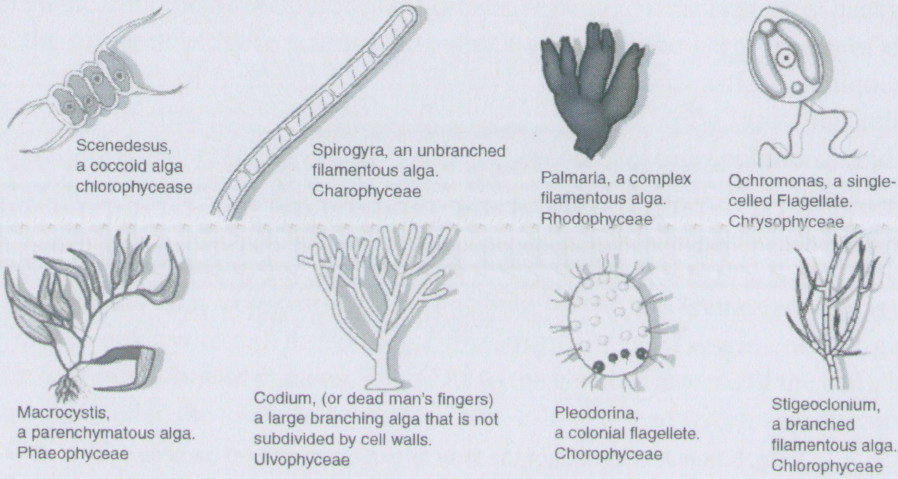


Fig. Representative algae.

FUNGI

Fungi are eukaryotic organisms that, like algae, have rigid cell walls and may be either unicellular or multicellular. Some may be microscopic in size, while others form much larger structures, such as mushrooms and bracket fungi that grow in soil or on damp logs. Unlike algae, fungi do not contain chlorophyll and thus cannot carry out photosynthesis. Fungi do not ingest food but must absorb dissolved nutrients from the environment. Of the fungi classified as microorganisms, those that are multicellular and produce filamentous, microscopic structures are frequently called molds, whereas yeasts are unicellular fungi.

In molds cells are cylindrical in shape and are attached end to end to form threadlike filaments (hyphae) that may bear spores. Individually, hyphae are microscopic in size. However, when large numbers of hyphae accumulate—for example, on a slice of bread or fruit jelly—they form a fuzzy mass called a mycelium that is visible to the naked eye.

The unicellular yeasts have many forms, from spherical to egg-shaped to filamentous. Yeasts are noted for their ability to ferment carbohydrates, producing alcohol and carbon dioxide in products such as wine and bread.

PROTOZOA

Protozoa, or protozoans, are single-celled, eukaryotic microorganisms. Some protozoa are oval or spherical, others elongated. Still others have different shapes at different stages of the life cycle. Cells can be as small as 1 ìm in diameter and as large as 2,000

ìm, or 2 mm (visible without magnification). Like animal cells, protozoa lack cell walls, are able to move at some stage of their life cycle, and ingest particles of food; however, some phytoflagellate protozoa are plantlike, obtaining their energy via photosynthesis. Protozoan cells contain the typical internal structures of an animal cell. Some can swim through water by the beating action of short, hairlike appendages (cilia) or flagella. Their rapid, darting movement in a drop of pond water is evident when viewed through a microscope.

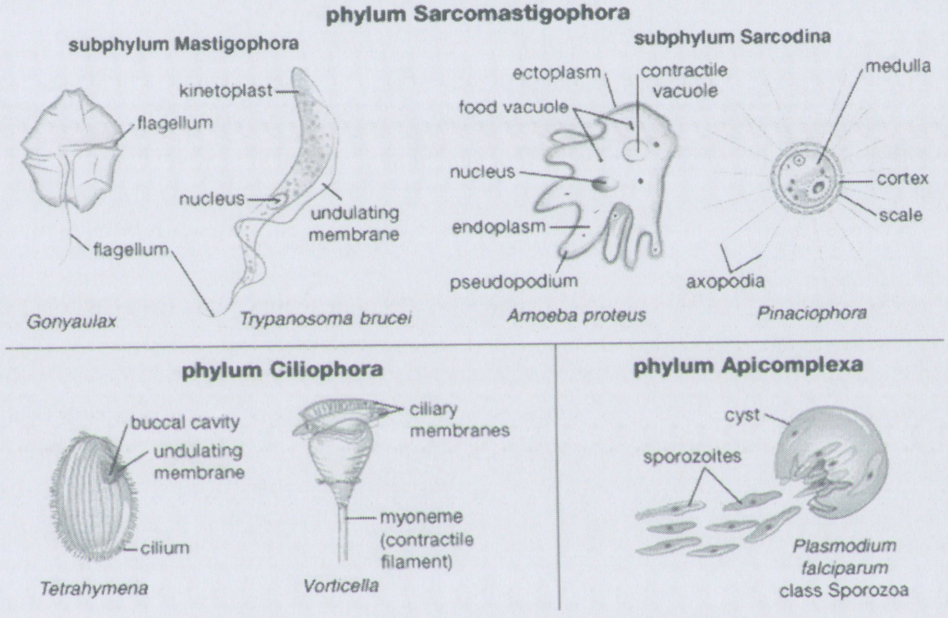


Fig. Representative protozoans. The phytoflagellate *Gonyaulax* is one of the dinoflagellates responsible for the occurrence of red tides.

The zooflagellate *Trypanosoma brucei* is the causative agent of African sleeping sickness. The amoeba is one of the most common sarcodines. Other members of the subphylum Sarcodina, such as the radiolarians, heliozoans, and foraminiferans, usually possess protective coverings.

The heliozoan*Pinaciophora* is shown covered with scales. The phylum Ciliophora, which includes the ciliated *Tetrahymena*and *Vorticella,* contains the greatest number of protozoan species but is the most homogeneous group. The malaria-causing *Plasmodium* is spread by the bite of a mosquito that injects infective spores (sporozoites) into the bloodstream.

The amoebas (also amoebae) do not swim, but they can creep along surfaces by extending a portion of themselves as a pseudopod and then allowing the rest of the cell to flow into this extension. This form of locomotion is called amoeboid movement. The sporozoans (phylum Apicomplexa) are so named because they form dormant bodies called spores during one phase of their life cycle. Protozoa occur widely in nature, particularly in aquatic environments.

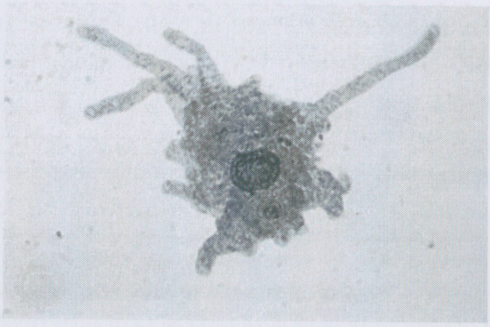


Fig. Amoeba (magnified).

VIRUSES

Viruses, agents considered on the borderline of living organisms, are also included in the science of microbiology, come in several shapes, and are widely distributed in nature, infecting animal cells, plant cells, and microorganisms. The field of study in which they are investigated is called virology. All viruses are obligate parasites; that is, they lack metabolic machinery of their own to generate energy or to synthesize proteins, so they depend on host cells to carry out these vital functions. Once inside a cell, viruses have genes for usurping the cell's energy-generating and protein-synthesizing systems. In addition to their intracellular form, viruses have an extracellular form that carries the viral nucleic acid from one host cell to another. In this infectious form, viruses are simply a central core of nucleic acid surrounded by a protein coat called a capsid. The capsid protects the genes outside the host cell; it also serves as a vehicle for entry into another host cell because it binds to receptors on cell surfaces. The structurally mature, infectious viral particle is called a virion.

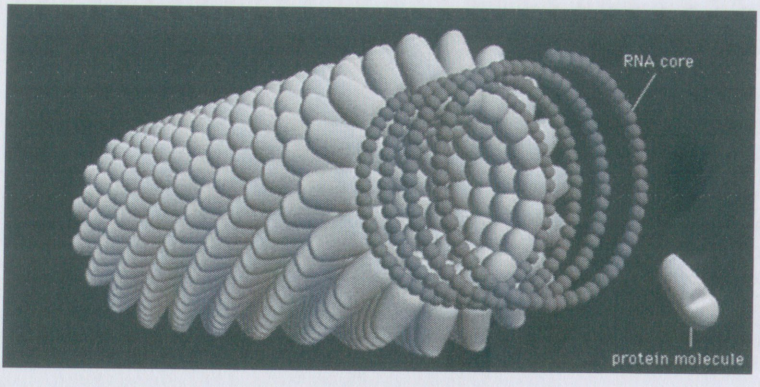


Fig. Schematic structure of the tobacco mosaic virus. The cutaway section shows the helical ribonucleic acid associated with protein molecules in a ratio of three nucleotides per protein molecule.

With the electron microscope it is possible to determine the morphological characteristics of viruses. Virions generally range in size from 20 to 300 nanometres (nm; billionths of a metre). Since most viruses measure less than 150 nm, they are beyond the limit of resolution of the light microscope and are visible only by electron

microscopy. By using materials of known size for comparison, microscopists can determine the size and structure of individual virions.

PRIONS

Even smaller than viruses, prions (pronounced "pree-ons") are the simplest infectious agents. Like viruses they are obligate parasites, but they possess no genetic material. Although prions are merely self-perpetuating proteins, they have been implicated as the cause of various diseases, including bovine spongiform encephalopathy ("mad cow disease"), and are suspected of playing a role in a number of other disorders.

LICHENS

Lichens represent a form of symbiosis, namely, an association of two different organisms wherein each benefits. A lichen consists of a photosynthetic microbe (an alga or a cyanobacterium) growing in an intimate association with a fungus. A simple lichen is made up of a top layer consisting of a tightly woven fungal mycelium, a middle layer where the photosynthetic microbe lives, and a bottom layer of mycelium. In this mutualistic association, the photosynthetic microbes synthesize nutrients for the fungus, and in return the fungus provides protective cover for the algae or cyanobacteria. Lichens play an important role ecologically; among other activities they are capable of transforming rock to soil.



Fig. Orange star lichen (*Xanthoria elegans*) and green lichen.

SLIME MOLDS

The slime molds are a biological and taxonomic enigma because they are neither typical fungi nor typical protozoa. During one of their growth stages, they are protozoa-like because they lack cell walls, have amoeboid movement, and ingest particulate nutrients. During their propagative stage they form fruiting bodies and sporangia, which bear walled spores like typical fungi. Traditionally, the slime molds have been classified with the fungi. There are two groups of slime molds: the cellular slime molds and the acellular slime molds.

THE STUDY OF MICROORGANISMS

As is the case in many sciences, the study of microorganisms can be divided into two generalized and sometimes overlapping categories. Whereas basic microbiology addresses questions regarding the biology of microorganisms, applied microbiology refers to the use of microorganisms to accomplish specific objectives.

BASIC MICROBIOLOGY

The study of the biology of microorganisms requires the use of many different procedures as well as special equipment. The biological characteristics of microorganisms can be summarized under the following categories: morphology, nutrition, physiology, reproduction and growth, metabolism, pathogenesis, antigenicity, and genetic properties.

MORPHOLOGY

Morphology refers to the size, shape, and arrangement of cells. The observation of microbial cells requires not only the use of microscopes but also the preparation of the cells in a manner appropriate for the particular kind of microscopy. During the first decades of the 20th century, the compound light microscope was the instrument commonly used in microbiology. Light microscopes have a usual magnification factor of 1000 × and a maximum useful magnification of approximately 2000 ×. Specimens can be observed either after they have been stained by one of several techniques to highlight some morphological characteristics or in living, unstained preparations as a "wet mount."

LIGHT MICROSCOPY

Several modifications of light microscopy are available, such as:

- *Bright field:* The specimen is usually stained and observed while illuminated; useful for observation of the gross morphological features of bacteria, fungi, algae, and protozoa.
- *Dark field:* The specimen is suspended in a liquid on a special slide and can be observed in a living condition; useful for determining motility of microorganisms or some special morphological characteristic such as spiral or coiled shapes.
- *Fluorescence:* The specimen is stained with a fluorescent dye and then illuminated; objects that take up the fluorescent dye will "glow."
- *Phase contrast:* Special condenser lenses allow observation of living cells and differentiation of cellular structures of varying density.

ELECTRON MICROSCOPY

The development of the electron microscope and complimentary techniques vastly increased the resolving power beyond that attainable with light microscopy. This increase

is possible because the wavelengths of the electron beams are so much shorter than the wavelengths of light. Objects as small as 0.02 nm are resolvable by electron microscopy, compared with 0.25 μm–allowing, for instance, the observation of virions and viral structures. Specimens are observed by either transmission electron microscopy or scanning electron microscopy. In TEM the electron beam passes through the specimen and registers on a screen forming the image; in SEM the electron beam moves back and forth over the surface of microorganisms coated with a thin film of metal and registers a three-dimensional picture on the screen.

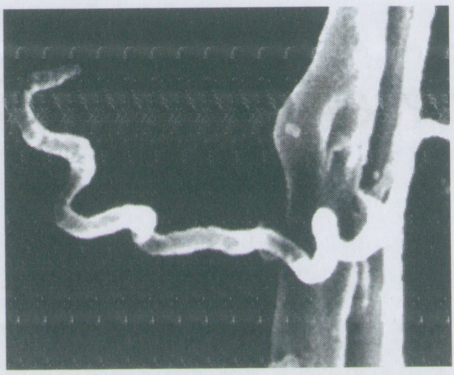


Fig. Scanning electron micrograph of the spirochete *Treponema pallidum* attached to testicular cell membranes.

Advances in microscopes and microscopic techniques continue to be introduced to study cells, molecules, and even atoms. Among these are confocal microscopy, the atomic force microscope, the scanning tunneling microscope, and immunoelectron microscopy. These are particularly significant for studies of microorganisms at the molecular level.

NUTRITIONAL AND PHYSIOLOGICAL CHARACTERISTICS

Microorganisms as a group exhibit great diversity in their nutritional requirements and in the environmental conditions that will support their growth. No other group of living organisms comes close to matching the versatility and diversity of microbes in this respect. Some species will grow in a solution composed only of inorganic salts (one of the salts must be a compound of nitrogen) and a source of carbon dioxide (CO_2); these are called autotrophs. Many, but not all, of these microbes are autotrophic via photosynthesis. Organisms requiring any other carbon source are termed heterotrophs. These microbes commonly make use of carbohydrates, lipids, and proteins, although many microbes can metabolize other organic compounds such as hydrocarbons. Others, particularly the fungi, are decomposers. Many species of bacteria also require specific additional nutrients such as minerals, amino acids, and vitamins. Various protozoans, fungi, and bacteria are parasites, either exclusively (obligate parasites) or with the ability to live independently (facultative parasites).

If the nutritional requirements of a microorganism are known, a chemically defined medium containing only those chemicals can be prepared. More complex media are also routinely used; these generally consist of peptone (a partially digested protein), meat extract, and sometimes yeast extract. When a solid medium is desired, agar is added to the above ingredients. Agar is a complex polysaccharide extracted from marine algae. It has several properties that make it an ideal solidifying substance for microbiological media, particularly its resistance to microbial degradation.

Microorganisms vary widely in terms of the physical conditions required for growth. For example, some are aerobes (require oxygen), some are anaerobes (grow only in the absence of oxygen), and some are facultative (they grow in either condition). Eukaryotic microbes are generally aerobic. Microorganisms that grow at temperatures below 20 °C (68 °F) are called psychrophiles; those that grow best at 20–40 °C (68–104 °F) are called mesophiles; a third group, the thermophiles, require temperatures above 40 °C. Those organisms which grow under optimally under one or more physical or chemical extremes, such as temperature, pressure, pH, or salinity, are referred to as extremophiles. Bacteria exhibit the widest range of temperature requirements. Whereas bacterial (and fungal) growth is commonly observed in food that has been refrigerated for a long period, some recently isolated archaea (*e.g.*, *Pyrodictium occutum* and *Pyrococcus woesei*) grow at temperatures above 100 °C (212 °F). Other physical conditions that affect the growth of microorganisms are acidity or basicity (pH), osmotic pressure, and hydrostatic pressure. The optimal pH for most bacteria associated with the human environment is in the neutral range near pH 7, though other species grow under extremely basic or acidic conditions. Most fungi are favoured by a slightly lower pH (5–6); protozoa require a range of pH 6.7–7.7; algae are similar to bacteria in their requirements except for the fact that they are photosynthetic.

REPRODUCTION AND GROWTH

Bacteria reproduce primarily by binary fission, an asexual process whereby a single cell divides into two. Under ideal conditions some bacterial species may divide every 10–15 minutes—a doubling of the population at these time intervals. Eukaryotic microorganisms reproduce by a variety of processes, both asexual and sexual. Some require multiple hosts or carriers (vectors) to complete their life cycles. Viruses, on the other hand, are produced by the host cell that they infect but are not capable of self-reproduction. The study of the growth and reproduction of microorganisms requires techniques for cultivating them in pure culture in the laboratory. Data collected on the microbial population over a period of time, under controlled laboratory conditions, allow a characteristic growth curve to be constructed for a species.

METABOLISM

Collectively, microorganisms show remarkable diversity in their ability to produce complex substances from simple chemicals and to decompose complex materials to

simple chemicals. An example of their synthetic ability is nitrogen fixation—the production of amino acids, proteins, and other organic nitrogen compounds from atmospheric nitrogen (N_2). Certain bacteria and blue-green algae (cyanobacteria) are the only organisms capable of this ecologically vital process. An example of microbes' ability to decompose complex materials is shown by the white and brown rot fungi that decompose wood to simple compounds, including CO_2.

Laboratory procedures are available that make it possible to determine the biochemical capability of a species qualitatively and quantitatively. Routine techniques can identify which compounds or substances are degraded by a specific microbe and which products are synthesized. Through more elaborate experimentation it is possible to determine step-by-step how the microbe performs these biochemical changes. Studies can be performed in a number of ways using growing cultures, "resting cells" (suspensions of cells), cell-free extracts, or enzyme preparations from cells.

Certain biochemical tests are routinely used to identify microbes—though more in the case of bacteria than algae, fungi, or protozoa. The adoption of routine sets of laboratory tests has allowed automated instrumentation to perform the tests. For instance, technicians often simply inoculate individual units of a "chamber" that is preloaded with a specific chemical substance (the substrate) and then place the chamber into an apparatus that serves as an incubator and analyzer. The apparatus automatically records the results and is frequently capable of calculating the degree of accuracy of the identification.

PATHOGENESIS

Some microorganisms cause diseases of humans, other animals, and plants. Such microbes are called pathogens. Pathogens are identified by the hosts they infect and the symptoms they cause; it is also important to identify the specific properties of the pathogen that contribute to its infectious capacity—a characteristic known as virulence. The more virulent a pathogen, the fewer the number needed to establish an infection.

ANTIGENIC CHARACTERISTICS

An antigen is a substance that, when introduced into an animal body, stimulates the production of specific substances (antibodies) that react or unite with the antigen. Microbial cells and viruses contain a variety of antigenic substances. A significant feature of antigen-antibody reactions is specificity; the antibodies formed as a result of inoculating an animal with one microbe will not react with the antibodies formed by inoculation with a different microbe. Antibodies appear in the blood serum of animals, and laboratory tests of antigen-antibody reactions are performed by using sera—hence the term *serological reactions*. Thus, it is possible to characterize a microorganism by its antigenic makeup as well as to identify microorganisms by using one of many different serological tests. Antigens and antibodies are important aspects of immunity, and immunology is included in the science of microbiology.

GENETIC CHARACTERIZATION

Since the last quarter of the 20th century, researchers have accumulated a vast amount of information elucidating in precise detail the chemical composition, synthesis, and replication of the genetic material of cells. Much of this research has been done by using microorganisms, and techniques have been developed that permit experimentation at the molecular level. For instance, experiments determining the degree of similarity between different organisms' DNA and RNA have provided new insights for the classification of microorganisms. Test kits are now available for the identification of microorganisms, particularly bacteria, by DNA probes.

Since the invention of recombinant DNA technology in 1973, techniques have been developed whereby genes from one cell can be transferred to an entirely different cell, as when a gene is transferred from an animal cell to a bacterium or from a bacterium to a plant cell. Recombinant DNA technology has opened the door to many new medical and industrial applications of microbiology, and it is often referred to as genetic engineering.

APPLIED MICROBIOLOGY

Genetic engineering is an example of how the fields of basic and applied microbiology can overlap. Genetic engineering is primarily considered a field of applied microbiology (that is, the exploitation of microorganisms for a specific product or use). The methods used in genetic engineering were developed in basic research of microbial genetics. Conversely, methods used and perfected for applied microbiology can become tools for basic microbiology. Applied microbiology can, however, be divided under the following headings.

SOIL MICROBIOLOGY

However "dead" soil may appear, it is in fact teeming with millions or billions of microbial cells per gram, depending upon soil fertility and the environment. Dead vegetation, human and animal wastes, and dead animals are deposited in or on soil. In time they all decompose into substances that contribute to soil, and microbes are largely responsible for these transformations.

Two great pioneer soil microbiologists were Martinus W. Beijerinck (1851–1931), a Dutchman, and Sergey N. Winogradsky (1856–1953), a Russian. These researchers isolated and identified new types of bacteria from soil, particularly autotrophic bacteria, that use inorganic chemicals as nutrients and as a source of energy. The relationship between legumes and bacteria in the nodules of legume roots was discovered by other scientists in 1888. The nodules contain large numbers of bacteria (*Rhizobium*) that are capable of fixing atmospheric nitrogen into compounds that can be used by plants.

The ecology of fertile soil consists of plant roots, animals such as rodents, insects, and worms, and a menagerie of microorganisms—viruses, bacteria, algae, fungi, and protozoa. The role of this microbial flora can be conveniently expressed in the Earth's

natural cycles. In the nitrogen cycle, for example, microorganisms capture nitrogen gas from the atmosphere and convert it into a combined form of nitrogen that plants can use as a nutrient; the plant synthesizes organic nitrogen compounds that are consumed by humans and animals; the consumed nitrogen compounds eventually reach the soil; microorganisms complete the cycle by decomposing these compounds back to atmospheric nitrogen and simple inorganic molecules that can be used by plants. In similar cycles for other elements such as carbon, sulfur, and phosphorus, microbes play a role; this makes them essential to maintaining life on Earth.

MICROBIOLOGY OF WATER SUPPLIES, WASTEWATER, AND OTHER AQUATIC ENVIRONMENTS

Long before the establishment of microbiology as a science, water was suspected of being a carrier of disease-producing organisms. But it was not until 1854 that an epidemic of cholera was proved to have had its origin in polluted water. Since that time there has been continuous research on the microbiology of public water supplies, including the development of laboratory procedures to determine whether the water is potable, or safe for human consumption. At the same time, purification procedures for these supplies have emerged.

A highly standardized and routine laboratory procedure to determine the potability of water is based upon detecting the presence or absence of the bacterium *Escherichia coli*. *E. coli* is a normal inhabitant of the intestinal tract of humans; its presence in water indicates that the water is polluted with intestinal wastes and may contain disease-producing organisms.

The principal operations employed in a municipal water-purification plant are sedimentation, filtration, and chlorination. Each of these operations removes or kills microorganisms, and the microbiological quality of the treated water is monitored at frequent intervals.

The used water supply of a community, commonly referred to as sewage, is microbiologically significant in two ways. First, sewage is a potential carrier of pathogenic microorganisms, so measures such as chlorination must be implemented to prevent these microbes from contaminating drinking-water supplies. Second, sewage-treatment plants purify water by exploiting the biochemical abilities of microbes to metabolize contaminants. Raw sewage is processed through large tanks, first for anaerobic degradation of complex substrates and later for aerobic oxidation of soluble products. This "activated sludge" treatment is dependent upon incubation conditions that favour the growth and metabolic activity of appropriate microorganisms.

Another aspect of the microbiology of water pertains to natural bodies of water such as ponds, lakes, rivers, and oceans. Aquatic microbes perform a host of biochemical transformations and are an essential component of the food chain in these environments. For example, the microbial flora of the sea comprises bacteria, algae, fungi, and protozoa. The microorganisms inhabiting aquatic environments are collectively referred to as

plankton; phytoplankton refers to the photosynthetic microbes (primarily algae), whereas protozoa, and other small animals, are zooplankton. Phytoplankton is responsible for converting solar energy into chemical energy—the components of plankton cells that serve as food for higher aquatic life. The magnitude of this process can be appreciated by calculations indicating that it takes 1,000 tons of phytoplankton to support the growth of one ton of fish.

Large populations of archaea live in volcanic ridges 2,600 metres (8,500 feet) below the ocean surface in areas immediately surrounding hydrothermal vents (deep-sea hot springs). The vents spew superheated water (350 °C [662 °F]) that contains hydrogen sulfide (H_2S); the water surrounding the vents has a temperature range of 10–20 °C (50–68 °F). Many bacteria concentrate in this region because of the availability of H_2S, which they can use for energy. The abundance of animal life that also inhabits this region is completely dependent on the microbes for food.

There is a growing interest in other ecological aspects of aquatic microbiology, such as the role of microbes in global warming and oxygen production. Experimental approaches are being developed to study the complex biology and ecology of biofilms and microbial mats. These assemblages of microbes and their products, while potentially useful in several ways, are complex. In many instances the microbial flora involved must sometimes be studied in its natural environment because the environment cannot be reproduced in the laboratory.

FOOD MICROBIOLOGY

Microorganisms are of great significance to foods for the following reasons: (1) microorganisms can cause spoilage of foods, (2) microorganisms are used to manufacture a wide variety of food products, and (3) microbial diseases can be transmitted by foods.

FOOD SPOILAGE

Foods can be considered as a medium for microbial growth. Considering the vast array of sources, substances, and methods with which food is produced, practically every kind of microbe is a potential contaminant. Given a chance to grow, microbes will produce changes in appearance, flavour, odour, and other qualities of the food. The changes vary according to the type of food degraded but can be summarized by examining the fates of the major nutrients found in food: proteins, carbohydrates, and fats.

Protein-containing foods, particularly meats, are putrefied by organisms (*e.g.*, *Proteus*, *Pseudomonas*, and *Clostridium* bacteria) that break down the long peptide chains of proteins into amino acids and foul-smelling compounds such as amines, ammonia, and hydrogen sulfide (H_2S).

Carbohydrates (sugars and starches) are fermented into acids (*e.g.*, the acetic acid in vinegar), alcohols, and gases, especially carbon dioxide. This process is responsible for the bursting of spoiled chocolate cream candies by yeasts.



Fig. Food spoilage detection

Fat-containing foods such as dairy products are spoiled by microbes that break down lipids into fatty acids and glycerol. Rancid milk, which can be caused by bacteria, yeast, or mold, is an example of this process.

Improperly canned foods are also subject to spoilage by bacteria, yeasts, and molds. Bacteria such as *Bacillus* and *Clostridium* are of particular significance in the canning industry because of the high level of resistance that their spores possess. One example of microbial spoilage of canned foods is "sulfide spoilage" caused by *C. nigrificans*, in which contents are blackened and have the odour of rotten eggs. Another example is called "flat sour," in which the spoiled product has an abnormal odour, a cloudy appearance, and a sour taste owing to its lowered pH. Putrefaction caused by *C. sporogenes* may cause a can to swell and burst, releasing its partially digested contents and a putrid odour.

FOOD PRESERVATION

All methods of food preservation are based upon one or more of the following principles: (1) prevention of contamination and removal of microorganisms, (2) inhibition of microbial growth and metabolism, and (3) killing of microorganisms. Prevention—or, more accurately, minimization—of contamination is achieved by the sanitary handling of raw food products, inhibition of growth by low temperatures (refrigeration or freezing), dehydration by evaporation or by high concentrations of salt or sugar, and killing of microbes by the application of high temperatures and, in some instances, radiation.

FOOD PRODUCTS FROM MICROORGANISMS

Important food items produced in whole or in part by the biochemical activities of microorganisms include pickles, sauerkraut, olives, soy sauce, certain types of sausage, all unprocessed cheeses except cream cheese, and many fermented milk products such as yogurt and acidophilus milk. In each instance a raw food item, such as cucumbers in the case of pickles or milk protein in the case of cheeses, is inoculated with microorganisms known to produce the changes required for a desirable product. The initial food item thus serves as a substrate that is acted upon by microorganisms during

the period of incubation. Frequently the manufacturer uses a "starter culture"—a commercial population of microorganisms already known to produce a good product.

INDUSTRIAL MICROBIOLOGY AND GENETIC ENGINEERING

Many substances of considerable economic value are products of microbial metabolism. From an industrial viewpoint the substrate may be regarded as a raw material and the microorganism as the "chemical factory" for converting the raw material into new products. If an organism can be shown to convert inexpensive raw material into a useful product, it may be feasible to perform this reaction on a large industrial scale if the following conditions can be met.

- The organism. The organism to be employed (a virus, bacterium, yeast, or mold) must have the capacity to produce appreciable amounts of the product. It should have relatively stable characteristics and the ability to grow rapidly and vigorously, and it should be non-pathogenic.
- The medium. The medium, including the substrate from which the organism produces the new product, must be cheap and readily available in large quantities.
- The product. A feasible method of recovering and purifying the desired end product must be developed. Industrial fermentations are performed in large tanks, some with capacities of 190,000 litres (50,000 gallons) or more. The product formed by the metabolism of the microorganism must be removed from a heterogeneous mixture that also includes a tremendous crop of microbial cells and unused constituents of the medium, as well as products of metabolism other than those being sought. Traditional products of industrial microbiology are antibiotics, alcoholic beverages, vaccines, vinegar, and miscellaneous chemicals such as acetone and butyl alcohol.

The development of recombinant DNA technology, however, has made it possible to conceive of virtually unlimited new products made by genetically engineered microorganisms. One example of what can be achieved via recombinant DNA technology is the production of human insulin by a genetically altered strain of *E. coli*. By inserting the human gene coding for insulin into the *E. coli* cell, biotechnologists give this bacterium the ability to synthesize the hormone on an industrial scale.

The scientific advances that have made genetic engineering a reality have broad implications for the future. By introducing foreign genes into microorganisms, it may be possible to develop strains of microbes that offer new solutions to such diverse problems as pollution, food and energy shortages, and the treatment and control of disease.

MEDICAL AND PUBLIC HEALTH MICROBIOLOGY

Following the establishment of the germ theory of disease in the mid-1880s and the development of laboratory techniques for the isolation of microorganisms (particularly bacteria), the causative agents of many common diseases were discovered in rapid

succession. Some common diseases and the date of discovery of their causative agent illustrate this point: anthrax (1876), gonorrhea (1879), typhoid fever (1880), malaria (1880), tuberculosis (1882), diphtheria (1883), cholera (1884), and tetanus (1884). Some of the most notable successes of medical microbiology include the development of vaccines beginning in the 1790s, antibiotics during the mid-20th century, and the global eradication of smallpox by 1977.

Despite such great advances in identifying and controlling agents of disease and in devising methods for their control, the world still faces the threat of new diseases such as AIDS and hantavirus pulmonary syndrome (HPS), the reemergence of old scourges such as tuberculosis, cholera, and diphtheria, and the increasing resistance of microbes to antibiotics.

PLANT PATHOLOGY

Plants are subject to infection by thousands of species of very diverse organisms, most of which are microbes. These disease-producing plant pathogens cause significant agricultural losses and include viruses, bacteria, and mycoplasma-like organisms and fungi. The study of plant diseases is called plant pathology.

2

Ecology of Microorganisms: Microflora of a Soil, Water, Air Methods of their Examination

MICROFLORA OF THE ENVIRONMENT

Microbes are distributed everywhere in the environment surrounding us. They are found in the soil, water, air, in plants, animals, food products, various utensils, in the human body, and on the surface of the human body.

The relationship of micro-organisms with the environment has been named *ecology* (*Gr. oikos* home, native land, *logos* idea, science). This is an-adaptive relationship. Micro-organisms have a remarkable ability to adapt themselves to certain environmental conditions. Individual ecology, population ecology, and association community ecology are distinguished. The study of micro-organism ecology forms the basis for understanding parasitism, zoonotic diseases, and particularly diseases with natural nidality, as well as for elaborating measures for the control of various infectious diseases.

SOIL MICROFLORA

TYPES OF MICROORGANISMS IN SOIL

Living organisms both plants and animals, constitute an important component of soil. The pioneering investigations of a number of early microbiologists showed for the

first time that the soil was not an inert static material but a medium pulsating with life. The soil is now believed to be a dynamic or rather a living system, containing a dynamic population of organisms/microorganisms. Cultivated soil has relatively more population of microorganisms than the fallow land, and the soils rich in organic matter contain much more population than sandy and eroded soils. Microbes in the soil are important to us in maintaining soil fertility/ productivity, cycling of nutrient elements in the biosphere and sources of industrial products such as enzymes, antibiotics, vitamins, hormones, organic acids etc. At the same time certain soil microbes are the causal agents of human and plant diseases.

The soil organisms are broadly classified in to two groups viz soil flora and soil fauna, the detailed classification of which is as follows.

SOIL ORGANISMS

Soil Flora

a. Microflora:
   1. Bacteria
   2. Fungi, Molds, Yeast, Mushroom
   3. Actinomycetes, Stretomyces
   4. Algae eg. BGA, Yellow Green Algae, Golden Brown Algae.
      i. Bacteria is again classified in I) Heterotrophic eg. symbiotic and non - symbiotic N_2 fixers, Ammonifier, Cellulose Decomposers, Denitrifiers II) Autrotrophic eg. Nitrosomonas, Nitrobacter, Sulphur oxidizers, etc.

b. *Macroflora:* Roots of higher plants

Soil Fauna

a. *Microfauna:* Protozoa, Nematodes
b. *Macrofauna:* Earthworms. moles, ants and others.
   - *Macroflora:* Vascular plants, Mosses, etc.
   - *Microflora:* Bacteria, Actinomycetes, Fungi, Algae

Influences on Microbial Activity

- Temperature (70°-100°F most active microbes)
- Moisture (Field capacity is optimal)
- Aeration (want a nice mix of pores filled with water and air)
- pH (optimal pH is 6-7)
- Soil organic matter

Soil Microorganisms: Bacteria

1. Most numerous in soil
2. Most diverse metabolism

3. Can be aerobic or anaerobic
4. Optimal growth at pH 6-8
5. Examples: *Nitrosomonas* and *Nitrobacter* in nitrification processes, N_2 fixers, fire blight is caused by a bacterium

Soil Microorganisms: Actinomycetes

1. Transitional group between bacteria and fungi
2. Active in degrading more resistant organic compounds
3. Optimal growth at alkaline pH
4. 2 important products:
   - Produce antibodies (streptomycin is produced by an actino)
   - Produce geosmin
5. Negative impact - potato scab (*Streptomyces scabies*)

Soil Microorganisms: Fungi

1. Dominate the soil biomass
2. Obligate aerobes
3. Can survive desiccation
4. Dominate in acid soils
5. Negative impacts:
6. – Apple replant disease (*Rhizoctonia, Pythium, Fusarium*, and *Phytophtora*)
7. – Powdery mildew is caused by a fungus
8. Beneficials:– *Penicillium*



Fig. Nematode

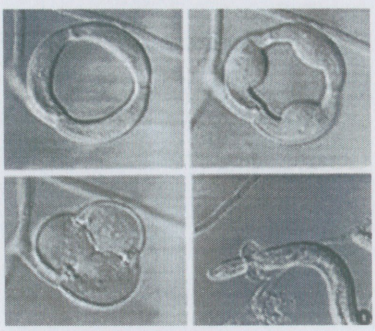


Fig. Trapping Fungus

PLANT ROOT/ SOIL/ MICROBIAL INTERACTIONS

Beneficial

- Symbiotic associations such as that found with *Rhizobia* (N_2 fixing bacteria, ex. legumes)
- Fungi-mycorrhizal associations: important for water and P uptake; also improves soil structure
- Earthworm channels: improve permeability and aeration

Deleterious

- *Agrobacterium* (bacteria) cause gall formation in plants
- Fungi causing soil-borne plant rot diseases
- *Rhizoctonia* and *Pythium* (involved with replant disease)

SOIL NUTRIENT CYCLING

- Materials are broken down by macro and meso-fauna
- Nutrients are taken up and converted by lower life forms in the soil
- They convert these nutrients to organic forms within the cell or to inorganic forms released to soil
- These organisms die and are decomposed by other organisms
- This also releases inorganic ions for plant or other microbe uptake and...
- The cycle starts all over

Nitrogen Cycle: Nitrogen is the nutrient needed in largest amounts by plants and is the most commonly applied fertilizer. Excess N can have negative affects on plant growth and crop quality as well as harming the environment, especially water quality.

Nitrogen is present in one of five forms in soil:

1. *Organic N:* 90% of N is in organic form. It must be mineralized to become available.
2. *Ammonium N (NH_4^+):* Inorganic, soluble form
3. *Nitrate (NO_3^-):* Inorganic, soluble form
4. *Atmospheric N (N_2):* 80% of atmosphere but unavailable to most plants except N-fixers
5. *Nitrite (NO_2^-):* Only under anaerobic conditions. This form is toxic to plants and normally will not be present in significant amounts in soil.

N: Nutrient Cycling and Composting

Soil science was founded by V. Dokuchaev, P. Kostychev. S. Vinogradsky, V. Williams, and others. Soil fertility depends not only on the presence of inorganic and organic substances, but also on the presence of various species of micro-organisms which influence the qualitative composition of the soil. Due to nutrients and moisture in the soil the number of microbes in 1 g of soil reaches a colossal number — from 200

million bacteria in clayey soil to 5 thousand million in black soil. One gram of the ploughed layer of soil contains 1-10 thousand million bacteria.

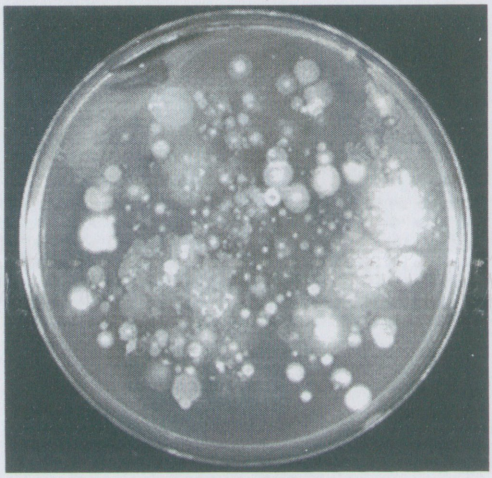


Fig. Soil microflora

Soil microflora consists algae nitrifying nitrogen-fixing, denitrifying, cellulose-splitting and sulfur bacteria, pigmented microbes fungi, protozoa, etc.

The blue-green algae play an important part in enrichment of the soil with nitrogen. The extent to which the soil is contaminated with microbes depends on its nature and chemical composition.

The greatest amount of microbes (1 000000 per cu cm) is found in the top layer of soil at a depth of 5-15 cm. In deeper layers (1.5-5 m) individual microbes are found. However, they have been discovered at a depth of 17.5 m in coal, oil, and artesian water.

Table. Total Amount of Microbes in Different Soils according to the Direct Counting Method

Kind of soil	Number of microbes per 1 g	Number of spores in 1 g
Clayey podsol	801 800000	4000
Forest soil	1219000000	12000
Chernozem	4771000000	100000-180000
Sandy soil	2854000000	200000-400000
Light soil	2661 100000	700000
Loose sand	904000000	600000-1200000
Gray soil	896000000	750000-1500000

Oil' bacteria live in oil wells. Using paraffins (distillates of oil) as nutrients, they turn part of the oil into a thick asphalt-like mass with the formation of which natural oil reservoirs become clogged up. It has been calculated that in the ploughed layer of cultivated soil over an area of 1 hectare there may be from 5 to 6 tons of microbial mass.

The number of microorganisms in the soil depends on the extent of contamination with faeces and urine, and also on the nature of treating and fertilizing the soil. For example, ploughed soil contains 2.5 times more microbes than forest soil.

Saprophytic spores *(B. cereus. B, meguterium,* etc.) survive for long periods in the soil.

Pathogenic bacteria which do not produce spores due to lack of essential nutrients, and also as a result of the lethal activity of light, drying, antagonistic microbes, and phages do not live long in the soil (from a few days to a few months).

Usually the soil is an unfavourable habitat for most pathogenic species of bacteria, rickettsiae, viruses, fungi, and protozoa. The survival period of some pathogenic bacteria. However, the soil as a factor of transmitting a number of causative agents of infectious diseases is quite a complex substrate. Thus, for example, anthrax bacilli after falling on the soil produce spores which can remain viable for many years. In favourable conditions (in dark brown soil and chernozem) they pass through the whole cycle of development: during the summer months the spores germinate into the vegetative forms and then this cycle is repeated.

Table. Survival Period of Pathogenic Bacteria in the Soil

Species of bacteria	Average period in weeks	Maximal period in months
Salmonella typhi	2-3	12
Shigella	1,5-5	9
Vibrio cholerae	1-2	4
Vibrio cholerae El Tor	4	6
Mycobacterium tuberculosis	13	7
Brucella	0,5-3	2
Yersnia pestis	0,5	1
Francisella tularensis	1,5	2,5

As is known, the spores of clostridia causing tetanus, anaerobic infections, and botulism, and of many soil microbes survive for long periods in the soil. The soil is the habitat for various animals (rodents) which are parasitized by the carriers of the causative agents of plague, tularaemia, the viruses of mosquito fever, haemorrhagic fever, encephalitis, agricultural leishmaniasis, etc. *The* cysts, of intestinal protozoa (amoeba, balantidium, etc.) spend a certain stage in the soil. The soil plays an important role in transmitting worm invasions (ascarids, hook-worms, nematode worms, etc.). Some fungi live in the soil. Entering the body they cause fusariotoxicosis, ergotism, aspergillosis, penicilliosis mucormycosis, etc.

Taking into consideration the definite epidemiological role played by the soil in spreading some infectious diseases of animals and man, sanitary-epidemiological practice involves measures directed at protecting the soil from pollution and infection with pathogenic species of microorganisms.

S. Vinogradsky, V. Omeliansky, N. Kholodny and others devised a method of investigating soil microbes and used the results obtained in agriculture.

A valuable index of the sanitary condition of the soil is the discovery of the colibacillus and related bacteria, also enterococci, and *Clostridium perfringens.* The presence of the latter indicates an earlier faecal contamination.

MICROFLORA OF THE WATER

Water microbiology is concerned with the microorganisms that live in water, or can be transported from one habitat to another by water.

Water can support the growth of many types of microorganisms. This can be advantageous. For example, the chemical activities of certain strains of yeasts provide us with beer and bread. As well, the growth of some bacteria in contaminated water can help digest the poisons from the water.

However, the presence of other disease causing microbes in water is unhealthy and even life threatening. For example, bacteria that live in the intestinal tracts of humans and other warm blooded animals, such as *Escherichia coli*, *Salmonella*, *Shigella*, and *Vibrio*, can contaminate water if feces enters the water. Contamination of drinking water with a type of *Escherichia coli* known as O157:H7 can be fatal. The contamination of the municipal water supply of Walkerton, Ontario, Canada in the summer of 2000 by strain O157:H7 sickened 2,000 people and killed seven people.

The intestinal tract of warm-blooded animals also contains viruses that can contaminate water and cause disease. Examples include rotavirus, enteroviruses, and coxsackievirus.

Another group of microbes of concern in water microbiology are protozoa. The two protozoa of the most concern are *Giardia* and *Cryptosporidium*. They live normally in the intestinal tract of animals such as beaver and deer. *Giardia* and *Cryptosporidium* form dormant and hardy forms called cysts during their life cycles. The cyst forms are resistant to chlorine, which is the most popular form of drinking water disinfection, and can pass through the filters used in many water treatment plants. If ingested in drinking water they can cause debilitating and prolonged diarrhea in humans, and can be life threatening to those people with impaired immune systems. *Cryptosporidium* contamination of the drinking water of Milwaukee, Wisconsin with in 1993 sickened more than 400,000 people and killed 47 people.

Many microorganisms are found naturally in fresh and saltwater. These include bacteria, cyanobacteria, protozoa, algae, and tiny animals such as rotifers. These can be important in the food chain that forms the basis of life in the water. For example, the microbes called cyanobacteria can convert the energy of the sun into the energy it needs to live. The plentiful numbers of these organisms in turn are used as food for other life. The algae that thrive in water is also an important food source for other forms of life. A variety of microorganisms live in fresh water. The region of a water body near the shoreline (the littoral zone) is well lighted, shallow, and warmer than other regions

of the water. Photosynthetic algae and bacteria that use light as energy thrive in this zone. Further away from the shore is the limnitic zone. Photosynthetic microbes also live here. As the water deepens, temperatures become colder and the oxygen concentration and light in the water decrease. Now, microbes that require oxygen do not thrive. Instead, purple and green sulfur bacteria, which can grow without oxygen, dominate. Finally, at the bottom of fresh waters (the benthic zone), few microbes survive. Bacteria that can survive in the absence of oxygen and sunlight, such as methane producing bacteria, thrive.

Saltwater presents a different environment to microorganisms. The higher salt concentration, higher pH, and lower nutrients, relative to freshwater, are lethal to many microorganisms. But, salt loving (halophilic) bacteria abound near the surface, and some bacteria that also live in freshwater are plentiful (*i.e.*, *Pseudomonas* and *Vibrio*). Also, in 2001, researchers demonstrated that the ancient form of microbial life known as archaebacteria is one of the dominant forms of life in the ocean. The role of archaebacteria in the ocean food chain is not yet known, but must be of vital importance

Another microorganism found in saltwater are a type of algae known as dinoflagellelates. The rapid growth and multiplication of dinoflagellates can turn the water red. This "red tide" depletes the water of nutrients and oxygen, which can cause many fish to die. As well, humans can become ill by eating contaminated fish.

Water can also be an ideal means of transporting microorganisms from one place to another. For example, the water that is carried in the hulls of ships to stabilize the vessels during their ocean voyages is now known to be a means of transporting microorganisms around the globe. One of these organisms, a bacterium called *Vibrio cholerae*, causes life threatening diarrhea in humans.

Drinking water is usually treated to minimize the risk of microbial contamination. The importance of drinking water treatment has been known for centuries. For example, in pre-Christian times the storage of drinking water in jugs made of metal was practiced. Now, the anti-bacterial effect of some metals is known. Similarly, the boiling of drinking water, as a means of protection of water has long been known.

Chemicals such as chlorine or chlorine derivatives has been a popular means of killing bacteria such as *Escherichia coli* in water since the early decades of the twentieth century. Other bacteria-killing treatments that are increasingly becoming popular include the use of a gas called ozone and the disabling of the microbe's genetic material by the use of ultraviolet light. Microbes can also be physically excluded form the water by passing the water through a filter. Modern filters have holes in them that are so tiny that even particles as miniscule as viruses can be trapped.

An important aspect of water microbiology, particularly for drinking water, is the testing of the water to ensure that it is safe to drink. Water quality testing can de done in several ways. One popular test measures the turbidity of the water. Turbidity gives an indication of the amount of suspended material in the water. Typically, if material such as soil is present in the water then microorganisms will also be present. The presence of

particles even as small as bacteria and viruses can decrease the clarity of the water. Turbidity is a quick way of indicating if water quality is deteriorating, and so if action should be taken to correct the water problem.

In many countries, water microbiology is also the subject of legislation. Regulations specify how often water sources are sampled, how the sampling is done, how the analysis will be performed, what microbes are detected, and the acceptable limits for the target microorganisms in the water sample. Testing for microbes that cause disease (*i.e.*, *Salmonella typhymurium* and *Vibrio cholerae*) can be expensive and, if the bacteria are present in low numbers, they may escape detection. Instead, other more numerous bacteria provide an indication of fecal pollution of the water. *Escherichia coli* has been used as an indicator of fecal pollution for decades. The bacterium is present in the intestinal tract in huge numbers, and is more numerous than the disease-causing bacteria and viruses. The chances of detecting *Escherichia coli* is better than detecting the actual disease causing microorganisms. *Escherichia coli* also had the advantage of not being capable of growing and reproducing in the water (except in the warm and food-laden waters of tropical countries). Thus, the presence of the bacterium in water is indicative of recent fecal pollution. Finally, *Escherichia coli* can be detected easily and inexpensively.

Pseudomonas fluorescens, Micrococcus roseus, etc., are among the specific aquatic aerobic microorganisms. Anaerobic bacteria are very rarely found in water.

The microflora of rivers depends on the degree of pollution and the quality of purification of sewage waters flowing into river beds. Micro-organisms are widespread in the waters of the seas and oceans. They have been found at different depths (3700-9000 m).

The degree of contamination of the water with organisms is expressed as saprobity which designates the total of all living matter in water containing accumulations of animal and plant remains. Water is subdivided into three zones. *Polysaprobic zone* is strongly polluted water, poor in oxygen and rich in organic compounds. The number of bacteria in 1 ml reaches 1 000000 and more. Colibacilli and anaerobic bacteria predominate which bring about the processes of putrefaction and fermentation. In the *mesosaprobic* zone (zone of moderate pollution) the mineralization of organic substances with intense oxidation and marked nitrification takes place. The number of bacteria in 1 ml of water amounts to hundreds of thousands, and there is a marked decrease in the number of colibacilli. The *ohgosaprobic* zone is characteristic of pure water. The number of microbes is low, and in 1 ml there are a few tens or hundreds; this zone is devoid of the colibacillus.

Depending on the degree of pollution pathogenic bacteria can survive in reservoirs and for a certain time can remain viable. Thus, for example, in tap water, river, or well water salmonellae of enteric fever can live from 2 days to 3 months, shigellae — 5-9 days, leptospirae — from 7 to 150 days. The cholera, vibrio El Tor lives in water for many months, the causative agent of tularaemia — from a few days to 3 months.

Tap water is considered clean if it contains a total amount of 100 microbes per ml, doubtful if there are 100-150 microbes, and polluted if 500 and more are present. In well water and in open reservoirs the amount of microbes in 1 ml should not exceed 1000. Besides, the quality of the water is determined by the presence of *E. coli* and its variants.

The degree of faecal pollution of water is estimated by the colititre or coli-index. The *colititre* is the smallest amount of water in millilitres in which one *E. coli* bacillus is found. The *coli-index* is the number of individuals off. *coli* found in 1 litre of water. Tap water is considered good if the colititre is within the limits of 300-500. Water is considered to be good quality if the coli-index is 2-3.

Due to the fact that *Str. faecalis* (enterococci) are constant inhabitants only of the intestine in man and warm-blooded animals, and are highly resistant to temperature variations and other environmental factors, they are taken into account with the colititre and coli-index for the determination of the degree of faecal pollution of water, sewage waters, soil, and other objects. At present new standards of enterococcus indices are being worked out.

Water is an important factor for the transmission of a number of infectious diseases (enteric fever, paratyphoids, cholera, dysentery, leptospiroses, etc.).

Due to the enormous sanitary-epidemiological role of water in relation to the intestinal group of diseases, it became necessary to work out rapid indicator methods for revealing colibacillus and pathogenic bacteria in water.

These include the methods of luminescent microscopy for the investigation of water for the presence of pathogenic microbes and the determination of the increase of the titre of the phage. Upon the addition of specific phages to liquids containing a homologous microbe in 6-10 hours a considerable increase in the amount of phage particles can be observed.

For a more complete and profound study of the microflora of the soil and water *capillary microscopy* is used. The principle is that very thin capillary tubes are placed in the soil or water reservoirs after which their contents are exposed to microscopic investigations. This method reveals those species of micro-organisms which do not grow in ordinary nutrient media, and which for many years were unknown to microbiologists.

MICROFLORA OF THE AIR

AIR MICROBIOLOGY

Of all environments, air is the simplest one and it occurs in a single phase gas. The relative quantities of various gases in air, by volume percentage are nitrogen 78%, oxygen 21 %, argon 0.9%, carbon dioxide 0.03%, hydrogen 0.01 % and other gases in trace amounts. In addition to various gases, dust and condensed vapor may also be found in air.

Various layers can be recognized in the atmosphere upto a height of about 1000km. The layer nearest to the earth is called as troposphere. In temperate regions, troposphere extends upto about 11 km whereas in tropics up to about 16km. This troposphere is characterized by a heavy load of microorganisms. The temperature of the atmosphere varies near the earth's surface. However, there is a steady decrease of about 1 DC per 150m until the top of the troposphere. Above the troposphere, the temperature starts to increase. The atmosphere as a habitat is characterized by high light intensities, extreme temperature variations, low amount of organic matter and a scarcity of available water making it a non hospitable environment for microorganisms and generally unsuitable habitat for their growth. Nevertheless, substantial numbers of microbes are found in the lower regions of the atmosphere.

Microbes Found in Air- In addition to gases, dust particles and water vapour, air also contains microorganisms. There are vegetative cells and spores of bacteria, fungi and algae, viruses and protozoan cysts. Since air is often exposed to sunlight, it has a higher temperature and less moisture. So, if not protected from desiccation, most of these microbial forms will die. Air is mainly it transport or dispersal medium for microorganisms. They occur in relatively small numbers in air when compared with soil or water. The microflora of air can be studied under two headings outdoor and indoor microflora.

Sources of Microorganisms in Air - Although a number of microorganisms are present in air, it doesn't have an indigenous flora. Air is not a natural environment for microorganisms as it doesn't contain enough moisture and nutrients to support their growth and reproduction.

Quite a number of sources have been studied in this connection and almost all of them have been found to be responsible for the air microflora. One of the most common sources of air microflora is the soil.

Soil microorganisms when disturbed by the wind blow, liberated into the air and remain suspended there for a long period of time. Man made actions like digging or plaguing the soil may also release soil borne microbes into the air. Similarly microorganisms found in water may also be released into the air in the form of water droplets or aerosols. Splashing of water by wind action or tidal action may also produce droplets or aerosols. Air currents may bring the microorganisms from plant or animal surfaces into air. These organisms may be either commensals or plant or animal pathogens. Studies show that plant pathogenic microorganisms are spread over very long distances through air. For example, spores of Puccinia graminis travel over a thousand kilometers. However, the transmission of animal diseases is not usually important in outside air.

The main source of airborne microorganisms is human beings. Their surface flora may be shed at times and may be disseminated into the air. Similarly, the commensal as well as pathogenic flora of the upper respiratory tract and the mouth are constantly discharged into the air by activities like coughing, sneezing, talking and laughing.

The microorganisms are discharged out in three different forms which are grouped on the basis of their relative size and moisture content. They are droplets, droplet nuclei and infectious dust. It was Wells, who described the formation of droplet nuclei. This initiated the studies on the significance of airborne transmission.

DROPLETS

Droplets are usually formed by sneezing, coughing or talking. Each consists of saliva and mucus. Droplets may also contain hundreds of microorganisms which may be pathogenic if discharged from diseased persons. Pathogens will be mostly of respiratory tract origin. The size of the droplet determines the time period during which they can remain suspended.

Most droplets are relatively large, and they tend to settle rapidly in still air. When inhaled these droplets are trapped on the moist surfaces of the respiratory tract. Thus, the droplets containing pathogenic microorganisms may be a source of infectious disease.

DROPLET NUCLEI

Small droplets in a warm, dry atmosphere tend to evaporate rapidly and become droplet nuclei. Thus, the residue of solid material left after drying up of a droplet is known as droplet nuclei.

These are small, 1-4 μm, and light. They can remain suspended in air for hours or days, traveling long distances. They may serve as a continuing source of infection if the bacteria remain viable when dry. Viability is determined by a set of complex factors including, the atmospheric conditions like humidity, sunlight and temperature, the size of the particles bearing the organisms, and the degree of susceptibility or resistance of the particular microbial species to the new physical environment. If inhaled droplet nuclei tend to escape the mechanical traps of the upper respiratory tract and enter the lungs. Thus, droplet nuclei may act as more potential agents of infectious diseases than droplets.

INFECTIOUS DUST

Large aerosol droplets settle out rapidly from air on to various surfaces and get dried. Nasal and throat discharges from a patient can also contaminate surfaces and become dry. Disturbance of this dried material by bed making, handling a handkerchief having dried secretions or sweeping floors in the patient's room can generate dust particles which add microorganisms to the circulating air. Microorganisms can survive for relatively longer periods in dust. This creates a significant hazard, especially in hospital areas. Infective dust can also be produced during laboratory practices like opening the containers of freeze dried cultures or withdrawal of cotton plugs that have dried after being wetted by culture fluids. These pose a threat to the people working in laboratories.

Significance of Air Microflora

Although, when compared with the microorganisms of other environments, air microflora are very low in number, they playa very significant role. This is due to the fact that the air is in contact with almost all animate and inanimate objects.

The significance of air flora has been studied since 1799, in which year Lazaro Spallanzani attempted to disprove spontaneous generation. In t 837, Theodore Schwann, in his experiment to support the view of Spallanzani, introduced fresh heated air into a sterilized meat broth and demonstrated that microbial growth couldn't occur. This formed the basis of modern day forced aeration fermentations. It was Pasteur in 1861, which first showed that microorganisms could occur as airborne contaminants. He used special cotton in his air sampler onto which the microorganisms were deposited.

He microscopically demonstrated the presence of microorganisms in the cotton. In his famous swan necked flask experiment, he showed that growth could not occur in sterile media unless airborne contamination had occurred.

Factors Affecting Air Microflora

A number of intrinsic and environmental factors influences the kinds and distribution of the microflora in air. Intrinsic factors include the nature and physiological state of microorganisms and also the state of suspension. Spores are relatively more abundant than the vegetative bacterial cells.

This is mainly due to the dormant nature of spores which enables them to tolerate unfavourable conditions like desiccation, lack of enough nutrients and ultraviolet radiation. Similarly fungal spores are abundant in the air since they are meant for the dispersal of fungi.

The size of the microorganisms is another factor that determines the period of time for which they remain suspended in air. Generally smaller microorganisms are easily liberated into the air and remain there for longer period. Fungal mycelia have a larger size and hence mainly fragments of mycelia will be present in air. The state of suspension plays an important role in the settling of microorganisms in air. Organisms in the free state are slightly heavier than air and settle out slowly in a quiet atmosphere. However, microorganisms suspended in air are only rarely found in the free state.

Usually they are attached to dust particles and saliva. Microorganisms embedded in dust particle settle out rapidly and in a quiet atmosphere they remain airborne only for a short period of time. Droplets which are discharged into the air by coughing or sneezing are also remain suspended in air for a short period of time. When their size decreases by evaporation they remain for a longer period in air.

Environmental factors that affect air microflora include atmospheric temperature, humidity, air current, the height at which the microorganisms are found etc. Temperature and relative humidity are the two important factors that determine the viability of microorganisms in aerosol. Studies with Serratia marcesens and E. coli show that the airborne survival is closely related to the temperature.

There is a progressive increase in the death rate with an increase in temperature from -18°C to 49°C. Viruses in aerosols show a similar behaviour. Particles of influenza, poliomyelitis and vaccinia viruses survive better at low temperature from 7 to 24°C. The optimum rate of relative humidity (RH) for the survival of most microorganisms is between 40 and 80 percent. Low and high relative humidity cause the death of most microorganisms. Almost all viruses survive better at a RH of 17 to 25 percent.

A notable exception is that of poliomyelitis which survives better at 80 to 81 percent. survival has been found to be a function of both RH and temperature. At all temperatures, survival is best at the extremes of RH. Irrespective of RH, an increase in temperature leads to decrease in survival time. Air current influences the time for which either the microorganisms or the particles laden with microorganisms remain suspended in air. In still air the particles tend to settle down. But a gentle air current can keep them in suspension for relatively long periods. Air current is also important in the dispersal of microorganisms as it carries them over a long distance.

Air currents also produce turbulence which causes a vertical distribution of air flora. Global weather patterns also influence the vertical distribution. High altitudes have a limiting effect on the air microflora. High altitudes are characterized by severe conditions like desiccation, ultraviolet radiation and low temperature. Only resistant forms like spores can survive these conditions. Thus high attitudes are characterized by the presence of spores and other resistant forms.

Distribution of Microbes in Air

No microbes are indigenous to the atmosphere rather they represent allochthonous populations transported from aquatic and terrestrial habitats into the atmosphere. Microbes of air within 300-1,000 or more feet of the earth's surface are the organisms of soil that have become attached to fragments of dried leaves, straw or dust particles, being blown away by the wind. Species vary greatly in their sensitivity to a given value of relative humidity, temperature and radiation exposures.

More microbes are found in air over land masses than far at sea. Spores of fungi, especially Alternaria, Cladosporium, Penicillium and Aspergillus are more numerous than other forms over sea within about 400 miles of land in both polar and tropical air masses at all altitudes up to about 10,000 feet.

Microbes found in air over populated land areas below altitude of 500 feet in clear weather include spores of Bacillus and Clostridium, ascos-pores of yeasts, fragments of myceilium and spores of molds and strepto-mycetaceae, pollen, protozoan cysts, algae, Micrococcus, Corynebacterium etc.

In the dust and air of schools and hospital wards or the rooms of persons suffering from infectious diseases, microbes such as tubercle bacilli, streptococci, pneumococci and staphylococci have been demonstrated.

These respiratory bacteria are dispersed in air in the droplets of saliva and mucus produced by coughing, sneezing, talking and laughing. Viruses of respiratory tract and

some enteric tract are also transmitted by dust and air. Pathogens in dust are primarily derived from the objects contaminated with infectious secretions that after drying become infectious dust.

Droplets are usually formed by sneezing, coughing and talking. Each droplet consists of saliva and mucus and each may contain thousands of microbes. It has been estimated that the number of bacteria in a single sneeze may be between 10,000 and 100,000. Small droplets in a warm, dry atmosphere are dry before they reach the floor and thus quickly become droplet nuclei.

Many plant pathogens are also transported from one field to another through air and the spread of many fungal diseases of plants can be predicted by measuring the concentration of airborne fungal spores.

Air Microflora Significance in Hospitals

Although hospitals are the war fields for combating against diseases, there are certain occasions in which additional new infectious diseases can be acquired during hospitalization. Air within the hospital may act as a reservoir of pathogenic microorganisms which are transmitted by the patients. Infection acquired during the hospitalization are called nosocomial infections and the pathogens involved are called as nosocomial pathogens. Infections, manifested by the corresponding symptoms, after three days of hospitalization can be regarded as nosocomial infection (Gleckman and Hibert, 1982 and Bontenand Stobberingh, 1995). Nosocomial infection may arise in a hospital unit or may be brought in by the staff or patients admitted to the hospital. The common microorganisms associated with hospital infection are Haemophilus influenzae, Streptococcus pneumoniae, Staphylococcus aureus, Pseudomonas aeruginosa, members of Enterobacteriaceae and respiratory viruses. Development of high antibiotic resistance is a potential problem among nosocomial pathogens. For example, Methicillin Resistant Staphylococcus aureus (MRSA) and gentamicin resistant Gram-negative bacilli are of common occurrence. Even antiseptic liquids used would contain bacteria, for example Pseudomonas, due to their natural resistance to certain disinfectants and antiseptics and to many antibiotics.

Nosocomial pathogens may cause or spread hospital outbreaks. Nosocomial pneumonia is becoming a serious problem nowadays and a number of pathogens have been associated with it.. Frequent agents are Staphylococcus aureus, Streptococcus pneumoniae, Pseudomonas aeruginosa, Enterobacter, Klebsiella, Escherichia coli and Haemophilus influenzae. Other less frequent agents are enterococci, streptococci other than S. pneumoniae, Serratia marcescens, Citrobacter freundii, Acinetobacter sp. and Xanthomonas sp.

In addition Legionella, Chlamydia pneumoniae and Mycobacterium tuberculosis have also been reported. Nosocomial transmissions of tuberculosis from patients to patients and from patients to health care workers have also been well documented. There are two main routes of transmission for nosocomial pathogens, contact (either

direct or indirect) and airborne spread. Airborne spread is less common than the spread by direct or indirect contact. It occurs by the following mechanisms. The source may be either from persons or from inanimate objects.

In case of spread from persons the droplets from mouth, skin scales from nose, skin exudates and infected lesion transmit diseases such as measles, tuberculosis, pneumonia, staphylococcal sepsis and streptococcal sepsis. Talking, coughing and sneezing produce droplets. Skin scales are shed during wound dressing or bed making.

In case of inanimate sources particles from respiratory equipment and air-conditioning plant may transmit diseases. These include Gram-negative respiratory infection, Legionnaire's disease and fungal infections.

Air Microflora Significance in Human Health

The significance of air microflora in human health relies on the fact that air acts as a medium for the transmission of infectious agents. An adult man inhales about '5m3 of air per day. Although most of the microorganisms present in air are harmless saprophytes and commensals, less than I % of the airborne bacteria are pathogens.

Eventhough the contamination level is very low, the probability of a person becoming infected will be greatest if he is exposed to a high concentration of airborne pathogens. Carriers, either with the manifestation of corresponding symptoms or without any apparent symptoms, may continuously release respiratory pathogens in the exhaled air.

Staphylococcus aureus is the most commonly found pathogen in air since the carriers are commonly present. The number of S. aureus in air may vary between 0-l/m3 and 50/m3.

Practically speaking, outdoor air doesn't contain disease causing pathogen in a significant number to cause any infection. The purity of outdoor air, however, is an essential part of man's environment. Dispersion and dilution by large volume of air is an inherent mechanism of air sanitation in outside air.

In the case of indoor air chance for the spread of infectious disease is more, especially in areas where people gather in large numbers. For example, in theatres, schools etc.

AIR-BORNE MICROORGANISMS AND HUMAN DISEASES

Air-borne microorganisms cause dangerous diseases in human beings. A detailed study of these diseases falls under the preview of a text book of medical microbiology. A chart representing air-borne diseases is given below for ready reference:

The composition of the microbes of the air is quite variable. It depends on many factors: on the extent to which air is contaminated with mineral and organic suspensions, on the temperature, rainfall, locality, humidity, and other factors. The more dust, smoke, and soot in the air, the greater the number of microbes. Each particle of dust or smoke is able to adsorb on its surface numerous microbes. Microbes are rarely found on the surfaces of mountains, in the seas of Arctic lands covered with snow, in oceans, and in snow.

The microflora of the air consists of very different species which enter it from the soil, plants, and animal organisms. Pigmented saprophytic bacteria (micrococci, various sarcinae), cryptogams (hay bacillus, *B. cereus, B. megaterium),* actinomycetes, moulds, yeasts, etc., are often found in the air.

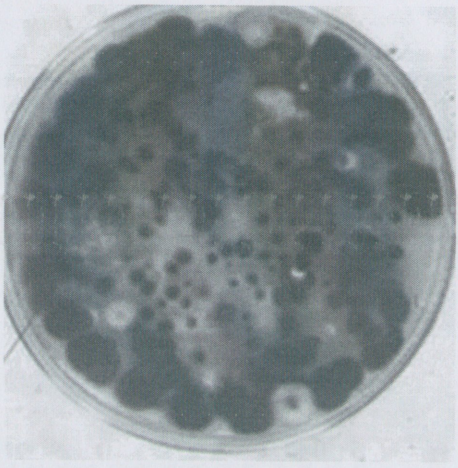


Fig. Actual indoor Air culture: A child's bedroom

The number of microbes in the air vanes from a few specimens to many tens of thousands per 1 cu m. Thus, for example, the air of the Arctic contains 2-3 microbes per 20 cu m. In industrial cities large numbers of bacteria are found per 1 ml of air. In the forests, especially coniferous forests, there are few microbes because the volatile plant substances, phytoncides, have bactericidal properties which cause a lethal effect.

According to the investigations of E. Mishustin, 1 cu m of air in Moscow at an altitude of 500 m contains from 1100 to 2700 microbes while at an altitude of 2000 m only from 500 to 700. Some microbes (sporulating and moulds) were found at an altitude of 20 km, others at an altitude of 61 to 67 km. One gram of dust contains up to 1 million bacteria. Pathogenic species of microbes (pyogenic cocci, tubercle bacilli, anthrax bacilli, bacteria of tularaemia, rickettsiae of Q-fever, etc.) may be found in the surroundings of sick animals and humans, infected arthropods and insects, and in dust.

At present *Streptococcus viridans* serves as sanitary indices for the air of closed buildings, and haemolytic streptococci and pathogenic staphylococci are a direct epidemiological hazard.

Depending on the time of the year, the composition and the amount of microflora change. If the total amount of microbes in winter is accepted as 1, then in spring it will be 1.7, in summer— 2 and in autumn — 1.2.

The total amount of microbes in an operating room before operation should not exceed 500 per 1 cu m of air, and after the operation not more than 1000. There should be no pathogenic staphylococci and streptococci in 250 litres of air. In operating rooms of maternity hospitals before work the number of saprophyte microflora colonies isolated from the air by precipitating microbes on meat-peptone agar within 30 minutes should

not exceed 20. In 1 gram of dust in hospitals, there are up to 200000 pyogenic (haemolytic) streptococci.

The number of microbes in factories and homes is associated closely with the sanitary hygienic conditions of the building. In overcrowding, poor ventilation and natural lighting and if the premises are not properly cleaned, the number of microbes increases. Dry cleaning processes, infrequent floor washing, the use of dirty rags and brushes, and drying them in the same room make the conditions favourable for the accumulation of microbes in air. The causative agents of influenza, measles, scarlet fever, diphtheria, whooping cough, meningococcal infections, tonsillitis, acute catarrhs of the respiratory tract, tuberculosis, smallpox, pneumatic plague, and other diseases can be transmitted through the air together with droplets of mucus and sputum during sneezing, coughing, and talking.

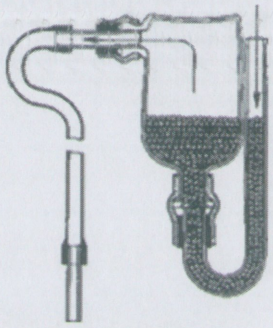
Microbes can be spread by air currents, by aerial dust and aerial droplets. During sneezing, coughing and talking, a sick person can expel pathogenic bacteria together with droplets of mucus and sputum into the surrounding environment within a radius of 1.0-1.5 m or more. Microorganisms contained in air can remain in three phases of the bacterial *aerosol* — droplet, droplet-nuclei, and dust. An aerosol is the physical system of solid or liquid particles suspended in a gaseous medium.

On the average a person breathes about 12000-14000 litres of air daily, while 99.8 per cent of the microbes contained in air are held back in the respiratory tract. The bacterial aerosol produced naturally in the nasopharynx, during sneezing and coughing is thrown into the air — up to 60000 droplets of different size. Among them almost 60 per cent consist of large droplets (100 mcm), 30 per cent — of average sized droplets (50 mcm), and 10 per cent — of small (5 mcm) droplets.

The greatest amount of bacteria is discharged during sneezing, less — during coughing, and still less — during talking. With each sneeze a man expels from 10000 to 1 000000 droplets. In one cough from 10 to 1000 droplets containing bacteria are discharged into the environment, and when a person utters 10-20 words — up to 80 droplets are expelled. The nature of the bacterial aerosol depends on the viscosity of the secretion excreted from the respiratory tract. A liquid secretion is dispersed into more minute droplets more easily than a viscous one. Near the person expelling the bacteria a more concentrated aerosol of bacterial droplets from 1 to 2000 mcm in size is produced. Most of the droplets are from 2 to 100 mcm in size. Large droplets from 100 to 2000 mcm in size are thrown out to a distance of 2-3 m and more and quickly settle on the ground. Small drops of the bacterial aerosol (1-10 mcm) can remain in a suspended condition for a long time (for hours or days).

The air is an unfavourable medium for microbes. The absence of nutrient substances, the presence of moisture, optimal temperature, the lethal activity of sunlight, and desiccation do not create conditions for keeping microbes viable and most of them perish. However, the relatively short period during which the microbes are in air is quite enough to bring about the transmission of pathogenic bacteria and viruses from

sick to healthy persons, and to cause extensive epidemics of diseases such as influenza. For the purpose of prophylaxis various methods are used in protecting humans from infection via air-borne dust. Thus, the sputum of tuberculosis patients is burned or decontaminated, the room is frequently ventilated, and cleaned by mopping, the streets are sprayed, drainage and absorbers are used, and masks are used during sorting of wool and rags, etc. The air of operating rooms, isolating rooms, wards, and bacteriological laboratories is decontaminated by ultraviolet radiation (mercury-quartz, uviol lamps, etc.).



The laboratory investigation of air is carried out to determine the qualitative and quantitative composition of its microflora. This is achieved by using simple and complex methods. For a more accurate investigation of microbial contents of the air special apparatus are used (Rechmensky's bacterial absorber, Krotov's apparatus, Kiktenko's apparatus, and others).

At present rapid methods for the indication of microbes in the environment are being devised which will allow quick determinations of the presence of micro-organisms in the soil, the water and air.

MICROFLORA OF FOOD PRODUCTS

Proteins, carbohydrates, vitamins and other nutrient substances contained in food products have a favourable effect not only on the preservation of different micro-organisms but also on their multiplication.

Products of sour milk and foodstuff's produced by fermentation contain a great number of microbes which lend them flavour and consistency *(specific microflora).* Besides, micro-organisms or their spores may get into foodstuff's from the environment *(non-specific microflora).*

The reproduction of some micro-organisms may cause spoiling of food products which become unsuitable for eating. In some cases the foodstuffs may be seeded with *Salmonella* and *Shigella* organisms, staphylococci, *Clostridium botulinun, Escherichia coli. Bacillus cereus, Clostridium perfringens,* and other microbes which cause food toxicoinfections and other diseases among humans.

Milk may be contaminated with *Mycobacterium bovis, Brucellae, Coxiella burnetti,* pathogenic streptococci, and encephalitis viruses from sick animals. During transportation or when it is being bottled or treated milk may be infected with *Salmonella* and *Shigella* organisms, pathogenic streptococci and staphylococci, *Corynebacterium diphtheriae. Vibrio cholerae,* and other microbes by personnel who are sick or are microbe carriers.

Meat may have been contaminated when the animals or poultry were still alive but sick or it may be infected when they are slaughtered, cut, or when the carcasses are improperly stored and transported. *Cl. perfringens, B. cereus,* enteric bacteria. *Streptococcus faecalis, Proteus,* and other bacteria are usually found in meat. Meat and meat products, minced meat in particular, are most frequently contaminated during treatment when pathogenic microbes are found on the surface of the meat chopper, on the hands, and on the kitchen utensils (cutting board, etc.).

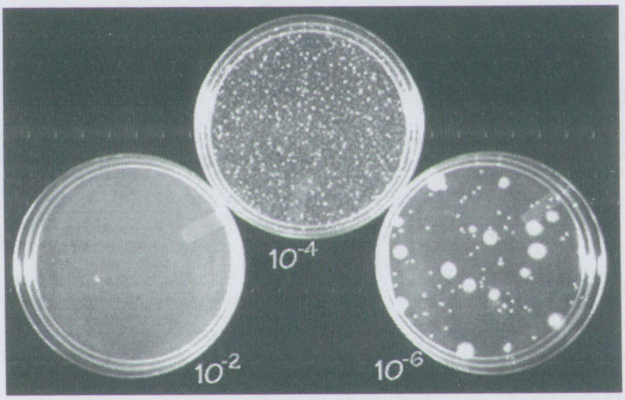


Fig. Bacteria from meat

The flesh of fish is infected with a wide variety of microbial species found in water, the scales and guts of fish, on the hands of persons involved in processing the fish products, and on various objects (knives, tables, boards used in preparing the fish, the deck of a fishing boat, etc.). The most dangerous micro-organisms are *Cl. botulinum* which produce an exotoxin in canned fish products and *Vibrio parahaemolytica.* When sanitary regimens are not observed, *S. typhi, Sh. flexneri,* and in some cases the *El Tor vibrio* are found in the flesh of fish and oysters.

Vegetables and fruit may be seeded with *Shigella* and *Salmonella* organisms, *Vibrio cholerae,* and microflora found in the soil and on the hands of persons who take part in their harvesting, packing, transportation, and those who sell them. Improperly canned vegetables (tomatoes, mushrooms, etc.) may sometimes be the cause of botulism.

Various microflora, pathogenic species among others *(Salmonella* organisms, fungi, actinomycetes), penetrate eggs quite often; egg powder may be contaminated with staphylococci.

Baker's products are a relatively rare source of infection of man with pathogenic micro-organisms. Only those baked from grain left in the field the whole winter cause

fusariotoxicosis due to pathogenic *Fusarium* genus moulds. Among all food poisonings encountered among humans, 70 per cent are due to pathogenic bacteria. *Salmonella* organisms, staphylococci, and streptococci are most dangerous; they multiply and accumulate in the foodstuff's without causing changes in the organoleptic properties.

In the different countries the quality norms of most foodstuffs are set by the All-State Standard (GOST) or Provisional Technical Specifications (VTU).

Microbiological methods for testing foodstuffs. Foodstuffs are tested in the following cases:

1. As a planned measure to control the observance of the sanitary and hygienic regimen in the preparation, storage, and realization of food, particularly those foodstuffs which are not subjected to treatment at high temperature;
2. When there is doubt concerning the quality of the food;
3. When food toxicosis or diseases due to the intake of food occur.

The main task of microbiological testing of a food product is the determination of the total content of microbes and the model sanitary microbes. The model sanitary microbe for most foodstuffs and water is *E. coli.*

Some foodstuffs are tested for the presence of *Proteus vulgaris. Salmonella* organisms, aerobic and anaerobic organisms and for the toxins of these microbes.

The technique of collecting the samples and the sanitary and bacteriologic examination are fixed strictly by instructions in the corresponding State Standard. It, for instance, specifies the methods for collecting samples and all stages in testing milk, cream, ice-cream, butter, koumiss (fermented mare's milk), yoghurt, sour clotted milk, sour cream, acidophilin (sour fermented milk), cottage cheese and food prepared from it, dried dairy products, condensed milk, and cold beverages prepared from milk. For testing, liquid foodstuffs are diluted with sterile isotonic solution 1:10. Compact products are melted or ground in the mortar and diluted in sterile water 1:10.

Sanitary and bacteriologic tests of milk and dairy products consist in determination of the total microbial content (microbial count) and the coli titre. In sour dairy products (yoghurt, cottage cheese, cheese, etc.) the microbial count is not determined. The microbial count in milk is determined by a direct count and by inoculating nutrient media with 1.0 ml of different dilutions of the product that is tested. The dairy products should only contain microorganisms specific for the given food, e. g. lactic streptococci and lactobacilli in sour clotted milk, lactobacilli and yeasts in koumiss, etc.

The permissible microbial count in various dairy products ranges between 500 (children's mixtures subjected to pasteurization and cooking) and 300000 (cow's milk in cans and cisterns). The microbial count for pausterized milk kept in bottles and packets is 75 000, for ice-cream 250000, for condensed milk 50000, for dried cow's milk 50000 per one millilitre.

The coli titre of dairy products is determined by a three-stage fermentation method and for most of them it ranges from 0.3 to 3; only for children's milk mixtures (pausterized and cooked) it is above 11.1. Since milk and dairy products may be vehicles of the

causative agents of certain infectious diseases (typhoid fever, paratyphoid fevers, brucellosis, tuberculosis, Q fever, etc.), these agents are identified by special methods discussed in the corresponding sections of the special part of this textbook. If pathogenic micro-organisms are detected in dairy products it is unquestionable that these products are not fit to be eaten. The sanitary and bacteriological testing of meat and meat products comprises determination of the total amount of microbes per 1.0 g of the product and the presence of *E. coli, Proteus vulgaris. Salmonella* organisms, and anaerobes.

No stable norms have been fixed to date for the sanitary and bacteriological assessment of meat and meat products. According to the accepted provisional norms, the permissible microbial count for roast meat should be less than 500, for boiled sausage and meat jelly less than 1000. The coli titre for roast meat should be above 1 g, for boiled sausage and meat jelly more than 10. The presence of pathogenic and putrefactive microbes indicates that these products are not suitable for use.

Canned foodstuffs, such as canned meat, lard, beans, fish, vegetables and juices are also subjected to sanitary and bacteriological testing. Canned food is tested microbiologically for aerobic and anaerobic micro-organisms and for the botulinum toxin. When there are epidemiological indications, canned food is tested for *Salmonella*organisms, pathogenic staphylococci, and *Proteus vulgaris;* the presence of these microbes shows that the canned food is spoiled and cannot be eaten. It is permissible for canned food to contain non-pathogenic sporulating microbes provided there is no bulging of the can and the organoleptic properties of the food are normal.

Fish, vegetables, and eggs are tested microbiologically usually in cases of food poisoning or diseases among humans. Tests are performed for detecting pathogenic and conditionally pathogenic microbes or their toxins by the commonly accepted methods.

Remnants of food and foodstuffs, vomit, lavage waters, faeces, blood, mucus, washings and scrapings, and autopsy material may be subjected to bacteriological testing according to the epidemiological indications or on instruction of a health officer.

The prevention of food poisoning and other diseases acquired through foodstuffs consists in the observance of sanitary and hygienic measures in preparation of food products, their storage, transportation, and realization. It is also necessary to observe strictly the rules for processing foodstuffs, especially for canning them. Since foodstuffs may be infected by the service staff among whom there may be sick persons or carriers of pathogenic microorganisms, all personnel of food-supplying establishments must be examined regularly. Control of the vectors of the causative agents of intestinal infections and health education among the population are extensively carried out.

MICROFLORA OF THE BODY

SIGNIFICANCE OF THE NORMAL FLORA

The normal flora influences the anatomy, physiology, susceptibility to pathogens, and morbidity of the host.

Skin Flora

The varied environment of the skin results in locally dense or sparse populations, with Gram-positive organisms (*e.g.*, staphylococci, micrococci, diphtheroids) usually predominating.

Oral and Upper Respiratory Tract Flora

A varied microbial flora is found in the oral cavity, and streptococcal anaerobes inhabit the gingival crevice. The pharynx can be a point of entry and initial colonization for *Neisseria*, *Bordetella*, *Corynebacterium*, and *Streptococcus* spp.

Gastrointestinal Tract Flora

Organisms in the stomach are usually transient, and their populations are kept low (10^3 to 10^6/g of contents) by acidity. *Helicobacter pylori* is a potential stomach pathogen that apparently plays a role in the formation of certain ulcer types. In normal hosts the duodenal flora is sparse (0 to 10^3/g of contents). The ileum contains a moderately mixed flora (10^6 to 10^8/g of contents). The flora of the large bowel is dense (10^9 to 10^{11}/g of contents) and is composed predominantly of anaerobes. These organisms participate in bile acid conversion and in vitamin K and ammonia production in the large bowel. They can also cause intestinal abscesses and peritonitis.

Urogenital Flora

The vaginal flora changes with the age of the individual, the vaginal pH, and hormone levels. Transient organisms (*e.g.*, *Candida* spp.) frequently cause vaginitis. The distal urethra contains a sparse mixed flora; these organisms are present in urine specimens (10^4/ml) unless a clean-catch, midstream specimen is obtained.

Conjunctival Flora

The conjunctiva harbours few or no organisms. *Haemophilus* and *Staphylococcus* are among the genera most often detected.

Host Infection

Many elements of the normal flora may act as opportunistic pathogens, especially in hosts rendered susceptible by rheumatic heart disease, immunosuppression, radiation therapy, chemotherapy, perforated mucous membranes, etc. The flora of the gingival crevice causes dental caries in about 80 percent of the population.

A diverse microbial flora is associated with the skin and mucous membranes of every human being from shortly after birth until death. The human body, which contains about 10^{13} cells, routinely harbours about 10^{14} bacteria. This bacterial population constitutes the *normal microbial flora*. The normal microbial flora is relatively stable, with specific genera populating various body regions during particular periods in an individual's life. Microorganisms of the normal flora may aid the host (by competing

for microenvironments more effectively than such pathogens as *Salmonella* spp or by producing nutrients the host can use), may harm the host (by causing dental caries, abscesses, or other infectious diseases), or may exist as commensals (inhabiting the host for long periods without causing detectable harm or benefit). Even though most elements of the normal microbial flora inhabiting the human skin, nails, eyes, oropharynx, genitalia, and gastrointestinal tract are harmless in healthy individuals, these organisms frequently cause disease in compromised hosts. Viruses and parasites are not considered members of the normal microbial flora by most investigators because they are not commensals and do not aid the host.

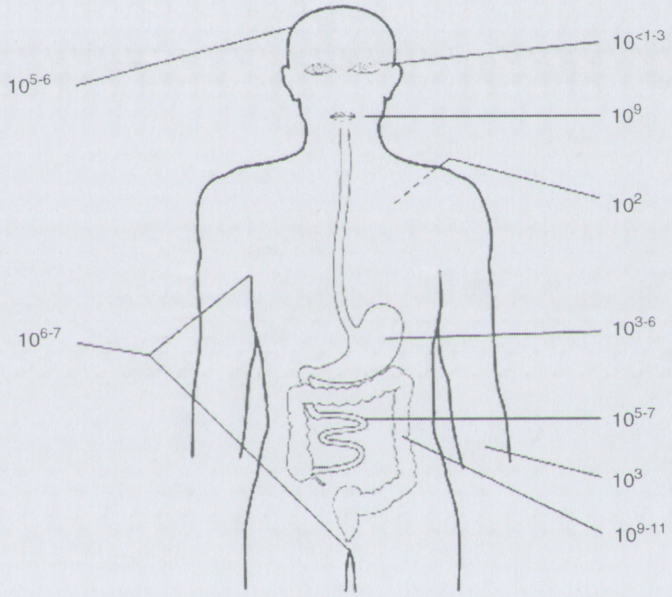


Fig. Numbers of bacteria that colonize different parts of the body. Numbers represent the number of organisms per gram of homogenized tissue or fluid or per square centimeter of skin surface.

Significance of the Normal Flora

The fact that the normal flora substantially influences the well-being of the host was not well understood until germ-free animals became available. Germ-free animals were obtained by cesarean section and maintained in special isolators; this allowed the investigator to raise them in an environment free from detectable viruses, bacteria, and other organisms. Two interesting observations were made about animals raised under germ-free conditions. First, the germ-free animals lived almost twice as long as their conventionally maintained counterparts, and second, the major causes of death were different in the two groups. Infection often caused death in conventional animals, but intestinal atonia frequently killed germ-free animals. Other investigations showed that germ-free animals have anatomic, physiologic, and immunologic features not shared with conventional animals. For example, in germ-free animals, the alimentary lamina

propria is underdeveloped, little or no immunoglobulin is present in sera or secretions, intestinal motility is reduced, and the intestinal epithelial cell renewal rate is approximately one-half that of normal animals (4 rather than 2 days).

Although the foregoing indicates that bacterial flora may be undesirable, studies with antibiotic treated animals suggest that the flora protects individuals from pathogens. Investigators have used streptomycin to reduce the normal flora and have then infected animals with streptomycin-resistant *Salmonella*. Normally, about 10^6 organisms are needed to establish a gastrointestinal infection, but in streptomycin-treated animals whose flora is altered, fewer than 10 organisms were needed to cause infectious disease. Further studies suggested that fermentation products (acetic and butyric acids) produced by the normal flora inhibited *Salmonella* growth in the gastrointestinal tract. Some of the factors that are important in the competition between the normal flora and bacterial pathogens.

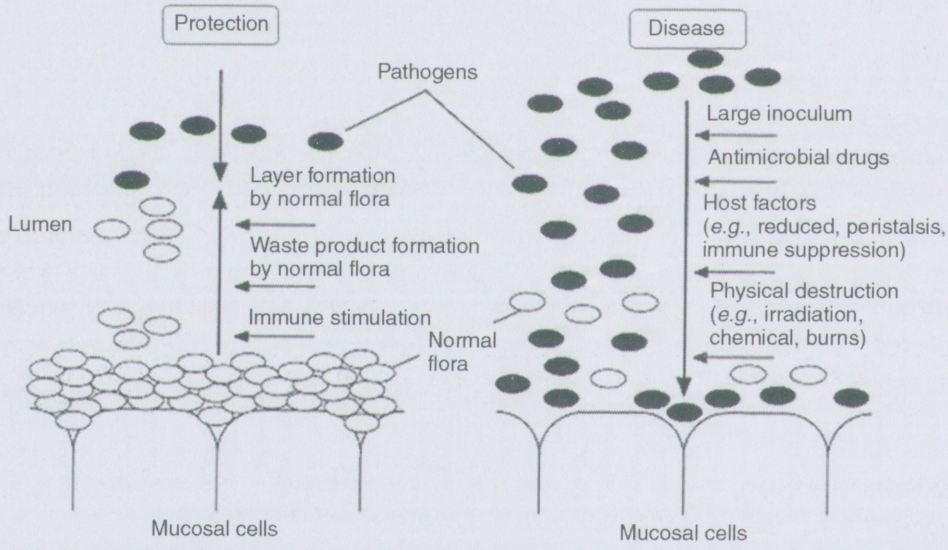


Fig. Mechanisms by which the normal flora competes with invading pathogens.

The normal flora in humans usually develops in an orderly sequence, or succession, after birth, leading to the stable populations of bacteria that make up the normal adult flora. The main factor determining the composition of the normal flora in a body region is the nature of the local environment, which is determined by pH, temperature, redox potential, and oxygen, water, and nutrient levels. Other factors such as peristalsis, saliva, lysozyme secretion, and secretion of immunoglobulins also play roles in flora control. The local environment is like a concerto in which one principal instrument usually dominates. For example, an infant begins to contact organisms as it moves through the birth canal. A Gram-positive population (bifidobacteria arid lactobacilli) predominates in the gastrointestinal tract early in life if the infant is breast-fed. This bacterial population is reduced and displaced somewhat by a Gram-negative flora (Enterobacteriaceae) when

the baby is bottle-fed. The type of liquid diet provided to the infant is the principal instrument of this flora control; immunoglobulins and, perhaps, other elements in breast milk may also be important.

What, then, is the significance of the normal flora? Animal and some human studies suggest that the flora influences human anatomy, physiology, lifespan, and, ultimately, cause of death. Although the causal relationship of flora to death and disease in humans is accepted, of her roles of the human microflora need further study.

Normal Flora of Skin

Skin provides good examples of various microenvironments. Skin regions have been compared to geographic regions of Earth: the desert of the forearm, the cool woods of the scalp, and the tropical forest of the armpit. The composition of the dermal microflora varies from site to site according to the character of the microenvironment.

A different bacterial flora characterizes each of three regions of skin:

1. Axilla, perineum, and toe webs;
2. Hand, face and trunk; and
3. Upper arms and legs.

Skin sites with partial occlusion (axilla, perineum, and toe webs) harbour more microorganisms than do less occluded areas (legs, arms, and trunk). These quantitative differences may relate to increased amount of moisture, higher body temperature, and greater concentrations of skin surface lipids. The axilla, perineum, and toe webs are more frequently colonized by Gram-negative bacilli than are drier areas of the skin.

The number of bacteria on an individual's skin remains relatively constant; bacterial survival and the extent of colonization probably depend partly on the exposure of skin to a particular environment and partly on the innate and species-specific bactericidal activity in skin. Also, a high degree of specificity is involved in the adherence of bacteria to epithelial surfaces. Not all bacteria attach to skin; staphylococci, which are the major element of the nasal flora, possess a distinct advantage over viridans streptococci in colonizing the nasal mucosa. Conversely, viridans streptococci are not seen in large numbers on the skin or in the nose but dominate the oral flora.

The microbiology literature is inconsistent about the density of bacteria on the skin; one reason for this is the variety of methods used to collect skin bacteria. The scrub method yields the highest and most accurate counts for a given skin area. Most microorganisms live in the superficial layers of the stratum corneum and in the upper parts of the hair follicles. Some bacteria, however, reside in the deeper areas of the hair follicles and are beyond the reach of ordinary disinfection procedures. These bacteria are a reservoir for recolonization after the surface bacteria are removed.

Staphylococcus Epidermidis

S. epidermidis is a major inhabitant of the skin, and in some areas it makes up more than 90 percent of the resident aerobic flora.

Staphylococcus Aureus

The nose and perineum are the most common sites for *S. aureus* colonization, which is present in 10 percent to more than 40 percent of normal adults. *S. aureus* is prevalent (67 percent) on vulvar skin. Its occurrence in the nasal passages varies with age, being greater in the newborn, less in adults. *S. aureus* is extremely common (80 to 100 percent) on the skin of patients with certain dermatologic diseases such as atopic dermatitis, but the reason for this finding is unclear.

Micrococci

Micrococci are not as common as staphylococci and diphtheroids; however, they are frequently present on normal skin. *Micrococcus luteus*, the predominant species, usually accounts for 20 to 80 percent of the micrococci isolated from the skin.

Diphtheroids (Coryneforms)

The term diphtheroid denotes a wide range of bacteria belonging to the genus Corynebacterium. Classification of diphtheroids remains unsatisfactory; for convenience, cutaneous diphtheroids have been categorized into the following four groups: lipophilic or non-lipophilic diphtheroids; anaerobic diphtheroids; diphtheroids producing porphyrins (coral red fluorescence when viewed under ultraviolet light); and those that possess some keratinolytic enzymes and are associated with trichomycosis axillaris (infection of axillary hair).

Lipophilic diphtheroids are extremely common in the axilla, whereas non-lipophilic strains are found more commonly on glabrous skin.

Anaerobic diphtheroids are most common in areas rich in sebaceous glands. Although the name *Corynebacterium* acnes was originally used to describe skin anaerobic diphtheroids, these are now classified as *Propionibacterium acnes* and as *P. granulosum*. *P. acnes* is seen eight times more frequently than *P. granulosum* in acne lesions and is probably involved in acne pathogenesis. Children younger than 10 years are rarely colonized with *P. acnes*.

The appearance of this organism on the skin is probably related to the onset of secretion of sebum (a semi-fluid substance composed of fatty acids and epithelial debris secreted from sebaceous glands) at puberty. *P. avidum*, the third species of cutaneous anaerobic diphtheroids, is rare in acne lesions and is more often isolated from the axilla.

STREPTOCOCCI

Streptococci, especially β-hemolytic streptococci, are rarely seen on normal skin. The paucity of β-hemolytic streptococci on the skin is attributed at least in part to the presence of lipids on the skin, as these lipids are lethal to streptococci. Other groups of streptococci, such as α-hemolytic streptococci, exist primarily in the mouth, from where they may, in rare instances, spread to the skin.

GRAM-NEGATIVE BACILLI

Gram-negative bacteria make up a small proportion of the skin flora. In view of their extraordinary numbers in the gut and in the natural environment, their scarcity on skin is striking. They are seen in moist intertriginous areas, such as the toe webs and axilla, and not on dry skin. Desiccation is the major factor preventing the multiplication of Gram-negative bacteria on intact skin. *Enterobacter*, *Klebsiella*, *Escherichia coli*, and *Proteus* spp. are the predominant Gram-negative organisms found on the skin. *Acinetobacter* spp also occurs on the skin of normal individuals and, like other Gram-negative bacteria, is more common in the moist intertriginous areas.

NAIL FLORA

The microbiology of a normal nail is generally similar to that of the skin. Dust particles and other extraneous materials may get trapped under the nail, depending on what the nail contacts. In addition to resident skin flora, these dust particles may carry fungi and bacilli. *Aspergillus*, *Penicillium*, *Cladosporium*, and *Mucor* are the major types of fungi found under the nails.

ORAL AND UPPER RESPIRATORY TRACT FLORA

The oral flora is involved in dental caries and periodontal disease, which affect about 80 percent. of the population in the Western world. The oral flora, its interactions with the host, and its response to environmental factors. Anaerobes in the oral flora are responsible for many of the brain, face, and lung infections that are frequently manifested by abscess formation.

The pharynx and trachea contain primarily those bacterial genera found in the normal oral cavity (for example, α-and β-hemolytic streptococci); however, anaerobes, staphylococci, neisseriae, diphtheroids, and others are also present. Potentially pathogenic organisms such as *Haemophilus*, mycoplasmas, and pneumococci may also be found in the pharynx. Anaerobic organisms also are reported frequently. The upper respiratory tract is so often the site of initial colonization by pathogens (*Neisseria meningitides*, *C. diphtheriae*, *Bordetella pertussis*, and many others) and could be considered the first region of attack for such organisms. In contrast, the lower respiratory tract (small bronchi and alveoli) is usually sterile, because particles the size of bacteria do not readily reach it. If bacteria do reach these regions, they encounter host defence mechanisms, such as alveolar macrophages, that are not present in the pharynx.

GASTROINTESTINAL TRACT FLORA

The stomach is a relatively hostile environment for bacteria. It contains bacteria swallowed with the food and those dislodged from the mouth. Acidity lowers the bacterial count, which is highest (approximately 10^3 to 10^6 organisms/g of contents) after meals and lowest (frequently undetectable) after digestion. Some *Helicobacter* species can colonize the stomach and are associated with type B gastritis and peptic ulcer disease.

Aspirates of duodenal or jejunal fluid contain approximately 10^3 organisms/ml in most individuals. Most of the bacteria cultured (streptococci, lactobacilli, *Bacteroides*) are thought to be transients. Levels of 10^5 to about 10^7 bacteria/ml in such aspirates usually indicate an abnormality in the digestive system (for example, achlorhydria or malabsorption syndrome). Rapid peristalsis and the presence of bile may explain in part the paucity of organisms in the upper gastrointestinal tract. Further along the jejunum and into the ileum, bacterial populations begin to increase, and at the ileocecal junction they reach levels of 10^6 to 10^8 organisms/ml, with streptococci, lactobacilli, *Bacteroides*, and bifidobacteria predominating.

Concentrations of 10^9 to 10^{11} bacteria/g of contents are frequently found in human colon and feces. This flora includes a bewildering array of bacteria (more than 400 species have been identified); nonetheless, 95 to 99 percent belong to anaerobic genera such as *Bacteroides*, *Bifidobacterium*, *Eubacterium*, *Peptostreptococcus*, and *Clostridium*. In this highly anaerobic region of the intestine, these genera proliferate, occupy most available niches, and produce metabolic waste products such as acetic, butyric, and lactic acids. The strict anaerobic conditions, physical exclusion (as is shown in many animal studies), and bacterial waste products are factors that inhibit the growth of other bacteria in the large bowel.

Although the normal flora can inhibit pathogens, many of its members can produce disease in humans. Anaerobes in the intestinal tract are the primary agents of intra-abdominal abscesses and peritonitis. Bowel perforations produced by appendicitis, cancer, infarction, surgery, or gunshot wounds almost always seed the peritoneal cavity and adjacent organs with the normal flora. Anaerobes can also cause problems within the gastrointestinal lumen.

Treatment with antibiotics may allow certain anaerobic species to become predominant and cause disease. For example, *Clostridium difficile*, which can remain viable in a patient undergoing antimicrobial therapy, may produce pseudomembranous colitis.

Other intestinal pathologic conditions or surgery can cause bacterial overgrowth in the upper small intestine. Anaerobic bacteria can then deconjugate bile acids in this region and bind available vitamin B_{12} so that the vitamin and fats are malabsorbed. In these situations, the patient usually has been compromised in some way; therefore, the infection caused by the normal intestinal flora is secondary to another problem.

More information is available on the animal than the human microflora. Research on animals has revealed that unusual filamentous microorganisms attach to ileal epithelial cells and modify host membranes with few or no harmful effects. Microorganisms have been observed in thick layers on gastrointestinal surfaces and in the crypts of Lieberkuhn. Other studies indicate that the immune response can be modulated by the intestinal flora. Studies of the role of the intestinal flora in biosynthesis of vitamin K and other host-utilizable products, conversion of bile acids (perhaps to cocarcinogens), and ammonia production (which can play a role in hepatic coma) show the dual role of the

microbial flora in influencing the health of the host. More basic studies of the human bowel flora are necessary to define their effect on humans.

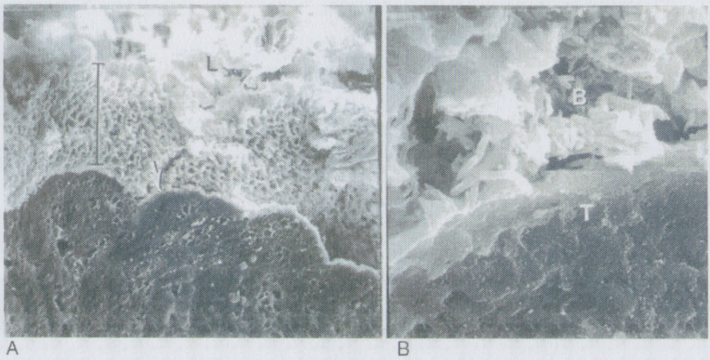


Fig. (A) Scanning electron micrograph of a cross-section of rat colonic mucosa. The bar indicates the thick layer of bacteria between the mucosal surface and the lumen (L) (X 262,) (B) Higher magnification of the area indicated by the arrow in **Fig.** A, showing a mass of bacteria (B) immediately adjacent to colonized intestinal tissue (T), (X2,624.)

UROGENITAL FLORA

The type of bacterial flora found in the vagina depends on the age, pH, and hormonal levels of the host. *Lactobacillus* spp. predominate in female infants (vaginal pH, approximately 5) during the first month of life. Glycogen secretion seems to cease from about I month of age to puberty. During this time, diphtheroids, *S. epidermidis*, streptococci, and *E. coli* predominate at a higher pH (approximately pH 7). At puberty, glycogen secretion resumes, the pH drops, and women acquire an adult flora in which *L. acidophilus,* corynebacteria, peptostreptococci, staphylococci, streptococci, and Bacteroides predominate. After menopause, pH again rises, less glycogen is secreted, and the flora returns to that found in prepubescent females. Yeasts (*Torulopsis* and *Candida*) are occasionally found in the vagina (10 to 30 percent of women); these sometimes increase and cause vaginitis.

In the anterior urethra of humans, *S. epidermidis*, enterococci, and diphtheroids are found frequently; *E. coli*, *Proteus*, and *Neisseria* (non-pathogenic species) are reported occasionally (10 to 30 percent). Because of the normal flora residing in the urethra, care must be taken in clinically interpreting urine cultures; urine samples may contain these organisms at a level of 10^4/ml if a midstream (clean-catch) specimen is not obtained.

CONJUNCTIVAL FLORA

The conjunctival flora is sparse. Approximately 17 to 49 percent of culture samples are negative. Lysozyme, secreted in tears, may play a role in controlling the bacteria by interfering with their cell wall formation. When positive samples show bacteria, corynebacteria, Neisseriae, and Moraxellae are cultured. Staphylococci and streptococci are also present, and recent reports indicate that *Haemophilus parainfluenzae* is present in 25 percent of conjunctival samples.

HOST INFECTION BY ELEMENTS OF THE NORMAL FLORA

This chapter has briefly described the normal human flora; however, the pathogenic mechanisms of various genera or the clinical syndromes in which they are involved was not discussed. Although such material is presented in other chapters, note that a breach in mucosal surfaces often results in infection of the host by members of the normal flora. Caries, periodontal disease, abscesses, foul-smelling discharges, and endocarditis are hallmarks of infections with members of the normal human flora. In addition, impairment of the host (for example, those with heart failure or leukemia) or host defences (due to immunosuppression, chemotherapy, or irradiation) may result in failure of the normal flora to suppress transient pathogens or may cause members of the normal flora to invade the host themselves. In either situation, the host may die.

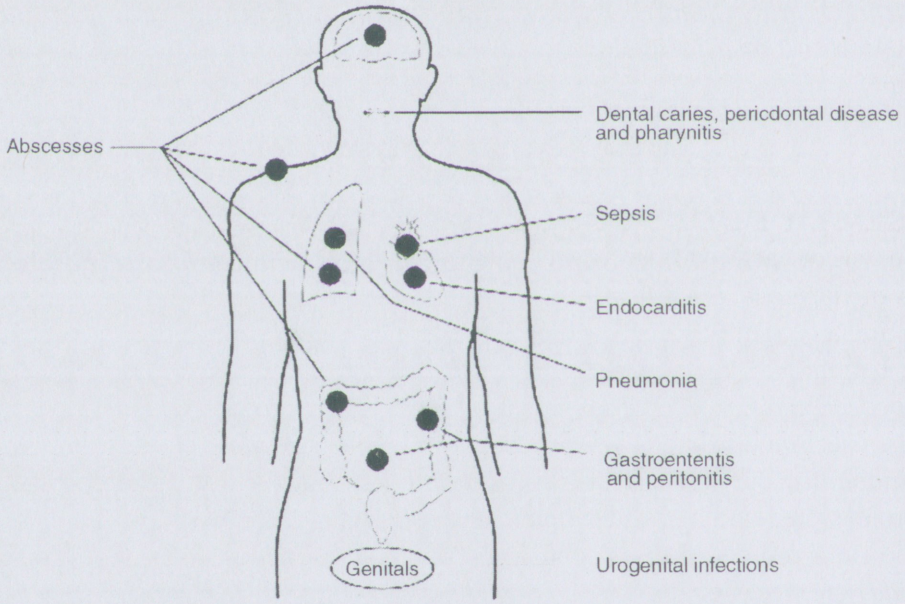


Fig. Clinical conditions that may be caused by members of the normal flora.

Microbiocenosis is microbial community of different bacterial populations, which colonize certain biotope.

Biotope is an area with relatively homogenous conditions where microbial population can survive.

Ecological niche is the place or status of microbes in their biotic environment.

Constant (obligate, resident, indigenous, autochthonous) microflora is native, no imported one of different biotopes.

Transient (temporary, facultative, allochthonous) microflora is not aboriginal, it is acquired one.

Before birth, the human body has no normal flora. During the birth process, the body comes in contact with microbes in the external environment. Later with the initial feedings and exposure to an expanding environment some microorganisms find their

way to a permanent residence in many parts of the body. Most organisms in the external environment apparently do not find the body to be a favourable habitat. Characteristic features of different body areas, such as temperature, oxygen availability, nutrient availability, natural inhibitors and pH influence the population that is able to survive and establish itself. Because these conditions vary from site to site in the body different sites acquire considerably different organisms as their normal flora. Once the normal flora is established it benefits the body by preventing the overgrowth of undesirable organisms. Destruction of the normal flora frequently disrupts the status quo resulting in the growth of harmful organisms. This can be seen after the prolonged administration of broad spectrum antibiotics. For example if the normal flora of the intestinal tract and vagina are largely destroyed, the yeast Candida albicans which is unaffected by these antibacterial antibiotics can grow unchecked to become the major organism in these areas. It then cm infect the mucous membranes and the skin, causing a severe inflammation. Another complication of antibiotic therapy is a severe gastroenteritis known as pseudomembranous colitis. This syndrome has been associated with several antimicrobial agents but the antibiotics clindamycin and lincomycin have been incriminated most often. The mechanism of this diarrhoea was elucidated when it was observed that the use of these antibiotics resulted in an overgrowth in the intestine of an organism identified is Clostridium difficile. This organism produces in enterotoxin that causes the gastroenteritis but it can do so only when antibiotic therapy destroys much of the other normal intestinal flora permitting it to grow unchecked.

Our normal flora can be categorized is helpful (mutualutic symbionts) harmless (commensals) or potentially harmful (opportunists) However these groups are not mutually exclusive. Under certain circumstances even a mutualism cause harm and, thus, become a pathogen. Therefore these categories are of value only in describing the usual role of the organism in relation to its host.

In a mutualistic relationship the microbe and the host benefit one another. This type of relationship is common in the plant kingdom and is essential in ruminants such as cattle in which microbes are necessary for digestion of the cellulose in plant material. Few such relation ships exist in humans, however. Probably the only good example of mutualism in humans is found in the normal flora of the large intestine where enteric organisms synthesize vitamin K and the vitamins of the B complex, enabling them to be absorbed through the intestinal wall and contribute to human nutrition. However considering that our normal flora provides us with protection by interfering with the growth of potentially harmful organisms much of our normal flora could be considered mutualistic symbionts.

The microbe that lives on and benefits from its host without either benefiting or harming the host is called a commensal. Most of the organisms that make up the normal flora of a healthy individual could be categorized as commensals.

Opportunists (microbes that are potential pathogens) are of greatest interest to us. These organisms seem to lack the ability to invade and cause disease in healthy

individuals but may be able to colonize as pathogens in ill or injured persons. Staphylococcus aureus is a good example of an opportunist. Many people (about 25 %) carry staphylococci in their nasopharynx without suffering any illness. However if these people acquire respiratory tract infections such as measles or influenza the staphylococci can invade the lung and cause severe pneumonia. Accidental contamination of the bladder with E coli or Enterococcus faecalis during a catheterization procedure also can lead to opportunistic infection. Both these organisms ire part of the normal flora of the large intestine and usually do not produce urinary tract infections. How ever if they gain access to the urethra or are transplanted mechanically to an environment in which they can grow they can cause disease. The most startling examples of opportunistic infections are associated with the viral infection known as acquired immunodeficiency syndrome (AIDS). This syndrome is caused by a virus that destroys certain subsets of T cells inhibiting the body's ability tomount in immune response. As a result infection by the virus causing AIDS is characterized by severe and eventually fatal infections or malignancies that do not occur in individuals with functional immune systems.

Because much of our normal flora can cause disease under the proper conditions these organisms could be considered opportunists. This is particularly true in elderly and debilitated individuals and in patients receiving immunosuppressive drug therapy to prevent rejection of organ transplants. Opportunists are especially important as causes of nosocomial infections (ic those acquired during hospitalization). Under appropriate circumstances most of the organisms that constitute our normal flora can cause disease.

Another group of bacteria that is not really part of our normal flora consists of pathogenic organisms that can exist in a large percentage of the population without causing disease. This group includes such organisms is Neisseria meningitidis (also called the meningococcus) the causative agent of epidemic meningitis. Many individuals carry this organism in their respiratory tracts without ever having meningitis, yet they can spread the bacterium to non-immune individuals and cause disease. Streptococcus pneumoniae (the pneumococcus) the major cause of lobar pneumonia also is carried by 10 % to 20 % of normal healthy individuals. Persons who harbour bacteria such is these without ever exhibiting overt symptoms of disease are referred to as carriers.

Thus, although our normal flora can be beneficial by preventing the growth of potential pathogens, it also can be a reservoir from which endemic and epidemic diseases are spread.

A diverse microbial flora is associated with the skin and mucous membranes of every human being from shortly after birth until death. The human body, which contains about 10^{13} cells, routinely harbours about 10^{14} bacteria. This bacterial population constitutes the normal microbial flora. The normal microbial flora is relatively stable, with specific genera populating various body regions during particular periods in an individual's life. Microorganisms of the normal flora may aid the host (by competing for microenvironments more effectively than such pathogens as Salmonella spp or by producing nutrients the host can use), may harm the host (by causing dental caries,

abscesses, or other infectious diseases), or may exist as commensals (inhabiting the host for long periods without causing detectable harm or benefit). Even though most elements of the normal microbial flora inhabiting the human skin, nails, eyes, oropharynx, genitalia, and gastrointestinal tract are harmless in healthy individuals, these organisms frequently cause disease in compromised hosts. Viruses and parasites are not considered members of the normal microbial flora by most investigators because they are not commensals and do not aid the host.

Human microflora is the result of a mutual adaptation of micro- and macro-organisms in the process of evolution. Most bacteria of the normal and constant microflora of the human body have adapted themselves to life in certain parts of the body. Besides, there are some microbes which make up a temporary (casual) microflora.

With the development of virology and the improvement of virological technique, our concepts on the microflora of the human body were increased. It has been established that not only the open cavities, but the tissues of the human organism are inhabited by numerous persisting viruses which are excreted into the environment with milk, saliva, sputum, perspiration, urine, and faeces.

There are different methods of human microbiocenosis studying. Among them, biopsy, pad method, impression method, sticky film method, swab-washing method, scrub-washing technique etc. After receiving of tested material it should be inoculated on different nutrient media.

ETIOLOGY OF DIFFERENT HUMAN INFECTIONS

MICROFLORA OF THE SKIN

Staphylococci, streptococci, moulds and yeasts, diphtheroids, and also certain pathogenic and conditionally pathogenic bacteria live on the surface of the skin. They receive their nutrition from the secretions of the sebaceous and sweat glands, dead cells, and waste products.

The total number of microbes on the skin of one person varies from 85000000 to 1212000000.

When the human body comes into contact with the soil, the clothes and skin are seeded with spores of different species of microbes (organisms responsible for tetanus, anaerobic infections, etc.).

Most frequently the exposed parts of the human body are infected, e. g. the hands, on the surface of which colibacilli, staphylococci, streptococci, enterococci, moulds, yeasts, fungi imperfecti, and spores of aerobic and anaerobic bacilli are found.

Pustular and fungal infections of the skin and gastrointestinal diseases often occur owing to violation of sanitary-hygienic conditions and normal conditions of the work and life of people.

MICROBES OF THE MOUTH CAVITY

In the mouth cavity there are more than 100 species of microbes. There are the natural inhabitants (acidophilic bacillus, Treponema microdentium, diplococci, Streptococcus salivarius, Entamoeba gingivalis, etc.). Besides, in the mouth cavity there are foreign microbes or those which have been carried in from the environment together with food, water, and air.

Pathogenic and conditionally pathogenic microbes (staphylococci, streptococci, diphtheria bacilli, diphtheroids, Borrelia organisms, spindle-shaped bacteria), protozoa (amoebae and trichomonads) are found on the mucous membrane of the mouth.

The mouth cavity is a favourable medium for many microbes; it has an optimal temperature, a sufficient amount of food substances, and has a weakly alkaline reaction.

The greatest amount of microbes can be found at the necks of the teeth and in the spaces between teeth. Streptococci and diplococci are found on the tonsils. There are many microbes in other parts of the mouth cavity, which are inaccessible to the bathing action of saliva and the action of lysozyme (an enzyme found in the saliva, lacrimal fluid and sputum). The presence of carious teeth is a condition for increasing the microflora in the mouth cavity, for the appearance of decaying processes and unpleasant odours.

THE MICROFLORA OF THE GASTROINTESTINAL TRACT

When the stomach functions normally, it is almost devoid of microflora due to the marked bactericidal properties of gastric juice.

The gastric Juice is considered to be a reliable defence barrier against the penetration of pathogenic and conditionally pathogenic microbes into the intestine. However, the degree of acidity of the gastric juice is not always constant. It varies according to the character of the food and the amount of water consumed.

Table. Bacteria Considered to be Normal flora of humans and their anatomical locations

Bacterium	Skin	Conjunctiva	Nose	Pharynx	Mouth	Lower Intestine	Anterior Urethra	Vagina
Staphylococcus epidermidis	++	+	++	+	++	+	++	+
Staphylococcus aureus	+	+/–	+	+	+	++	+/–	+
Streptococcus mitis	–	–	–	+	++	+/-	+	+
Streptococcus salivarius				++	++	–		
Streptococcus mutans				+	++			
Enterococci				+/–	+	++	+	+
Streptococcus pneumoniae		+/–	+/–	+	+			+/–
Streptococcus								

pyogenes	+/–	+/–		+	+	+/–		+
Neisseriae		+	+	++	+		+	+
Neisseria meningitides			+	+	++			+
Veillonellae					+	+/–		
Coliforms (E. coli)		+/–	+/–	+/–	+	++	+	+
Proteus mirabilis		+/–	+	+	+	+	+	+
Pseudomonas aeruginosa				+/–	+/–	+	+/–	
Haemophilus influenzae		+/–	+	+	+			
Bacteroides				+	+	++	+	+/–
Spirochetes				+	+	+		
Lactobacilli				+	++	+	++	
Clostridia					+/–	++		
Clostridium tetani						+/–		
Corynebacteria	++	+	++	+	+	+	+	+
Mycobacteria	+		+/–	+/–		+	+	
Actinomycetes				+	+			
Mycoplasmas				+	+	+	+/–	+

"++" – prominent; "+" – common; "+/-" –"irregular, occasional or transient.

Together with food, lactic acid bacteria, Sarcina ventriculi. hay bacillus, yeasts, etc., enter the stomach from the mouth. In some cases, dysentery, enteric fever, and paratyphoid bacilli and other pathogenic microbes are capable of penetrating into the stomach and then the intestine.

Table. Examples of tissue specificities of some bacteria associated with humans

Bacterium	Tissue
Corynebacterium diphtheriae	Throat
Neisseria gonorrhoeae	Urogenital epithelium
Streptococcus mutans	Tooth surfaces
Streptococcus salivarius	Tongue surfaces
Vibrio cholerae	Small intestine epithelium
Escherichia coli	Small intestine epithelium
Staphylococcus aureus	Nasal membranes
Staphylococcus epidermidis	Skin

Enterococci, fungi, and various other microbes are relatively rarely found in the duodenum. There are few microbes in the small intestine. Enterococci are found more often than others – In the large intestine there are large amounts of micro-organisms. Almost one-third of the dry weight of the faeces of certain animal species is made up of microbes.

Daily, an adult human excretes about 17 million billion micro-organisms with the excrements.

Table. Examples of specific attachments of bacteria to host cell or tissue surfaces

Bacterium	Ligand	Receptor	Attachment site	Disease
Streptococcus pyogenes	Protein F	Amino terminus of fibronectin	Pharyngeal epithelium	Sore throat
Streptococcus mutans	Glycosyl transferase	Salivary glycoprotein	Pellicle of tooth	Dental caries
Streptococcus salivarius	Lipoteichoic acid	Unknown	Buccal epithelium of tongue	None
Streptococcus pneumoniae	Cell-bound protein	N-acetylhexosamine-galactose disaccharide	Mucosal epithelium	pneumonia
Staphylococcus aureus	Cell-bound protein	Amino terminus of fibronectin	Mucosal epithelium	Various
Neisseria gonorrhoeae	N-methylphenyl-alanine pili	Glucosamine-galactose carbohydrate	Urethral/cervical epithelium	Gonorrhea
Enterotoxigenic E. coli	Type-1 fimbriae	Species-specific carbohydrate(s)	Intestinal epithelium	Diarrhea
Uropathogenic E. coli	Type 1 fimbriae	Complex carbohydrate	Urethral epithelium	Urethritis
Uropathogenic E. coli	P-pili (pap)	Globobiose linked to ceramide lipid	Upper urinary tract	Pyelonephritis
Bordetella pertussis	Fimbriae ("filamentous hemagglutinin")	Galactose on sulfated glycolipids	Respiratory epithelium	Whooping cough
Vibrio cholerae	N-methylphenylalanine pili	Fucose and mannose carbohydrate	Intestinal epithelium	Cholera
Treponema pallidum	Peptide in outer membrane	Surface protein(fibronectin)	Mucosal epithelium	Syphilis
Mycoplasma	Membrane protein	Sialic acid	Respiratory epithelium	Pneumonia
Chlamydia	Unknown	Sialic acid	Conjunctival or urethral epithelium	Conjunctivitis or urethritis

Table. Bacteia found in the large intestine of humans

Bacterium	Range of Incidence (%)
Bacteroides fragilis	100
Bacteroides melaninogenicus	100
Bacteroides oralis	100
Lactobacillus	20-60
Clostridium perfringens	25-35
Clostridium septicum	5-25
Clostridium tetani	1-35
Bifidobacterium bifidum	30-70
Staphylococcus aureus	30-50
Streptococcus faecalis	100
Escherichia coli	100
Salmonella enteritidis	3-7

Salmonella typhi	0.00001
Klebsiella species	40-80
Enterobacter species	40-80
Proteus mirabilis	5-55
Pseudomonas aeruginosa	3-11
Peptostreptococcus	common
Peptococcus	moderate
Methanogens	common

The intestinal microflora undergoes essential changes with the age of man. The intestinal tract of the newly-born baby in the first hours of life is sterile. During the first days it becomes inhabited by temporary microflora from the environment, mainly from breast milk. Later on, in the intestine of the newly-born baby a specific bacterial flora is established consisting of lactic acid bacteria (biphidobacteria, acidophilic bacillus), which is retained during the year. It has antagonistic properties in relation to many microbes capable of causing intestinal disorders in breastfed children, and remains during the whole period of breast feeding. However, on the 3rd-5th day of life in the intestine of breast-fed children E. coli and enterococci can be found, the amount of which sharply increases with the change to mixed feeding. After breast feeding is stopped the microflora of the child's intestine is completely replaced by a microflora typical of adults (E. coli, Clostridium perfringens, Clostridium sporogenes, Streptococcus faecalis. Proteus vulgaris, etc.).

At present it has been established that such a constant inhabitant of the intestine of man as Clostridium perfringens is capable of secreting digestive enzymes. The colibacillus and other species of microbes in the intestine produce the vitamins essential for the human body (B_1, B_2, B_{12}, K). Microbe antagonists (acidophilic, Lactobacillus bulgaricus etc.) are beneficial to the organism as they hinder the development of pathogenic bacteria which, together with infected food and water, may enter the intestine.

The pathogenic serotypes of E. coli which are capable of causing severe diseases (colienteritis) mostly in children have been found to be present in the human intestine together with the on pathogenic species.

Anaerobic bacteria which do not produce spores, the so-called bacteroids, inhabit mainly the lower part of the large intestine in human. They are found during acute appendicitis, postpartum infection, pulmonary abscesses, septicaemia of different aetiology, postoperative infectious complications in the peritoneal cavity, inflammatory processes of the gastrointestinal tract, respiratory tract, and on the skin

Metchnikoff considered some species of intestinal bacteria to be harmful, causing chronic intoxications. He suggested the method (if combating them by introducing lactic acid bacilli (Lactohacillus bulgaricus) bearing antagonistic properties into the intestine. Besides, Metchnikoff recommended a diet of vegetables and fruit, rich in sugar, and considered it advisable to build one's life according to the principles of orthobiosis (normal work, healthy relaxation, hygienic conditions, and prophylaxis of

diseases). Enteroviruses live in large quantities in the intestine. They may be found for a long time in healthy persons without causing diseases. In unfavourable conditions associated with some species of bacteria they cause the most varied clinical forms of disease.

MICROFLORA OF THE RESPIRATORY TRACT

People breathe in a large number of dust particles and adsorbed micro-organisms. Experimentally, it has been established that the amount of microbes in inspired air is 200-500 times greater than in expired air Most of them are trapped in the nasal cavity and only a small amount enters the bronchi, The pulmonary alveoli and the terminal branches of bronchi are usually sterile. The upper respiratory tract (nasopharynx, pharynx) contains relatively constant species (Staphylococcus epidermidis, streptococci, diphtheroids, Gaffkya tetragena, etc.).

When the defence mechanisms of the body are weakened as a result of cooling, starvation, vitamin deficiency, or traumas, the constant inhabitants of the respiratory tract become capable of causing different diseases (acute catarrhs of the respiratory tract, tonsillitis, pneumonia, bronchitis, etc.).

The nasal cavity contains a small amount of microbes. The mucous membrane of the nose produces mucin and lysozyme which have a bactericidal action. However, in spite of this, the nasal cavity has a relatively constant microflora (haemolytic or nasal micrococcus, diphtheroids, non-haemolytic staphylococci, haemolytic staphylococci, saprophytic Gram-negative diplococci, capsular Gram-negative bacteria, haemoglobinophilic bacteria of influenza, Proteus, etc). In the respiratory tract, besides the bacterial microflora. many viruses, in particular adenoviruses. can remain viable for long periods without causing pathological processes.

MICROFLORA OF THE VAGINA

In the first 2 days after birth the baby's vagina is sterile. Sometimes it contains a small amount of Gram-positive bacteria and cocci. After 2-5 days of life the coccal microflora becomes fixed and remains constant until puberty, when it is replaced by Dodderlein's lactic acid bacilli.

During the menstrual cycle the contents of the vagina become alkaline which is favourable for the development of coccal microflora. During sexual life the microflora of the vagina changes, and many microbes appear which are introduced from outside.

The microflora of the vagina undergoes profound changes during gynaecological diseases (endometritis, metritis, ovaritis, etc.), and after abortions.

The vaginal contents of the healthy woman have a relatively high concentration of sugar and glycogen, and a low content of the diastatic enzyme and proteins. The pH is 4.7 during which all other microbes except for Doderlein's lactic acid bacilli, cannot develop. As has been established, the acid medium of the vagina depends on the presence of glycogen which under the influence of vaginal bacteria is transformed into mono-

and disaccharides and then into lactic acid. The amount of glycogen depends on the function of the ovaries and the condition of the whole body.

Vaginal bacteria have antagonistic properties; because of this, normal microflora should be protected and should not be exposed to the harmful effect of medicines (antibiotics, sulphonamide preparations, rivanol, osarsol. potassium permanganate, etc.) to which Doderlein's lactic acid bacilli are more sensitive than the bacteria against which these substances are employed.

MICROFLORA OF THE URINARY TRACT

In men in the anterior part of the urethra there are Staphylococcus epidermidis. diphtheroids and Gram-negative non-pathogenic bacteria. Mycobacterium smegmatis and mycoplasmas are found on the external parts of the genitalia, and also in the urine of men and women.

The female urethra is usually sterile, in some cases it contains a small amount of non-pathogenic cocci.

The bacteria of the mucous membranes of the eyes include Staphylococcus epidermidis, Corynebacterium xerosis, mycoplasmas, etc. When the organism is weakened or when there are visual disturbances and vitamin deficiency, the normal inhabitants of the mucous membranes may become relatively pathogenic and may cause different diseases of the mucous membrane, such as conjunctivitis, blepharitis and other suppurative processes.

The normal microflora is not constant but depends on the age, nutrition and general condition of the macro-organism. The microflora of the human body undergoes profound changes, especially during various diseases.

Disturbances in the species composition of the normal microflora occurring under the influence of infectious and somatic diseases, and long-term and irrational use of antibiotics bring about the state of dysbacteriosis. This is characterized by disturbances in the assimilation of products of digestion, by changes in the enzymatic processes, and by the cleavage of ready-made physiological secretions. The territorial deviations of microflora cause a whole series of complications: intestinal dyspepsia, toxinfections, suppurative processes, catarrhs of the respiratory tract, pneumonia, candidiasis, etc. In dysbacteriosis the number of lactic acid bacteria is diminished, the number of anaerobes increased, Gram-positive bacteria change to Gram-negative and Gram-negative to Gram-positive, etc.

The question arises whether animal life is possible without microbes, It was already known in the last century that micro-organisms were very rarely found in birds and animals of the arctic regions. There were cases with absolutely no microflora found in the body of some birds. Pasteur made an attempt to raise amicrobic animals, but with the level of techniques of that time the problem could not be solved.

A new branch of biology, gnotobiology, is now developing. It studies the microbe-free organisms. Amicrobic chicks, rats, mice, guinea pigs, sucking pigs. and other animals

have been reared. Amicrobic animals, or gnotobiotes, are subdivided into several groups, monobiotes. (absolutely microbe-free animals), dibiotes (animals infected with one microbial species), polyobiotes (animals harbouring more than one species of microbes in their body).

Germ-free (gnotobiotic) animals are good experimental models for investigating the interactions of animals and microorganisms. To determine the role of the normal microbiota, animals can be delivered by aseptic Caesarean section (the surgical removal of the fetus from the uterus via the abdomen) so they will not be contaminated by the normal microbiota of the vagina and birth canal during vaginal delivery. Germ-free animals can been be raised in the absence of microorganisms by being kept in a sterile environment. They are fed sterile food and water and given sterile air to breathe. Comparing animals possessing normal associated microbiota with germ-free animals permits the exploration of the complex relationships between microorganisms and host animals.

Germ-free animals develop abnormalities of the gastrointestinal tract. They are more susceptible to disease than animals with normal associated microbiota. Germ-free animals are more susceptible to bacterial infection. Organisms such as Bacillus subtilis and Micrococcus luteus, which are harmless to other animals, cause disease in germ-free animals. More exotic pathogenic microorganisms such as Vibrio cholerae and Shigella dysenteriae are far more readily able to establish infections where there are no normal microbiota. They do not have to compete for survival within the intestinal tract. At the same time, though, germ-free animals are resistant to Entamoeba histolytica, the causative organism of amebic dysentery. This is because this protozoan requires normal intestinal bacteria as a food source. Likewise, tooth decay is no problem to germ-free animals, even those on high sugar diets, because they do not have lactic acid bacteria — the bacteria that cause tooth decay — in their oral cavities.

Scientists focused their attention at gnotobiotes because it was necessary to study deeply the role of normal microflora in the mechanisms of infectious pathology and immunity. As compared to the commonly encountered animals, gnotobiotes have a larger caecum, underdeveloped lymphoid tissue, internal organs of lesser weight, smaller blood volume, a reduced content of water in the tissue and of antibodies in blood serum. Gnotobiology provides the means for revealing more precisely the role of normal microflora in the synthesis of vitamins and amino acids, in the production of congenital and acquired immunity, and the relationship of bacteria and viruses. Much importance is attached to gnotobiology in the study of space and the life conditions of man and animals during space flight.

MICROBIOLOGICAL INVESTIGATION OF SOIL

For this purpose it is necessary to select most typical area not more then 25 m^2. The samples are taken from different places of the are field along the diagonal, the angles and the center 10 — 20 cms deep. The weight of each sample must be 100 – 200 g. The total weight of the soil 0,5 – 1 kg.

After careful mixing take an average sample of weight 100 – 200 g. Put the samples of soil in the sterile banks, mark and deliver to the laboratory. The soil specimens for plating are grinded in sterile mortar, make serial dilutions in an isotonic solution of sodium chloride 1: 10, 1:100, 1: 1000 etc. Plate 0,1 – 1 ml of specimens into special media for aerobic and anaerobic microbes. After incubation at optimal temperature count the colonies on the plates.



Fig. Collection of soil

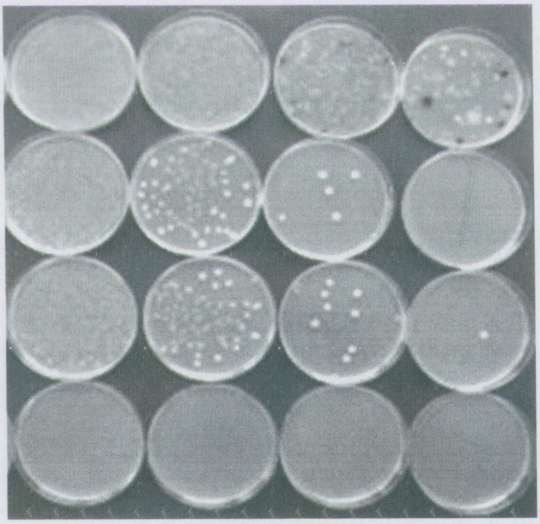


Fig. Examination of the general microbe number

MICROBIOLOGICAL INVESTIGATION OF WATER

The sanitary - bacteriological investigation of water includes determination of total number of microbes in 1 ml of water, determination of a coli-index or coli-titer, and detection of pathogenic microbes, their toxins and Å. ñîli bacteriophages.

There are quantitative parameters of faecal pollution: a coli-titre and coli-index. Coli-titre is an index, which characterise an amount of water in millilitres which contain

one E.coli. Coli-index characterises a number of E. coli in one litre of water. The important part of investigation is taking of water samples. This procedure can do only by special persons (sanitary doctor or his assistant).

The samples of water for investigation are taken in 0,5 L sterile bottles.



Fig. Water collection

Water cocks, pumps, tubes previously must be sterilize by a flame using a cotton plug moistened before with alcohol. Then the water on for 10 min to wash off the bacteria which are on their surface inside. From the open reservoirs water for investigation is taken with the bathometer. This instrument is metal frame with a sterile bottle inside. It gives the possibility to take the water samples from any depth. Usually water is taken from the depth of 15 cms. The bottles with samples of water should have labels, which should mark the source, place of sample, time (day, hour), surname of the person who has taken the sampleassay, and also purpose of research.

Water is delivered to the laboratory immediately after its receival. The transportation should be done within 2 hours. When doctor examines chlorinated water, it is taken in sterile bottles with 2 mL of 1,5 % of solutions of Sodium hyposulphitum ($Na_2S_2O_3 \cdot 5H_2O$). Such quantity of Sodium hyposulfite binds chlorine at its concentration up to 2 mg/L in 500 ml. In summer water transports in ice, and in winter in special hot-water bottle (temperature must be 1–5 °C). After delivery of samples to the laboratory the investigation begins. It includes determination of total number of microbes and determination of a coli-titre and coli-index.

Quantitative Analysis

Bacteria cannot be accurately counted by microscopic examination unless there are at least 100 million (10^8) cells per mililiter Natural bodies of water, however, rarely contain more than 10^5 cells per millilitre. The method employed is therefore the plate count. A measured volume of water is serially diluted, following which 1 mL from each dilution tube is plated in nutrient agar and the resulting colonies counted. Since only cells able to form colonies are counted, the method is also known as the "viable count".

A typical example of serial dilution would be the following. One millilitre of the water sample is aseptically transferred by pipette to 9 mL of sterile water. The mixture

is thoroughly shaken, yielding a 1:10 dilution (For obvious reasons, this is also known as the "10^{-1}" dilution). The process is repeated serially until a dilution is reached that contains between 30 and 300 colony-forming cells per millilitre, at which point several 1-mL samples are plated in a nutrient medium. Since the original sample may have contained up to 1 million (10^6) viable bacteria, it is necessary to dilute all the way to 10^{-5}, plate 1-mL samples from each dilution tube, and then count the colonies only on those plates containing 30-300 colonies. The reasons for these numerical limits are that with over 300 colonies the plate becomes too crowded to permit each cell to form a visible colony, whereas with below 30 colonies the percent counting error becomes too great. (The statistical error of sampling can be calculated as follows' The standard deviation of the count equals the square root of N, where N equals the average of many samples.

Ninety-five percent of all samples will give counts within 2 standard deviations of the average. For example, if the average count is 36, then 95% of all samples will lie between 24 and 48 [36 ± 12]. In other words, within 95% confidence limits a sample count of 36 has an error of plus or minus 33%.) Assume that the above procedure has been carried out with the results. The 10^{-3} dilution has a suitable number of colonies, the others being either too high or too low for accuracy. The original water sample is calculated to have contained 72,000 (72×10^3) viable cells per millilitre.

Qualitative Analysis

The methods of plating and enrichment culture are used to obtain a picture of the aquatic bacterial population. Although such methods are satisfactory for general biologic studies, they are inadequate for the purpose of sanitary water analysis; this involves the detection of intestinal bacteria in water, since their presence indicates sewage pollution and the consequent danger of the spread of enteric diseases. Since any enteric bacteria would be greatly outnumbered by other types present in the water samples, a selective technique is necessary in order to detect them. Two widely used procedures for sanitary water analysis are as follows:

Table. Example of a viable count

Dilution	Plate Count*
Undiluted	Too crowded
10-'	To count
10^{2}	510
10^{3}	72
10^{4}	6
10^{5}	1

*Each count is the average of 3 replicate plates

1. Tube method. Dilutions of a water sample are inoculated into tubes of a medium which is elective for coliform bacteria and in which all coliform bacteria but

few non-coliform bacteria will form acid and gas. Such media include MacConkey's medium, which contains bile salts as inhibitors of non-coliform bacteria; lactose-containing media; and glutamatecontaining media. Cultures showing both acid and gas may then be subjected to further tests to confirm the presence of *Escherichia coli* or closely related enteric gram-negative rods. Such tests include streaking cultures on a lactose-peptone agar containing eosin and methylene blue (EMB agar), on which *E coli* forms characteristic blue-black colonies with a metallic sheen; subculturing at 44 °C; and a series of diagnostic biochemical tests

2. Membrane filtration method. A large measured volume of water is filtered through a sterilized membrane of a type that retains bacteria on its surface while permitting the rapid passage of smaller particles and water. The membrane is then transferred to the surface of an agar plate containing a selective differential medium for coliform bacteria. Upon incubation, coliform bacteria give rise to typical colonies on the surface of the membrane. The advantages of this method are speed (the complete test takes less than 24 hours) and quantitation, the number of coliform cells being determined for a given volume of water.







Fig. Water samples (100 ml) are passed through bacteriological filters (0,2 to 0,45 μm pore size) to trap bacteria The filters with trapped bacteria are placed on a medium containing lactose as a carbon source, an inhibitor to suppress growth of non-coliforms and indicator substances to facilitate differentiation of coliforms. Coliform bacteria form distinct colonies on Endo medium

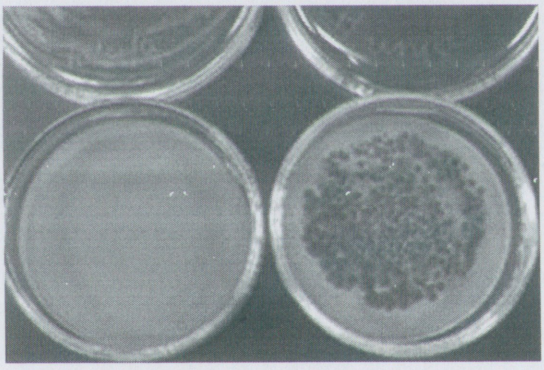


Fig. Colonies of E. coli on membranous filters.

The drinking water should not have more than 100 microbes in 1 ml. The microbic number in water of wells and open reservoirs can be up 1000.

During determination of a coli-index and coli-titre of water it is necessary to take into consideration the ability of Å. coli of the man and animal to grow at 43 °C

MICROBIOLOGICAL INVESTIGATION OF THE AIR

The sanitary - hygienic investigation of the microflora of the air includes determination both the total number of microbes in 1 $m^3$of the air and revealing of pathogenic staphylococci and streptococci. For taking the samples sedimentation and aspiration methods are used.

PLATE METHOD (SEDIMENTATION METHOD)

The Petry's dishes with meat-peptone agar or another special nutrient media for staphylococci and streptococci, for example blood agar, yolk-salt agar are used. They

stay in open form at various height from a floor. It is recommend to take one sample on every 20 m^2 of a premises. Term of exposition depends on prospective quantity of microbes in the air. With a plenty of microorganisms a cup is opened for 5 – 10 minutes, with a little – for 20 — 40 minutes.

Place the dishes into 37 °C incubator for 24 hrs and then incubate for 48 hrs at room temperature (18-20 °C). Study colonies, count them, and isolate pure culture of different microbes.

According to Omeliansky data on a surface of medium by 100 cm^2 sedimentate in 5 minutes as so many microbes, as they present in 10 L of air. For example, on the dish surface with MPA after 5 minute exposure 32 colonies have grown. It is necessary to calculate amount of microbes which are present in 1 m^3 of the air, applying the Omeliansky's formula. The plate has 78,5 cm^2 ($S = \pi r^2 = 3,14 \cdot 5^2 = 78,5$ CM^2). Thus, it is possible to determine, what quantity of microbes (õ) would grow at the given exposure on a surface of medium in 100 CM^2,

$$x = (32 \cdot 100): 78,5 = 40$$

This quantity of microbes contains in 10 L of the air, and in 1 m^3 (1000 π) there will be–(40 • 1000): 10 = 4000.

There is a special table for determination of total number of microbes in 1 m^3 of the air (Table.).

Table. Account of bacteria number in 1 m^3 of the air at a 10-minute exposure

No	Dish diameter	Dish area (cm^2)	Multiplier
1	8	50	100
2	9	63	80
3	10	78,5	60

For determination of microbial dissemination degree quantity of the colonies on the dish surface which have been counted should be multiplied with one of multiplier.

If on a Petry's dish (78,5 cm^2) at a 10-minute exposure 40 colonies have grown, the quantity of microbes in 1 m^3 of the air will be equal 40 • 60 = 2400.

ASPIRATION METHOD

It is based on a shock action of an air jet about a surface of a medium. Krotov's apparatus is used for this purpose. It give us the possibility to let pass 50 –100 L of air with a speed of 25 L per minute through clinoid chink in the special glass above the open dish MPA. The rotation of Petry's dish (1 rotation/sec) provides uniform dispersion of microorganisms on all surface of a medium. Then dish is incubated in a thermostat at 37 °C for 18-24 hrs. For example, 250 colonies are revealed on the surface of dish after 2-minutes exposure with a 25 l/min speed. Thus the number of microbes (x) in 1 l of the air is: x = (250 •1000): 50 = 5000.

There are temporary standards of a sanitary - hygienic state of the air: in operating room the total number of microbes prior to the beginning of the operation must be no

more than 500 in 1 m^3, after the operation – 1000. In preoperative and dressing rooms limiting number of microbes prior before the beginning of work – 750 microbes in 1 m^3, after work – 1500. In birth wards the total number of microbes is about 2000 in 1 m^3 of the air, and staphylococci and streptococci are not higher then 24 in 1 m^3, and in newborn rooms – about 44 in 1 m^3.

SOIL MICROORGANISMS AND THEIR INTERACTIONS

The soil is considered as the land surface of the earth which provides the substratum for plant and animal life. The soil represents a favourable habitat for microorganisms and is inhabited by a wide range of microorganisms, including bacteria, fungi, algae, viruses and protozoa. The physical structure, aeration, water holding capacity and availability of nutrients are determined by the mineral constituents of soil, which are formed by the weathering of rock and the degradative metabolic activities of the soil microorganisms. Cultivated soil has relatively more population of microorganisms than the fallow land, and the soils rich in organic matter contain much more population than sandy and eroded soils. Microbes in the soil are important to us in maintaining soil fertility, cycling of nutrient elements in the biosphere and sources of industrial products such as enzymes, antibiotics, vitamins, hormones, organic acids etc. But certain microbes in the soil are the causal agents of various human and plant diseases.

The plant and animal remains deposited in the soil contribute organic substances. Soil microorganisms breakdown a variety of organic materials and use a portion of these breakdown products to generate or synthesize a series of compounds that make up humus, a dark coloured amorphous substance composed of residual organic matter not readily decomposed by microorganisms. The three major fractions of humus are humic substances, poly-saccharides and other non-humic substances, and humin. These materials impact on the physical, chemical and bio-chemical properties of soil in many ways. Humus improves the texture and structure of the soil, contributes to its buffering capacity and increase the water holding capacity of the soil.

MICROBIAL FLORA OF SOIL

The vast differences in the composition of soils, together with differences in their physical characteristics and the agricultural practices by which they are cultivated, result in corresponding large differences in the microbial population both in total numbers and in kinds. The great diversity of the microbial flora makes it extremely difficult to determine accurately the total number of microorganisms present.

BACTERIAL POPULATION IN SOIL

The bacterial population of the soil exceeds the population of all other groups of microorganisms in both number and variety. Bacterial population is one-half of the

total microbial biomass in the soil ranging from 1,00000 to several hundred millions per gram of soil, depending upon the physical, chemical and biological conditions of the soil. As per the system proposed in the Bergey's Manual of Systematic Bacteriology, most of the bacteria which are predominantly encountered in soil are taxonomically included in the three orders, Pseudomonadales, Eubacteriales and Actinomycetales of the class Schizomycetes. Bacteria are also classified on the basis of physiological activity or mode of nutrition, into two groups, *i.e.*, autotrophs and heterotrophs. Autotrophic bacteria are capable of synthesizing their food from simple inorganic nutrients. They are of two types, *i.e.*, photoautotrophs (*Chromatrum*, *Chlorobium*), which utilize CO_2 as carbon source and derive energy from sunlight and chemoautotrophs (*Nitrobacter*, *Nitrosomonas*), which utilize CO_2 as carbon source and derive energy from the oxidation of simple inorganic substances present in soil. Herterotrophic bacteria derive their carbon and energy from complex organic matter, decaying roots and plant residues. Most of the bacteria present in soil are heterotrophic in nature. Both aerobic and anaerobic bacteria are present in soil. The majority of the beneficial soil-dwelling bacteria need oxygen and therefore aerobic in nature, whilst those that do not require air are referred to as anaerobic, and tend to cause putrefaction of dead organic matter. It is generally agreed that there are many species of bacteria in soil are yet to be discovered.

PROCESSES PERFORMED BY BACTERIA IN SOIL

Bacteria bring about a number of changes and biochemical transformations in the soil and thereby directly or indirectly help in the nutrition of higher plants growing in the soil. The important transformations and processes in which soil bacteria play vital role are: decomposition of cellulose and other carbohydrates, ammonification, nitrification, denitrification, biological fixation of atmospheric nitrogen, oxidation and reduction of sulphur and iron compounds.

The bacterial genera *Nocardia*, *Streptomyces*, and *Micromonospora* belong to the order actinomycetes (aerobic and heterotrophic), are capable of degrading many complex organic substances and consequently play an important role in building soil fertility. The actinomycetes are also able to synthesize and excrete antibiotics, *e.g.*, streptomycin is produced by growing soil actinomycetes in pure culture.

Ammonification is a process where amino acids are subject to a variety of pathways for microbial decomposition. The production of ammonia is referred to as ammonification. The soil bacteria belong to the genera *Bacillus* and *Pseudomonas* carry out the process of ammonification. Nitrification is a process where microorganisms convert ammonia to nitrate. This process happens in two steps and each step is performed by a different group of bacteria. The first step is oxidation of ammonia to nitrite which is performed by ammonia-oxidizing bacteria (genera include *Nitrosomonas*, *Nitrosococcus*, *Nitrosovibrio*), and the second step is the oxidation of nitrite to nitrate which is performed by nitrite-oxidizing bacteria (genera include *Nitrobacter* and*Nitrospina*).

Dentrification is a process where the transformation of nitrates to gaseous nitrogen is accomplished by a series of biochemical reactions. Species of several genera of bacteria are capable of transforming NO_3^- to N_2, *e.g.*, *Agrobacterium*, *Bacillus*, *Chromobacterium*, *Flavobacterium*, *Achromobacter*, *Hyphomicrobium*, *Pseudomonas*, *Alcaligenes*, *Thiobacillus* and *Vibrio*.

Many microorganisms are capable of using molecular nitrogen in the atmosphere as their nitrogen source. The conversion of molecular nitrogen into ammonia by soil microorganisms is known as nitrogen fixation. The process is carried out by both non-symbiotic and symbiotic microorganisms. Non-symbiotic microorganisms live freely and independently in the soil whereas symbiotic microorganisms live in roots of plants. The bacterial genera*Clostridium* and *Azotobacter* carry out non-symbiotic nitrogen fixation whereas symbiotic nitrogen fixation is carried out by the genus *Rhizobium*. *Rhizobium* accomplishes the process in association with the plants belong to the family leguminoceae. It is a process where both the plant and the bacteria benefit by the association. The bacteria convert atmospheric nitrogen into fixed nitrogen, which is available to the plant, and in turn, the bacteria derive nutrients from plant tissues.

Some bacteria are capable of synthesizing organic matter from inorganic carbon. The organic carbon compound that eventually are deposited in the soil are degraded by microbial activity. Carbon dioxide is released as the end product into the air and soil. Cellulose is the most abundant organic material in plants which is readily attacked by many species of bacteria and fungi.

Some bacterial species oxidize and others reduce various sulphur compounds. Sulphur in its elemental form cannot be utilized by plants or animals. The bacterium *Thiobacillus thiooxidans* oxidize sulphur into sulphates. Sulphates may also be reduced to hydrogen sulphide by soil microorganisms. Certain pigmented sulphur bacteria oxidize hydrogen sulphide to elemental sulphur.

SOIL FUNGI

More than hundreds of different species of fungi inhabit the soil. They prefer to live in the soil in an aerobic condition. Fungi perform important functions within the soil in relation to nutrient cycling, disease suppression and water dynamics, all of which help plants become healthier and more vigorous. Fungi exist in both the mycelial and spore stage. Soil fungi are microscopic plant-like cells that grow in long threadlike structures or hyphae that make a mass called mycelium.

The mycelium absorbs nutrients from the roots it has colonised, surface organic matter or the soil. From the mycelia the fungi is able to throw up its fruiting bodies, the visible part above the soil (*e.g.*, mushrooms), which may contain millions of spores. When the fruiting body bursts, these spores are dispersed through the air to settle in fresh environments, and are able to lie dormant for up to years until the right conditions for their activation arise. The physical structure of soil is improved by the accumulation of mold mycelium within it.

Fungi are active in decomposing the major constituents of plant tissues namely cellulose, lignin and pectin. Saprophytic fungi convert dead organic matter into fungal biomass, carbon dioxide and organic acids. These fungi have enzymes that work to "rot" or "digest" the cellulose and lignin found in the organic matter, with the lignin being an important source of carbon for many organisms. Without their digestive activities, organic material would continue to accumulate until the forest became a huge rubbish dump of dead leaves and trees. By consuming the organic matter fungi play an important role in immobilising and retaining nutrients in the soil.

Some fungi live in a mutually beneficial relationship with plants. Mycorrhizal fungi are perhaps the best known of the mutualists. Mycorrhizal fungi form a partnership mainly with trees but also with some plants, but rather then harming the tree, their presence significantly increases the roots' effectiveness. In a mycorrhizal association, the fungus colonizes the host plant's roots, either intracellularly as in arbuscular mycorrhizal fungi (AMF), or extracellularly as in ectomycorrhizal fungi. Arbuscular mycorrhiza (VAM) are the most common form of mycorrhiza, especially in agricultural plant associations. This mutualistic association provides the fungus with relatively constant and direct access to carbohydrates, such as glucose and sucrose. The carbohydrates are translocated from the leaves to root tissue and on to the plant's fungal partners. Plant roots alone may be incapable of taking up phosphate ions that are demineralized in soils with a basic pH. The mycelium of the mycorrhizal fungus can, however, access these phosphorus sources, and make them available to the plants they colonize.

Another group of fungi also known as pathogenic fungi (parasitic fungi), the second largest group present in the soil. This group includes the fungi genera *Verticillium*, *Phytophthora*, *Rhizoctonia* and *Pythium*. These group of fungi being parasitic on plants, draw all the nutrients from the plant and ultimately cause its death.

Fungi tend to dominate over bacteria and actinomycetes in acid soils as they can tolerate a wide pH range. Fungi can survive in the soil for long periods even through periods of water deficit by living in dead plant roots and as spores or fragments of hyphae.

SOIL ALGAE

Algae population in soil is generally smaller than that of either bacteria or fungi. Their number in soil usually ranges from 100 to 10,000 per gram of soil. They are photoautotrophic, aerobic organisms and obtain CO_2 from atmosphere and energy from sunlight and synthesize their own food.

Their photosynthetic nature accounts for their predominance on the surface or just below the surface layer of soil. On bare and fretted land, algae initiate the accumulation of organic matter because of their ability to carry out photosynthesis and other metabolic activities. The major types of algae are present in the soil are green algae and diatoms.

Soil algae are divided into four major classes, *i.e.*, cyanophyta (blue-green algae), chlorophyta (grass-green algae), xanthophyta (Yellow-green algae), and bacillariophyta (diatoms). Out of these four classes, class cyanophyta (blue-green algae) and chlorophyta (grass-green algae) are more abundant in soil. Algae of the class chlorophyta and bacillariophyta are dominant in the soils of temperate region while blue-green algae are dominant in tropical soils. *Chlorella*, *Chlamydomonas*, *Chlorococcum* are some of the common genera of grass-green algae (chlorophyta) present in the soil where as *Navicula*, *Pinnularia* are some of the genera of diatoms present in the soil.

Cyanobacteria, also known as blue green algae are the unicellular, oxygenic photosynthetic prokaryotes grow on the surface of freshly exposed rocks where the accumulation of their cells result in simultaneous deposition of organic matter. This gives a nutrient base that will support growth of other bacterial species. Unlike bacteria, which are heterotrophic decomposers of the wastes and bodies of other organisms, cyanobacteria contain the green pigment chlorophyll (as well as other pigments), which traps the energy of sunlight and enables these organisms to carry on photosynthesis. Cyanobacteria are thus autotrophic producers of their own food from simple raw materials. The dominant genera of blue green algae in soil are:*Chrococcus*, *Phormidium*, *Anabaena*, *Aphanocapra*, *Oscillatoria* etc. Some blue green algae help in nitrogen fixation. Cyanobacteria are common in neutral to alkaline soil. They secrete a substance known as mucilage, which helps in increasing water retention capacity of the soil. The cyanobacteria play a key role in the transformation of rock to soil, a first step in rock-plant succession.

Most of the soil algae, specially blue-green algae act as cementing agent in binding soil particles and thereby prevent soil erosion. In un-cropped soil, soil algae check the loss of nitrates through leaching and drainage. They liberate large quantity of oxygen through photosynthesis in the soil environment and thus facilitate the aeration in submerged soils. In tropical soils, soil algae maintain soil fertility.

PROTOZOA IN SOIL

Most soil protozoa are flagellates or amoebas; the number per gram of soil ranges from a few hundred to several hundred thousand in moist soils rich in organic matter. They are larger than bacteria and are abundant in surface soil. Their dominant mode of nutrition involves ingestion of bacteria. They can withstand adverse soil conditions as they are characterized by "cyst stage" in their life cycle. Most of them reproduce asexually by binary fission. Most of the soil protozoa possess flagella, cillia or pseudopodia as their locomotive organ. Depending upon the type of locomotion, protozoa can be classified as four different classes: rhizopoda, mastigophora, ciliophora, and sporophora.

Class rhizopoda includes protozoa without appendages, having naked protoplasm without cell-wall. *Amoeba*, *Biomyxa*, *Euglypha*, etc. are some of the important genera belong to class rhizopoda. Flagellated protozoa which are predominant in soil belong to class mastigophora. Some of the important genera belong to class mastigophora

include *Allention*, *Bodo*, *Cercobodo*, *Cercomonas* etc. Some of the members of this class are saprophytic whereas some are autotrophic in nature. The class ciliophora, according to the name possess members which have the presence of cilia around their body. Cilia are short, hair like appendages which help in locomotion. The important genera present in soil belong to class ciliophora include *Balantiophorus*, *Colpidium*, *Uroleptus*, *Vortiicella* etc.

As the dominant mode of nutrition in protozoa, involves ingestion of bacteria, they play an important role in maintaining bacterial equlibrium in soil. The soil bacterial genera upon which they depend include *Agrobacterium*, *Bacillus*, *Enterobacter*, *Escherichia*, *Micrococcus*, and *Pseudomonas*. Some protozoa can be used as biological control agents against phytopathogens.

VIRUSES

Bacterial viruses as well as plant and animal viruses present in soils through additions of plant and animal wastes. Soil viruses are of great importance as they may influence the ecology of soil biological communities through both an ability to transfer genes from host to host and as a potential cause of microbial mortality. Soils probably harbour many absolutely novel viral species that together may represent a large reservoir of genetic diversity. Different virus morphotypes including tailed, spherical, rod-shaped, filamentous and bacilliform particles were detected in the soil samples.

Soil-borne wheat mosaic virus (SBWMV) can cause severe stunting and mosaic in susceptible wheat, barley and rye cultivars. Soil-borne wheat mosaic (SBWM) affects autumn-sown small grains. Irregular, chlorotic patches in the field suggest soil-borne viral infection, although similar symptoms may be caused by a number of other viruses or other biotic or abiotic factors.

INTERACTIONS AMONG SOIL MICROORGANISMS

The microbial ecosystem is the sum of the biotic and abiotic components of soil. It includes the total microbial flora together with the physical composition and physical characteristics of the soil.

The microorganisms that inhabit the soil exhibit many different types of interactions or associations. Some interactions are indifferent or neutral; while some are positive and some are negative in nature. The associations existing between different soil microorganisms, whether of a symbiotic or antagonistic nature, influence the activities of microorganisms in the soil.

NEUTRAL ASSOCIATIONS

Neutral association or neutralism is the association between microorganisms, where two different species of microorganisms occupy the same environment without affecting each other. Such an association might be transitory; as conditions change in the environment, like nutrients availability, there might be a change in the relationship.

POSITIVE ASSOCIATIONS

There are three types of positive associations exist between microorganisms.

Mutualism

Mutualism is an example of a symbiotic relationship in which each organism benefits from the association. The way in which benefit is derived depends on the type of interactions. Syntrophism is a type of mutualistic association, which involves the exchange of nutrition between two species. The association between blue green algae and a fungus (lichen) is known as syntrophism.

The fungus surrounds the algal cells, often enclosing them within complex fungal tissues unique to lichen associations. In this type of association, algae benefits by protection afforded to it by the fungal hyphae from environmental stresses, while the fungus obtain and use CO_2 released by the algae during photosynthesis. The algal or cyanobacterial cells are photosynthetic, and as in plants they reduce atmospheric carbon dioxide into organic carbon sugars to feed both symbionts. Both partners gain water and mineral nutrients mainly from the atmosphere, through rain and dust. The lichen association is a close symbiosis. It extends the ecological range of both partners but is not always obligatory for their growth and reproduction in natural environments, since many of the algal symbionts can live independently.

Another mutalistic association is characterized by different metabolic products from the association as compared with the sum of the products of the separate species. A mutualism between *Thiobacillus ferrooxidans* and *Beijerinckia lacticogenes* helps in ore leaching. Both of these species when grown in a medium free of added carbon and nitrogen sources and with a sterile ore concentrate, the growth of the two species in association and the resulting effect on the rate of leaching copper from the ore concentrate is observed. Leaching is process of recovery of metal from the ore, where microorganisms play the important role of oxidizing insoluble metal sulphides to soluble sulphates.

Microorganisms may also form mutualistic relationships with plants in soil, an example of which is nitrogen fixing bacteria *i.e. Rhizobium* growing in the roots of legumes (Plants of the family leguminoceae). In this Rhizobium-legume association, *Rhizobium* bacteria are benefited by protection from the environmental stresses while in turn plant is benefited by getting readily available nitrate nitrogen released by the bacterial partner.

Commensalism

Commensalism refers to a relationship between organisms, in which one species of a pair benefits whereas the other is not affected. This happens commonly in soil with respect to degradation of complex molecules like cellulose and lignin. For example, many fungi can degrade cellulose to glucose, which is utilized by many bacteria. Many bacteria are unable to utilize cellulose, but they can utilise the fungal breakdown products of cellulose, *e.g.*, glucose and organic acids.

Another example of commensalism is that of a change in the substrate produced by a combination of species and not by individual species. For example, lignin which is major constituent of woody plants and is usually resistant to degradation by most of the microorganisms. But in forest soils, lignin is readily degraded by a group of Basidiomycetous fungi and the degraded products are used by several other fungi and bacteria which can not utilize lignin directly.

Proto-cooperation

It is a mutually beneficial association between two species. Protocooperation is a form of mutualism, but they do not depend on each other for survival. An example of protocooperation happens between soil bacteria or fungi, and the plants that occur growing in the soil. None of the species rely on the relationship for survival, but all of the fungi, bacteria and higher plants take part in shaping soil composition and fertility. Soil bacteria and fungi interrelate with each other, forming nutrients essential to the plants survival. Plants utilize these microorganism synthesized nutrients through root nodules thereby decomposing organic substances. Soil bacteria and fungi help in improving the fertility of the soil and shaping of soil. Plants get essential carbon dioxide and nutrients. Nutritional proto-cooperation between bacteria and fungi has been reported for various vitamins, amino and purines in terrestrial ecosystem and are very useful in agriculture.

NEGATIVE ASSOCIATIONS

Antagonism

It is the relationship in which one species of an organism is inhibited or adversely affected by another species in the same environment. The relationship is also known as antagonism. The species which adversely affects the other is said to be antagonistic. Such organisms may be of great practical importance, since they often produce antibiotics or other inhibitory substances which affect the normal growth processes or survival of other organisms.

Antagonistic relations are most common in nature. One example of which is the antagonistic nature of both *Staphylococcus aureus* and *Pseudomonas aeruginosa* towards the fungus *Aspergillus terreus*. Certain *Pseudomonas* pigments inhibit germination of *Aspergillus* spores. *Staphylococcus aureus* produces a diffusable antifungal material that causes distortions and hyphal swellings in *Aspergillus terreus*.

An antibiotic is a microbial inhibitor of biological origin. Soil microorganisms are the most common producers of antibiotics. Production of antibiotics in soil may enable the antibiotic producing organism to thrive successfully in a competitive environment. One example of which is the presence of large populations of actinomycetes in the chitinaceous shells of dead crustaceans in the sea. Their existence, in the environment free of other microorganisms, is may be due to the production of antibodies by them.

Several species of *Streptomyces* from soil produces antibacterial and antifungal antibiotics. Most of the commercial antibiotics such as streptomycin, chloramphenicol, Terramycin and cyclohexamide have been produced from the mass culture of *Streptomyces*. Thus, species of *Streptomyces* are the largest group of antibiotic producer's in soil. The bacterial genus *Bacillus* produces an antifungal agent which inhibits growth of several soil fungi.

Antibiosis may result from a variety of other conditions operative in mixed populations. Certain fungi produce cyanide in concentrations toxic to other microorganisms and the algae elaborate fatty acids which exhibit a marked antibacterial activity. Many soil microorganisms, for example the myxobacteria and streptomycetes are antagonistic because they secret potent lytic enzymes which destroy other cells by digesting their cell wall or other protective surface layers. It appears that in the natural environment producers of lytic substances are often found in close proximity with sensitive organisms and do not predominate over them.

Ammensalism is the interaction between two species, where one species suppresses the growth of other by producing toxins like antibiotics or harmful gases like methane, ethylene, nitrite, or HCN or sulphides and other volatile sulphur compounds.

Competition

Soil is inhabited by different kinds of microorganisms, and therefore they exhibit competition among themselves for nutrients and space. In this kind of situation, the best adapted microorganism will predominate or eliminate the others which are dependent upon the same limited nutrient substance. The organisms with inherent ability to grow fast are better competitors.

Exogeneous nutrients are required for the germination of chlamydospores of *Fusarium*, Oospores of *Aphanomyces* and conidia of *Verticillium dahlae*in soil. But other fungi and soil bacteria deplete these critical nutrients required for spore germination and thereby hinder the spore germination resulting into the decrease in population. Soil bacteria compete for space and suppress the growth of the fungal population.

Parasitism

Parasitism is the relationship between two organisms, in which one organism lives in or on another organism. The parasite is dependent upon the host and feeds on the cells, tissues or fluids of the host organism. The parasite lives in intimate physical contact with the host and forms metabolic association with the host. All major groups of plants, animals, and microorganisms are susceptible to attack by microbial parasites.

The bacterial parasite of Gram-negative bacteria *Bdellovibrio bacteriovorus* which is widespread in soil and sewage attaches to a host cell at a special region and eventually causes the lysis of that cell. As a consequence, plaque like areas of lysis appear when these parasites are plated along with their host bacteria. Parasitism is widely spread in soil communities. Viruses which attack bacteria (bacteriophages), fungi, and algae are

strict intracellular parasites since they cannot be cultivated as free-living forms. There are also many strains of fungi which are parasitic on algae and other fungi by penetration into the host. Fungi with antagonistic activity towards plant pathogens have an essential role in plant growth and health. Mycoparasites and presumptive mycoparasites have biocontrol potential, some are responsible for natural suppressiveness of soils to certain plant pathogens. Several species of *Trichoderma* were used successfully against certain pathogenic fungi. *Trichoderma* sp. was used as commercial bio-fungicides to control a range of economically important soil-borne fungal plant pathogens. Soils contain a large number and great diversity of oospore parasites, which may have the potential to reduce populations of plant pathogenic Phycomycetes in soil.

Predation

Predation is an association in which predator organism directly feed on and kills the pray organism. Predators may or may not kill their prey prior to feeding on them, but the act of predation often results in the death of its prey and the eventual absorption of the prey's tissue through consumption.

Many species of the soil-dwelling myxobacteria are predators of other microbes. Many myxobacteria, *e.g.*, *Myxococcus xanthus*, exhibit several complex social traits, including fruiting body formation and spore formation cooperative swarming with two motility systems, and group predation on both bacteria and fungi. Myxobacteria use gliding motility to search the soil matrix for prey and produce a wide range of antibiotics and lytic compounds that kill and decompose prey cells and break down complex polymers, thereby releasing substrates for growth. The nematophagous fungi are the best predatory soil fungi. Species of *Arthrobotrytis* and *Dactylella* are known as nematode trapping fungi.

AIRBORNE MICROORGANISMS

Airborne particles are a major cause of respiratory ailments of humans, causing allergies, asthma, and pathogenic infections of the respiratory tract. Airborne fungal spores are also important agents of plant disease, and the means for dissemination of many common saprotrophic (saprophytic) fungi.

Here we consider:

- Some important respiratory diseases of humans
- The roles of airborne spores in crop diseases
- The methods used to monitor spore populations in the air

During a sneeze, millions of tiny droplets of water and mucus are expelled at about 200 miles per hour (100 metres per second). The droplets initially are about 10-100 micrometres diameter, but they dry rapidly to droplet nuclei of 1-4 micrometres, containing virus particles or bacteria. This is a major means of transmission of several diseases of humans, shown in the table below.

Some important diseases of humans transmitted from person to person by inhaled airborne particles

Virus diseases	Bacterial diseases
(virus type in brackets)	(bacterial name in brackets)
Chickenpox (Varicella)	Whooping cough (*Bordetella pertussis*)
Flu (Influenza)	Meningitis (*Neisseria* species)
Measles (Rubeola)	Diphtheria (*Corynebacterium diphtheriae*)
German measles (Rubella)	Pneumonia (*Mycoplasma pneumoniae, Streptococcus* species)
Mumps (Mumps)	Tuberculosis (*Mycobacterium tuberculosis*)
Smallpox (Variola)	

Several other diseases, below, are acquired by inhaling particles from environmental sources, not directly from an infected person.

Disease	Source
Psittacosis (*Chlamydia psittaci*)	Dried, powdery droppings from infected birds (parrots, pigeons, etc.)
Legionnaire's disease (*Legionella pneumophila*)	Droplets from air-conditioning systems, water storage tanks, etc., where the bacterium grows.
Acute allergic alveolitis (various fungal and actinomycete spores)	Fungal or actinomycete spores from decomposing organic matter (composts, grain stores, hay, etc.)
Aspergillosis (*Aspergillus fumigatus, A. flavus, A. niger*)	Fungal spores inhaled from decomposing organic matter
Histoplasmosis (*Histoplasma capsulatum*)	Spores of the fungus, in old, weathered bat or bird droppings
Coccidioidomycosis (*Coccidioides immitis*)	Spores in air-blown dust in desert regions (Central, South and North America) where the fungus grows in the soil

Psittacosis is a serious disease acquired by handling birds or by inhaling dust from bird faeces. It is caused by the bacterium *Chlamydia psittaci*, an obligate intracellular parasite.

After entering the respiratory tract, the cells are transported to the liver and spleen, multiply there and then invade the lungs, causing inflammation, haemorrhage and pneumonia.

Legionnaire's disease is a fairly common form of pneumonia in older or immunocompromised people. It is seldom transmitted directly from person to person. The bacterium is an aquatic rod-shaped species with a temperature optimum of about 36°C, and is a common inhabitant of warm-water systems in buildings. Infection occurs when people inhale aerosol droplets containing the bacteria.

Extrinsic allergic alveolitis is a serious hypersensitive response, usually associated with repeated exposure to airborne spores in the work environment. A classic example is the condition termed farmer's lung, caused by exposure to spores of thermophilic actinomycetes.

Aspergillosis, Histoplasmosis and Coccidioidomycosis are examples of serious fungal infections of humans, initiated by spores deposited in the alveoli. They can be life-threatening diseases of immunocompromised people, when the fungi disseminate from the lungs to major organs of the body. However, in all cases the infection of humans is incidental to the fungus, playing no part in its normal biology. These are fungi that grow naturally as decomposer organisms in soil, bird faeces or other organic substrates.

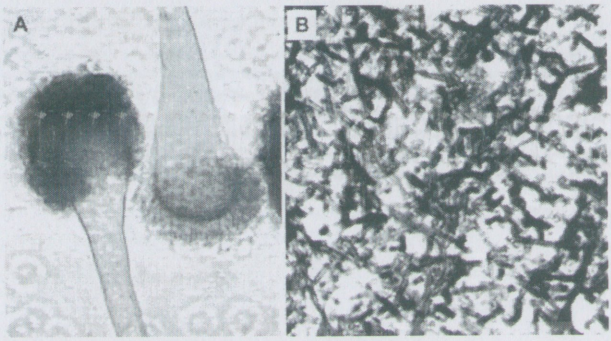


Fig. *Aspergillus fumigatus.* (A) Typical sporing heads of the fungus in laboratory culture. Spores are produced from phialides that arise from the upper part of a club-shaped swelling (vesicle) of an erect hypha (the sporangiophore).. (B) Microscopic section of lung tissue, stained to show hyphae of *Aspergillus* in an air sac. Such a ball of hyphae growing saprotrophically in the lung is termed an aspergilloma.

AIR-SAMPLING METHODS

Air sampling is used routinely to monitor the populations of airborne particles, and to inform the public about air quality and pollen/spore counts through public broadcasting (weather reports, etc.). It is used by major hospitals to monitor the populations of specific allergenic particles (fungal spores, etc.), so that the causes of patients' allergies can be determined. And it is used in crop pathology for disease-forecasting, so that growers can apply fungicides as and when required.

Here we will consider three major types of sampling device for detecting fungal spore loads in air:

- The rotorod sampler
- The Burkard sampler
- The Anderson sampler.

THE ROTOROD SPORE SAMPLER

The rotorod sampler is a cheap, simple and portable air sampler. It consists of a U-shaped metal rod attached by a spindle to a battery-powered electric motor. The motor causes the upright arms of the metal rod to rotate at high speed. To use the sampler, the upright arms are covered with narrow strips of sticky tape, so that any spores in the air will impact onto the tapes. Then the tapes are removed and examined microscopically to identify the spores and other particles such as pollen grains in the air.

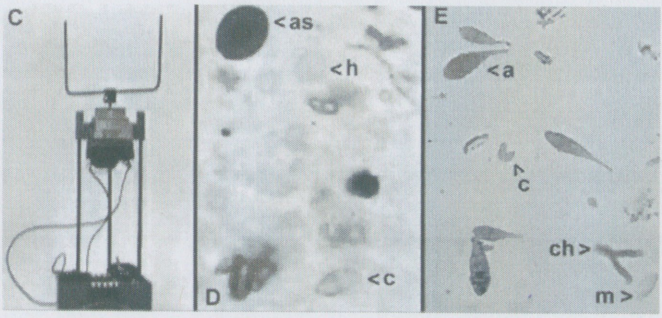
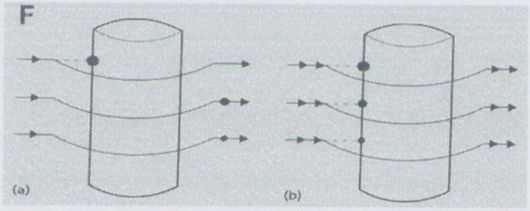


Fig. Rotorod sampler. Figures: Pieces of sticky tape on which spores and other particles were impacted. The identifiable particles include: in D, an ascospore (as), a hyaline (colourless) fungal spore (h) and a conidium of the common leaf-surface fungus *Cladosporium* (c), multicellular conidia (resembling snowshoes) of a common leaf-surface fungus *Alternaria* (a), conidia (c) and hyphal fragments (ch) of *Cladosporium*, and a large hyaline spore of a powdery mildew fungus (m).

This type of sampler is most effective for trapping relatively large particles (upwards of about 7 micrometres) such as the larger fungal spores and pollen grains. The reason for this is shown in Figure below.



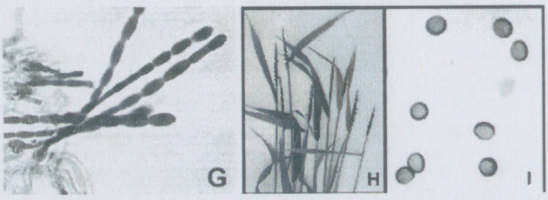
When air is travelling towards an object such as a narrow cylinder, or vice-versa, it is deflected around the object. Any particles in the air will tend to continue along their original trajectory, but their ability to do this (and to impact onto the object) is governed by their momentum (defined as mass x velocity). At any given air speed, the heavier particles are most likely to impact (a in the diagram) whereas smaller (lighter) particles are likely to be deflected round the object. Very high air speeds would be required to impact the smaller particles, and such air speeds are seldom found in natural conditions.

In practice, therefore, fungal spores and other airborne particles can be grouped into two broad categories - those that can impact on surfaces (impactors), and those that are smaller and are only removed from the air by sedimentation in prolonged calm conditions or that are removed from the air by rain.

One of the advantages of the rotorod sampler is that it can be used to precisely locate a source of spores of a particular fungus. The famous aerobiologist, PH Gregory, did this in the 1950s by placing rotorod samplers at different positions in a field and "homing in" on a source of spores of the fungus *Pithomyces chartarum*, which causes a condition known as facial eczema of sheep.

Many important pathogens of crop plants have large spores that impact readily onto plant surfaces to initiate infection. Examples include powdery mildew of wheat, *Erysiphe graminis* and loose smut of wheat, *Ustilago tritici*. This smut disease is characterised

by a mass of black spores where the grain would normally be produced. These spores are 8-10 micrometres diameter..



THE BURKARD SPORE TRAP

The Burkard spore sampler acts on the same principle as the rotorod sampler, but is used to give a continuous record of particles in the air over a period of 24 hours or up to 7 days. The apparatus consists of an air-sealed drum that contains a clockwork rotating disc which makes a single revolution in 7 days. The surface of this disc is covered with adhesive tape, to trap spores that impact onto it. When the apparatus is assembled, air is sucked into the drum at high speed through a slit orifice by means of a motor at the base of the apparatus. Any particles in the air impact onto the sticky tape near the slit orifice, giving a record of the particles in the atmosphere at a specific time of day. At the end of a 7-day run, the tape is removed, cut into sections representing hourly or daily periods, then examined microscopically. In this way, it is possible to distinguish clearly between night-released and day-released spores or other particles, and also to relate the types of particle to different weather conditions (*e.g.* humid or dry periods) while the apparatus was running. The Burkard spore trap is commonly used for continuous monitoring of spore or pollen loads in the air. For example, these traps are commonly sited on hospital roofs, meteorological stations, and other public buildings, and provide public information through TV and radio broadcasts. The principle is exactly the same as in the rotorod sampler because the trapping of particles is based on impaction. The limitations also are the same: only the larger particles with sufficient mass will impact on the tapes at the air speeds generated by this type of sampler.

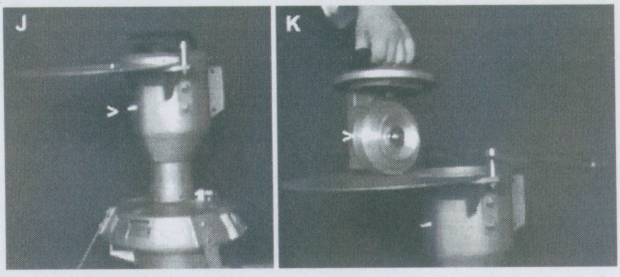


Fig. The Burkard spore sampling device, shown in assembled form and during preparation.

THE ANDERSON SAMPLER

The Anderson sampler is an ingenious device for selectively trapping different sizes of particles according to their size (momentum). This sampler consists of a stack of 8

metal sections that fit together with ring seals to form an air-tight cylinder. Each metal section has a perforated base, and the number of perforations is the same in each section, but the size of these perforations is progressively reduced from the top of the column to the bottom. To use this sampler, open agar plates are placed between each metal section, resting on three studs.

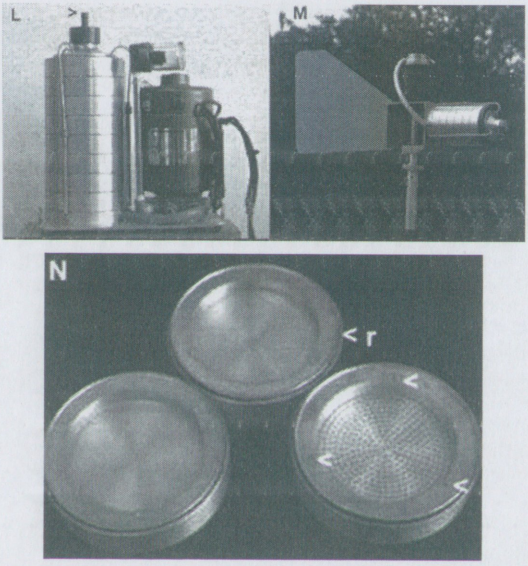
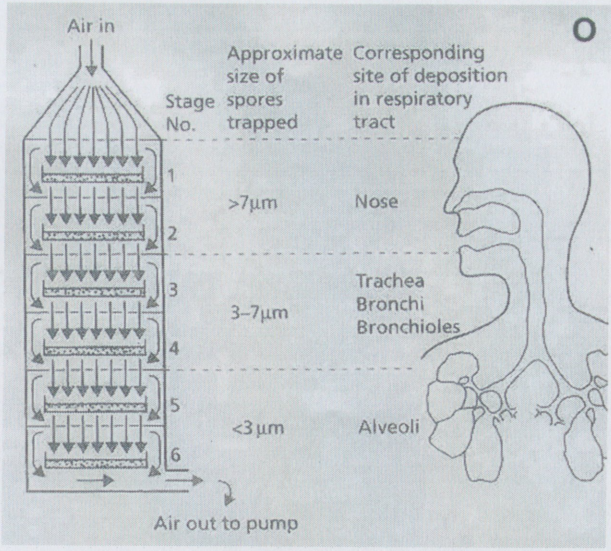


Fig. The Anderson air sampler, shown in a laboratory and mounted with a wind-vane in a field site.

When fully assembled (with an open agar plate between each unit) an electric motor sucks air from the bottom of the unit, causing spore-laden air to enter at the top and to pass down through the cylinder. The path taken by this air is shown in Figure below.



Air sucked in at the top of the column travels at relatively low speed towards the first agar plate, and so only the largest particles impact onto the agar surface. The air

then travels round the edge of the agar plate and through the perforations to the second agar plate, and so on. As this process continues down the stack, the same volume of air is forced to travel through successively smaller perforations, and so the air speed is progressively increased. The progressively increased air speed lower down the column raises the momentum of the air-borne particles, so that even the very smallest particles (less than 3 micrometres diameter) can impact onto the lower agar plates.

When the sampler has run for 5-15 minutes or more, the metal plates are separated and the Petri dishes are removed for incubation to identify the colonies that develop. Some examples of agar plates from an Anderson sampler. In this case the air sample contained spores from mouldy hay, and the agar plates were incubated at 37°C.

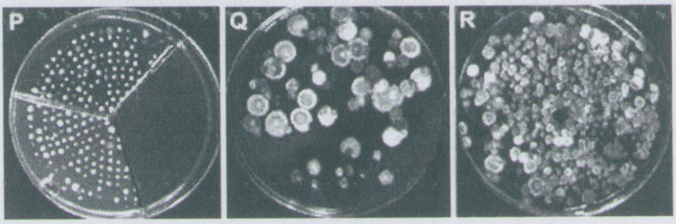


Fig. An agar plate from the bottom level of an Anderson sampler. The colonies are of thermophilic actinomycetes (*Micropolyspora faeni* or *Thermoactinomyces vulgaris*) that are common causes of Farmer's lung disease (extrinsic allergic alveolitus). Actinomycete spores are very small (1-2 micrometres) so they commonly enter the lungs. They form dense, slow-growing colonies on agar, and the pattern of colonies seen on this agar plate reflects the pattern of the perforations through which the air had passed. This Figure also shows how a divided (three-sectored) Petri dish can be filled with different agar media to detect different types of organism in the air. Figures show agar plates from the midlle part of the Anderson sampler, where several species of *Aspergillus* and *Penicillium* have developed from spores about 3-5 micrometres diameter.

One of the interesting features of the Anderson sampler is that it mimics the deposition of spores (or other ariborne particles) in the human respiratory tract. For example, relatively large fungal spores and pollen grains tend to be trapped on the mucus-covered hairs of our nostrils, where they can cause "hay fever" symptoms in sensitised individuals. Smaller particles are not trapped in the nostrils but instead are carried down into the bronchioles and alveoli. Here the air speed is very low, because the successive branching of the respiratory tract has reduced the air speed to a minimum. But spores of about 2-4 micrometres diameter can settle onto the mucosal surfaces of the alveoli. Some of these spores are important in initiating infections of the lungs. However, it is important to note that the underlying mechanisms of spore deposition in the Anderson sampler are entirely different from those in the human respiratory tract - the Anderson sampler traps spores by impaction, whereas spores are deposited in the human respiratory tract mainly by sedimentation.

THE HUMAN RESPIRATORY TRACT AS AN AIR-SAMPLING DEVICE

The respiratory tract is highly effective in trapping airborne particles, with sometimes serious consequences for health.

The mechanisms involved depend on particle size.

1. Large particles (about 10 micrometres) have sufficient mass to impact onto surfaces, even at low air speeds. They break free from the air as it flows around obstacles. During normal breathing, the airflow in the nose and trachea is about 100 cm per second - sufficient for pollen grains and larger fungal spores (*Alternaria*, etc.) to be retained on the mucosa, where they can cause typical hay fever symptoms like rhinitis and asthma.
2. As we have seen, these are the types of particle - the "impactors" - detected by the rotorod and Burkard samplers, and also found on the top plates of the Anderson sampler.
3. Smaller particles do not impact at these air speeds, and the air speed decreases as the repiratory system branches further down. So all the particles of 5 micrometres or less are carried deep into the lungs. There they can settle out by sedimentation in the brief periods when the air is calm between successive breaths. Particles of 2-4 micrometres are optimal for alveolar deposition, and this range includes the spores of many *Aspergillus* and *Penicillium* species.
4. This is how some of the serious fungal infections of humans are initiated - aspergillomas, Histoplasmosis, Coccidioidomycosis, etc.
5. Even smaller particles, such as the spores of actinomycetes (about 1 micrometre) are less efficient at being deposited in the alveoli, but repeated exposure to spore clouds by agricultural workers can lead to sensitisation and extrinsic allergic alveolitis (Farmer's lung, etc.)
6. Very small particles, less than about 0.5 micrometres, do not impact but are moved by diffusion (Brownian motion) which brings them randomly into contact with surfaces in the lungs. This is true of the fine dusts that cause many occupational diseases.

Where do the Bacterial and Viral Pathogens fit into this Scheme?

The nasopharyngial infections by viruses are associated with large sneeze droplets which impact in the upper airways. Most bacterial diseases also are initiated in the upper airways, when bacteria are carried in large droplets or on "rafts" of skin that impact onto the mucosa. However, infections by *Mycobacterium* (tuberculosis) and *Bacillus anthracis* (anthrax) are initiated in the lungs. These are highly virulent pathogens, and even single cells or spores (about 3 micrometres for *Bacillus*) can initiate infections after deposition in the alveoli.

BIOPHYSICAL MANAGEMENT OF SOIL

SOIL BIOLOGY

The dead plants contribute to the formation of soil organic matter, which in turn provides food, energy and nutrients to microorganisms and also higher plants – a process

of cycling of plant nutrients. Continuous decay of plant roots adds organic matter to soil, thereby changing the soil properties, *viz.* Soil aggregation, cation exchange capacity, water and nutrient retention capacity, etc. of soil. If the vegetation is removed, the soil characters change completely. When the roots decay, the vacant space makes room for water and air to move in.

SOIL MICROFLORA

Biological nitrogen fixation plays an important role in the economy of crop production. The microbes in this class of microflora are, besides bacteria, fungi, actinomycetes and algae. Of these, bacteria are the most abundant in soil, next in order are actinomyeetes, followed by fungi. Soil microorganisms are divided into two broad groups – heterotrophs and autotrophs.

Factors

- *Moisture:* In the presence of excess water, waterlogging, anaerobic condition occur the aerobes become suppressed and inactive. In the absence of adequate moisture in soil, some of the microbes die due to tissue dehydration and some of them change their form into resting stages of spores or cysts.
- *Temperature:* Temperature is the most important environmental factor influencing the biological processes and the microbial activity. When the temperature is low, the number and activity of microorganisms fall. Most of the soil organisms are mesophiles and grow well between 15°C and 45°C. A temperature of 37°C is considered to be optimum for most mesophiles.
- *Aeration:* Microbes consume oxygen from soil air and give out carbon dioxide. In the absence of such gaseous exchange, carbon dioxide accumulates in soil air and becomes toxic to the microbes. Rate of oxygen intake and simultaneous evolution of carbon dioxide are measures of microbial activity. Direct sunlight is injurious to most of the microorganisms except algae.
- *Reaction:* Bacteria prefer near neutral to slightly alkaline reaction between pH 6.5 and 8.0; fungi grow in acidic reaction between pH 4.5 and 6.5; actinomyeetes prefer slightly alkaline conditions.
- *Food:* Well-aerated soil rich in organic matter is an essential prerequisite for maximum number and activity of heterotrophic microorganisms. The microbial cells undergoing senescence serve as a source of food for the organisms.
- *Soil Factor:* A soil in good physical condition has good aeration and moisture supplying capacity, which are so essential for optimum microbial activity.

Soil Bacteria

- *Function:* Through a number of transformations and biochemical reactions in soil and thereby directly or indirectly help nutrition of biological fixation of nitrogen-symbiotic and non-symbiotic; decomposition of carbohydrates and

lignins; decomposition of proteins with the liberation of ammonia or ammonification, nitrification and denitrification, the transformation of carbon, nitrogen, phosphorous, sulphur, iron, manganese etc. All these processes play a significant role in plant nutrition. The process of conversion of molecular nitrogen into complex proteins through the agency of biological organisms is known as biological nitrogen fixation. Symbiotic nitrogen fixing bacteria *e.g. Rhizobium* and Non-symbiotic nitrogen fixing bacteria *e.g. Azotobacter, Clostridium pasteurianum*

- *Nitrogen Transforming Bacteria:* Nitrogen is utilized by micro-organisms and higher plants in inorganic form as nitrate or ammonium. The complex proteinaceous and nitrogenous organic compounds are broken down to produce ammonia through a microbiological process known as ammonification and the microbes responsible for this are ammonifiers or ammonifying bacteria. In nitrification, first, nitrites are formed by nitrite forming bacteria (*Nitrosomonas*) and then to nitrate by nitrifying bacteria or nitfifier *(Nitrobacter*). The immobilized nitrogenous is dead bodies of the organisms is again converted by microbes into inorganic forms, ammonium or nitrate, which can be utilized by plants and micro-organisms.
- *Denitrifying Bacteria or Denitrifiers:* Denitrification is the process by which nitrates are reduced to oxides of nitrogen and even too gaseous nitrogen. The bacteria, which are responsible for this transformation, are known as denitrifying bacteria or denitrifiers. *e.g. Pseudomonas, Bacillus* and *Paracoccus*. These microbes are aerobic, but Denitrification mostly takes place under anaerobic condition.

SOIL FUNGI

Fungi are heterotrophic plants larger than the bacteria. Those that live on the dead tissues of organic substances are saprophytic. Fungi may be regarded as the scavengers who will decompose in soil almost anything of organic nature that bacteria cannot tackle and many of them serve as food for the bacteria.

Cellulose and Hemicellulose Decomposing Fungi

In acid soils, the fungi are the main decomposers of cellulose as under acidic conditions, bacteria and actinomycetes become inactive. In acid soils, *Penicillium* and *Trichoderma* take part in cellulose decomposition, whereas in other soils the fungi species are *Aspergillus, Fusarium*, etc.

Humus Forming Fungi

Certain species of fungi, *Alternaria, Aspergillus*, etc. produce substances similar to humic substances in soil and may be important in the synthesis of soil humus. The black or dark brown colour of soil humus may be due to their presence.

SOIL ACTINOMYCETES

Actinomycetes have characteristics, which are transitional between bacteria and fungi and are sometimes called fungi-like bacteria. Actinomycetes are more abundant in dry soil than in wet soils and more in grassland and pasture soils than in the cultivated soils. They are responsible for the decomposition of the more resistant organic matter of soil and produce a number of dark black to brown pigments, probably contributing to the dark colour of soil humus.

SOIL ALGAE

Soil algae are microscopic, chlorophyll containing organisms, being the simplest chlorophyllous plants. Moisture and adequate sunlight are the most significant environmental conditions influencing the algal population. One of the important roles of certain strains of blue-green algae is the fixation of nitrogen from air.

Soil Macrofauna

- *Earthworms:* They transform the food so as to be more beneficial for the higher plants. These animals are more abundant in moist soils having high organic matter and undecomposed plant residues. They are more common in fine textured soils than in the coarse sandy soils.
- *Moles:* Molehills, frequently observed in some fields, are composed of subsoil deposited by moles. They need a good reserve of calcium in soil.
- *Ants:* More active in humifying insects than plants.

Soil Microfauna

- *Soil Protozoa:* Form only a small part of the soil population. They are more abundant in surface soil. Feeds on decaying organic matter are called saprohytic; those on earthworms, other nematodes, etc. are predatory, and those on roots of higher plants are parasitic. As they feed on the bacteria and actinomycetes, they probably help to maintain a favourable balance of the microflora in soil. Nematodes are the abundant soil microfauna in soil. They cause loss of vigour of the root system and make plants growing in nematode infested soil liable to diseases.
- *Soil Viruses:* The viruses in soils are known to parasitize bacteria and are specifically known as bacteriophages. Clay and organic matter in soil adsorb bacteriophages and thus cause their retention and spread in soil.

BENEFICIAL ROLE OF SOIL ORGANISMS

The soil organisms play a significant role in the life cycles of plants and animals through a number of processes such as decomposition, synthesis and transformation. The most important reactions which the micro-organisms carry out and have significant bearing on soil properties and plant growth are decomposition of organic matter and

synthesis of humic substances in soil, biological fixation of nitrogen, microbial transformation of nutrients and nutrient recycling in soil. From the animal and plant bodies, through processes of decomposition, nitrogen enters into the bodies of soil organisms and organic substances (humus) in soil and is recycled through plants and animals. Carbon and nitrogen cycles are the two major biological processes, which take part in the decomposition of added organic matter to soil and formation of humus substances in soil.

SYNTHESIS OF HUMUS SUBSTANCES IN SOIL

The carbon and nitrogen cycles show the probable pathways of breakdown of added organic substances in soil. They ultimately lead to the formation of microbial cells in soil and soil organic matter. The main partners are plants, microorganisms, and soil. The organic residues, which undergo breakdown and transformation, are complex in nature, containing carbohydrates, proteins and other nitrogenous compound lignins, fats, etc. in course of the microbial reactions, the soil is enriched with the dead tissues of organisms forming part of its organic matter. Humus is a complex mixture of amorphous and colloidal organic substances. The whole process of decomposition of organic matter, mainly of plant origins, is due to the microbes.

Phosphorus: - microbial grown a requires available and utilizable forms of phosphorus. Immobilization of available soil phosphate may occur when large amounts of available carbon and nitrogen are present in the decomposing material. Thus addition of straw and similar materials causes biological phosphorus depletion and immobilization.

Sulphur: - Sulphur ion in soil is the major source of sulphur for plants, which can also utilize a small amount of sulphur dioxide from air. When plant and animal residues are incorporated in soil, organically bound sulphur is mineralized by micro-organisms into sulphate ions. Part of the mineralized sulphur is immobilized by the microflora and part is available to the plants for their nutrition. The autotrophic bacteria, chiefly members of the genus Thiobacillus, are capable of oxidizing inorganic sulphur compounds. Hydrogen sulphide, it should be noted, is toxic to plants even in small concentration.

Other Elements: -Other plant nutrient elements that undergo microbial transformations and influence their availability for plant growth are potassium, calcium, magnesium, iron, manganese, copper, zinc, molybdenum, boron, etc. certain bacteria and fungi are capable of decomposing alumina silicate minerals in soil, thus releasing a portion of the potassium contained therein. The potassium thus liberated to satisfy the demand of the microbial nutrition becomes ultimately available to plants due to the release of soluble potassium ion during decomposition of microbial cells. Iron transformation in soil depends on the activity of the microorganisms which, in turn, depend upon the compounds of iron. The iron bacteria may be performing the function of oxidation and reduction, and iron precipitation. Bacteria are more dominant in these transformations. Deficiency of manganese is closely related to the number of manganese oxidizing bacteria in soil.

BIOFERTILIZERS

Biofertilizers are the cultures of micro-organisms used for inoculating seed or soil or both under ideal conditions to increase the availability of plant nutrients. Their purpose is to supplement chemical fertilizers and not to replace them. Some of the microorganisms have the beneficial role of biological nitrogen fixation to supply nitrogen to crops, solubilizing insoluble phosphates to soluble forms to make them available to crops, synthesizing biomass for manuring crops, particularly rice, and hasten the process of decomposition of cellulose in composts and farmyard manures through cellulolytic organisms.

SOIL AGGREGATION

Some organisms may play a beneficial role indirectly be creating better soil physical condition, *e.g.* by improving soil aggregation. Soil microorganisms cause soil aggregation probably by the gum or polysaccharides produced by them. *Azotobacter, Beijerinckia* and *Rhizobium* are examples of gum producing bacteria.

EFFECTS OF CULTURAL PRACTICES ON SOIL ORGANISMS

Cultural practices, *viz.* Cultivation, crop rotation, application of manures and fertilizers, liming and gypsum application, application of pesticides for crop production have their effect on the soil organisms.

Ploughing and tilling operations facilitate air movement in soil and expose soil surface to sunshine, and thereby increase biological activity, particularly of bacteria. Cultivation of a single crop causes accumulation of a particular group of microbes, which dominate over the others. Crop rotation disturbs the unfavourable population balance. Crop rotation with a legume is the common practice. Irrigation of soil brings about a significant proliferation of soil microbes.

Soil Amendments: - Liming of acid soil increases activity of bacteria and actinomycetes and lowers the fungal population. Gypsum application of sodic soil is favourable for bacterial activity. Application of fertilizers and manures increases crop production supply food and nutrition not only to the crops but also to the microbial population in the soil. Phosphatic fertilizers applied to berseem (*Trifolium alexandrimum*) increase significantly the activity of nitrogen fixing bacteria. Organic manures provide a readily available source of carbon for the heterotrophs. Repeated heavy fertilization with nitrogenous fertilizer alone promotes rapid growth of fungi.

Oilcakes, *viz.* Neem, karanj and groundnut encourage the growth of nematode-trapping fungi. Application of chemicals (pesticides) to control damage to crops by insects, fungi, nematodes and weeds is imperative. The pesticide molecules may interact with soil constituents and get adsorbed on the soil particles or they may move with water to find their way into ground water, rivers and stems. The pesticides are systemic in nature, they persist in soil and may be taken up by plants and ultimately by animals. Some pesticides are biodegradable by soil organisms, other are liable to leave toxic

residues, which are likely to be hazardous. The usual dosage is not high enough to cause any profound change in the normal microbial activity of soil.

PHYSICAL PROPERTIES

Soil is a heterogeneous mixture of silicate particles, humus, and a variety of insoluble salts and oxides of metals called the solid phase, a liquid phase and a gaseous phase. Depending on the relative proportions of the various size groups we can define soil texture. Depending on the size and shape of the aggregates we can define soil structure.

- *Texture:* Many of the important soil properties are related to texture. Clayey soils show high water holding capacity, high plasticity, stickiness and swelling whereas sandy soils are conspicuous by the absence of these properties. The most important way in which soil texture affects plant growth is water and with it the nutrient supply. The available water capacity of soil is related to soil texture.
- *Soil Structure:* This kind of arrangement and organization of secondary and primary particles under natural condition brings about what has been termed as soil structure. Under natural soil conditions, the primary particles (clay, silt and sand) are mostly bonded together by cementing agents into secondary aggregates of varying sizes.
- *Bulk and Particle Density and Pore Space:* Bulk density of a soil is defined as the mass per unit volume of soil consisting of solid and gas phases. Particle density of a soil is the mass per unit volume occupied by the soil particles alone. Bulk density of soil is influenced by soil texture, organic matter content and cultivation practices. The constituents of soil organic matter contribute significantly to aggregation of soil particles. The humus portion in the aggregation is susceptible to biodegradation. To maintain soil aggregation status of cultivates soils, renewed addition of organic matter is essential.

MANAGEMENT PRACTICES

The management practices for crop production have a profound effect on the formation and stability of soil aggregates

- *Cultivation:* Continuous cultivation of arable land year after year, without incorporation of organic matter, deteriorates soil structure, lowering the level of soil structure, lowering the level of soil organic matter. Addition of organic matter helps in improving the structural status of soil. The tillage operation affects the size distribution of peds, density and packing of soil particles, amount of organic matter and moisture content of soil. Tillage is to loosen the surface soil, to facilitate water infiltration and aeration. Friable conditions of soil are the optimum soil condition for tillage operation to produce aggregates of suitable size.
- *Crops and Cropping Practices:* Crops affect soil structure through their

vegetative canopy above the ground and their roots below the ground. Grasses are conducive to well structured soil. The vegetative canopy protects the soil from the beating action of raindrops and destruction of the structure of the surface soil and prevents crusting, improve soil structure. The role of legumes in building up soil fertility is well known and legumes have, therefore, their place in sound crop rotation practices. The beneficial effect is usually attributed to nitrogen added to the soil by legumes. The structure is built up with the advancement of stages of crop growth. Legumes treated with phosphatic fertilizers significantly improve soil structure.

Manures and Fertilizers

Organic matter level and structural improvement of soil can be built up, to a varying degree, and maintained by continuous judicious application of manures. The degree of improvement depends upon the quantity and length of application of manure, the climatic conditions, and nature of soil. Phosphatic fertilizers used in conjunction with nitrogenous fertilizers improve and maintain soil structure.

MANAGEMENT OF SOIL STRUCTURE

The objective of soil structure management is the improvement and maintenance of soil structure. Inclusion of a suitable legume in a crop rotation is the most effective way of improving and maintaining soil structure. Coupled with phosphatic fertilizers, legumes improve soil structure still further. Use of balanced fertilizers for raising crops is the other means. Judicious application of adequate quantities of well-decomposed manures, as frequently as possible, improves soil structure. In coarse-textured soils, use of organic manures is the only way of improving structure. Application of pond sediments or clay soil brought from another locality is helpful in this respect. In the case of very fine-textured soils, organic manure is no doubt helpful, but the quantity required well be high. Crop rotation and use of phosphatic fertilizers are better methods for such soils. Structural management of acid soils involves liming followed by organic manuring. Highly alkali soil application of gypsum or other amendments in combination with green manuring or manures or incorporation of crop residues has been successful in improving structure and helps in reclamation of such soils.

WATER INFILTRATION INTO SOIL

Water infiltration is the process of water entry into soil through the surface and the direction of entry may be either downward or lateral or both. Water infiltration characteristics of soil are of practical significance in soil and water conservation, irrigation and watershed management. Factors influencing infiltration- texture, structure and initial moisture content of soil control infiltration rate. Coarse textured and well aggregated soils have usually high infiltration rate. Dry soil condition is conducive to rapid infiltration. Vegetative covers help infiltration while the presence of a somewhat

impervious subsoil layer reduces it. The volume of water that enters into soil and the depth to which water moves and wets the soil below the surface are of utmost importance in the soil water plant relationship as this is one of the main sources of water supply to plants.

IMPORTANCE OF SOIL WATER STUDIES

Infiltration studies are important for soil and water conservation. The design of furrows or basins for ensuring even distribution of irrigation water will, therefore, depend upon the infiltration rate. Plants meet their water requirement from water stored in soil. Microbes and plants require, besides water, an adequate level of oxygen in soil for their growth and activity. Low porosity and hydraulic conductivity of soil cause inadequate aeration. Proper drainage ensures adequate aeration and removal of salts and other toxic substances from the root zone. Recharge of groundwater is often necessary where excess of rainfall is lost as surface run-off, due to low infiltration capacity of the soil. The soil air and soil temperatures are closely related to water content of soil.

SOIL AERATION AND PLANT GROWTH

Oxygen is required by microbes and plants for respiration. Oxygen taken up and carbon dioxide evolved are stoichiometric. Root elongation is particularly sensitive to aeration conditions. Oxygen deficiency disturbs metabolic processes in plants, resulting in the accumulation of toxic substances in plants and low uptake of nutrients. Certain plants such as rice are adapted to grow under submerged conditions. These plants have large internal air spaces, which facilitate oxygen transport to the roots.

SOIL TEMPERATURE AND MANAGEMENT

Soil micro-organisms show maximum growth and activity at optimum soil temperature range. Soil temperature has a profound influence on seed germination, root and shoot growth, and nutrient uptake and crop growth. Seeds do not germinate below or above a certain range of temperature. Root elongation is very much dependent on soil temperature. Each crop plant has a specific optimum range of soil temperature for its rapid growth and maximum yield.

Soil temperature under field conditions can be altered by suitable cultural practices such as mulching, irrigation, drainage, and tillage. Tillage loosens the surface soil, increases its porosity and decreases its thermal conductivity. Soil compaction has the reverse effect on porosity and soil temperature. Mulching the surface soil with plastic cover or crop residues may increase or decrease surface soil temperature, depending upon environmental conditions. Mulches conserve soil moisture also. In tropical areas, irrigation generally causes rapid and substantial reduction in maximum temperature in summer and increase in minimum soil temperature in winter. In the cold season, the higher temperature of irrigation water relative to soil, and high heat capacity of irrigation water check lowering of minimum soil temperature.

SOIL COMPACTION

Soil compaction is the process of increasing dry bulk density of soil, reducing the pore space by expulsion of air through applied pressure on a soil body. Initially, when water content is low, the soil is stiff and difficult to compress, low density is the result. Compaction of coarse-extured soil, sometimes desirable, for better seed germination, reducing hydraulic conductivity of soil, and enhancing moisture conservation. Continued compaction will practically remove all air. As the water content of soil increases, the water acts as a lubricant, and the soil becomes workable with the expulsion of soil air. Compacting creating problems for seed germination water transmission and aeration.

SOIL CRUSTING

Crusting of soil is a form of soil compaction. The crusts present a serious barrier for seedling emergence, high exchangeable sodium percentage, poor structure, low organic matter content of soil and also puddling during tillage operations are some of the factors responsible for crust formation. Lowering the exchangeable sodium percentage and incorporation of organic matter prevent crust formation.

3

Microbial Food Spoilage and Food Borne Diseases

SPOILING FOOD

Microbes are all around us – in the air, the soil, water and our bodies. This means they can soon get into food and, if the conditions are right, multiply rapidly. Unfortunately, when certain microbes grow on food, it soon begins to smell nasty, look slimy, change colour, taste awful or even acquire a furry coating. The food 'goes off' – it is spoiled. Even though it may not harm us, it is inedible and must be thrown away. There is also a chance that pathogenic microbes are present along with the spoilers.

FOODBORNE DISEASE

Foodborne disease is a pervasive problem caused by consumption of contaminated food and drink. More than 200 pathogens are associated with foodborne disease. An estimated 76 million cases occur annually (one in every four Americans), resulting in 300,000 hospitalizations and 5,000 deaths. Fewer cases are documented because of underreporting. International travel and food importation have further expanded the problem. The onset of foodborne disease is generally acute, with resolution of an uncomplicated illness in 72 hours for most episodes. Proper food handling and preparation, personal hygiene, and improved methods of decontamination of consumer products could significantly reduce the extent of morbidity and mortality of this common problem.

Foodborne illness is tracked in the United States through a system called FoodNet, a joint effort of the U.S. Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA). Data are collected annually from ten different monitoring sites throughout the country (representing 15% of the population) and compiled by the Centers for Disease Control and Prevention (CDC). Only documented cases are used for reporting. The target organisms include *Campylobacter* spp., *Salmonella* spp., *Shigella* spp., *Listeria* spp., Shiga toxin-producing *Escherichia coli* O157:H7 (STEC O157), non-O157 STEC, *Vibrio* spp., *Yersinia* spp., *Cryptosporidium* spp., and *Cyclospora* spp. The hemolytic-uremic syndrome (HUS) is also tracked.

EPIDEMIOLOGY

Foodborne disease can be caused by bacteria, parasites, toxins, and viruses. Despite efforts to investigate foodborne disease, less than 50% of all outbreak causes are identified, usually because of limited diagnostic capabilities. Viruses are likely the most common cause of foodborne disease but are seldom investigated and confirmed because of the short duration and self-limited nature of the illness. In addition, the inherent difficulty of laboratory investigation and subsequent cost of viral studies lead to a lack of clinician investigation and therefore overall underreporting. Bacteria are the most common documented cause.

Cultural and demographic factors, as well as increased mobility, have resulted in major epidemiologic shifts in foodborne disease during recent decades. Previous outbreaks of foodborne disease were smaller and limited in scope, more often originated in the home, and were associated with *Staphylococcus* or *Clostridium* spp. Family picnics or dinners and home-canned foods were the typical sources for the outbreaks. Today, many more people dine outside the home and travel more extensively. As a result, more than 80% of foodborne disease cases occur from exposures outside the home.

Table. Common Causes of Foodborne Disease

Bacteria
Salmonella spp.
Campylobacter jejuni
Shigella spp. STEC O157:H7
Listeria monocytognes
Vibrio spp.
Yersinia spp.
Parasites
Cryptosporidium spp.
Cyclospora spp.
Trichinella spiralis
Giardia lamblia
Toxoplasma caris
Entamoeba histolytica
Toxins

Enterotoxins
Staphylococcus aureus
Clostridium perfringens
Bacillus cereus
Botulinum toxin
Clostridium botulinum
Fish toxins
Scombrotoxin
Ciguatera toxin
Paralytic shellfish toxin
Mushrooms
Amatoxin
Phallotoxin
Miscellaneous
Niacin
Monosodium glutamate
Viruses
Norwalk
Hepatitis A

Technology has provided the means for mass production and distribution of food. Therefore, foodborne disease often occurs on a massive scale, whereby hundreds or thousands are exposed and may become ill. Mobility and travel have resulted in exposure to foods abroad, where regulation of food safety and food products for sale may vary. When traveling, the axiom "boil it, peel it, cook it, or forget it" remains true in many areas of the world. Travelers bringing home unique foods as gifts may unwittingly expose family members and friends to unexpected illness. International ships discharging their bilge in ports are another possible means of disseminating pathogens.

Food importation has steadily increased to meet the demand for seasonal and non-seasonal foods. Conditions of production and harvest may be unsupervised or uncontrolled, with resultant importation of contaminated foods. Raw manure is frequently used as fertilizer, causing contamination of fresh produce. If improperly cleaned, the fertilized produce may cause illness when consumed.

Unique ethnic food preferences and preparation have been associated with several food-related illnesses. One example is the African American tradition of eating chitterlings (cooked swine intestines) during the Christmas holiday season. This food has been associated with an outbreak of *Yersinia enterocolitica* infection in infants. Fresh cheese made from unpasteurized milk has been associated with episodes of listeriosis in Hispanic neighbourhoods.

Foodborne disease is more likely to affect the extremes of age as well as immunocompromised patients and pregnant women. These groups suffer higher incidence, morbidity, and mortality. The effect of foodborne disease may extend beyond the immediate illness. This has been shown by a Danish study, which demonstrated a

greater than threefold risk of dying in the year after contracting a foodborne illness. Most foodborne disease has a short duration of illness and a self-limited course. Others may cause a more protracted illness, such as *Cryptosporidium* and *Cyclospora*. However, some foodborne diseases are associated with long-term chronic sequelae. *Salmonella, Shigella, Yersinia*, and *Campylobacter* spp. are linked to reactive arthritis; *Campylobacter* has also been associated with the Guillain-Barré syndrome, and STEC O157:H7 has been linked to renal failure.

Table. Sequelae of Foodborne Illness

Reactive Arthritis
• *Campylobacter*
• *Salmonella*
• *Shigella*
Hemolytic-Uremic Syndrome, Renal Failure
• STEC O157:H7
• *Shigella*
Neurologic Effects
• *Listeria*
• Botulinum toxin
• *Campylobacter*
• STEC O157:H7

The most commonly identified pathogens are *Campylobacter* spp., *Salmonella* spp., *Shigella* spp., and STEC O157:H7. These organisms have evolved and now have greater cold, heat, and acid tolerance, as well as resistance to multiple antibiotics. Increased drug resistance has been associated with prolonged illness and a greater risk of hospitalization.

Almost any food can be a source of foodborne disease. Some foods are more commonly associated with particular organisms. *Salmonella* has traditionally been associated with poultry and eggs, *Campylobacter* with chicken and unpasteurized milk, and STEC O157:H7 with ground beef. An outbreak of STEC O157:H7 was associated with steak that had been needle-tenderized, thereby exposing the center of the meat to surface organisms. When the steak was not thoroughly cooked to an adequate internal temperature, the microorganisms survived and illness occurred after consumption.

Table. Pathogens and Food Associations

Campylobacter: chicken, unpasteurized milk and dairy products, water
Salmonella: eggs, poultry, fruits, vegetables, meats
Shigella: fruits, vegetables
Escherichia coli O157:H7: hamburger, salami, alfalfa sprouts, unpasteurized milk and dairy products and juice
Clostridium botulinum: home-canned foods
Cryptosporidium: water
Cyclospora: raspberries
Listeria monocytogenes: delicatessen meats, soft cheeses, unpasteurized milk and dairy

products, vegetables
Vibrio vulnificus: shellfish
Yersinia enterocolitica: raw pork, unpasteurized milk and dairy products, water

Water may be the vector of illness when contaminated with viruses, bacteria, parasites, or chemicals. Crowding, poor sanitation, disruption of water supplies, and natural disasters are closely linked to waterborne illness. Viruses are the most common cause of waterborne illness and include rotaviruses, enteric adenovirus, astrovirus, caliciviruses and hepatitis A virus. Outbreaks of gastroenteritis aboard cruise ships in recent years were a result of noroviruses. *Salmonella* spp., *Shigella* spp., *E. coli*, and *Vibrio* spp. are the predominant bacterial pathogens involved. *Cryptosporidium* spp. and *Giardia lamblia* are the parasitic pathogens most commonly encountered in waterborne illness. Immunocompromised hosts, particularly organ transplant recipients and HIV-infected patients, should exercise extra precaution in situations of potential waterborne illness.

Incubation periods of foodborne disease may offer clues to the cause. Four time frames may be envisioned: very brief, short, intermediate, and long durations of incubation.

The very brief category (<8 hours) is generally caused by preformed toxins, which may be found in staphylococcal or bacillus-contaminated food. Short incubation periods (24-48 hours) are more typical of viral causes. Intermediate incubation periods (1-5 days) correlate with many bacterial pathogens. The long-duration incubation group (>5 days) approximates the time course of parasitic infections. These time frames are crude groupings and areas of overlap exist between them. In addition, the inoculum of organisms ingested may influence the incubation period and the rapidity of onset of illness—for example, a large inoculum may cause a shortened time to onset of illness.

Bloody diarrhea or a febrile illness is often associated with invasive organisms. The more common microorganisms associated with bloody diarrhea and fever.

Table. Clinical Manifestations

Bloody Diarrhea
• *Campylobacter*
• *Salmonella*
• *Shigella*
• *Escherichia coli* O157:H7
• *Yersinia*
Fever
• *Salmonella*
• *Campylobacter*
• *Shigella*
• *Listeria*
• *Vibrio*
• *Yersinia*

DIAGNOSIS

Diagnosis is accomplished through a careful history, physical examination, and laboratory evaluation. The history should include questioning about the suspected time of exposure, recent travel, the food and drink consumed, other people who may have been present and eaten similar foods, and the specific symptoms involved (*e.g.*, nausea, vomiting, diarrhea with or without visible blood, cramping, gas, fever, neurologic symptoms, alteration of mental status). Dietary history may include intake during the last 2 to 3 weeks.

The physical examination should focus on vital signs, including orthostatic measurements, skin turgor, mental status, abdominal findings, and stool testing for blood. Fresh stool samples for culture and analysis (<6 hours old) provide the highest yield. The clinician must be knowledgeable of the laboratory's assay procedures to facilitate proper sample testing. Specific culture requests for suspected organisms may be necessary, as well as microscopic examination of stool samples for parasites. Three samples on different days will generally provide adequate diagnostic results. Special circumstances may dictate the need to perform special assays for toxins (*e.g.*, botulinum toxin) on gastric aspirates or stool samples. Blood cultures are often useful, particularly if *Salmonella* or *Listeria* is suspected or when evaluation involves high-risk groups and immunocompromised hosts.

DESCRIPTION AND TREATMENT

Most foodborne disease is self limited and requires only supportive care. The very young, older adults, immunocompromised patients, and pregnant women may benefit from antibiotic treatment for certain bacterial or parasitic infections. Drug-resistant pathogens require knowledge of regional, national, and international patterns of resistance to allow appropriate empirical selection of therapy.

SPECIFIC BACTERIA

Salmonella

The most recent FoodNet data list non-typhoidal *Salmonella* as the most commonly identified bacterial cause of foodborne disease. It is estimated that 1,400,000 cases occur annually. Fever, abdominal cramps, and diarrhea (occasionally bloody in a minority of cases) are the usual manifesting symptoms after 8 to 48 hours of incubation. Although generally self limited, *Salmonella* infection may cause sepsis and localized infections, such as septic arthritis and infection of endovascular prosthetic devices, such as grafts. The most common serotypes are *Salmonella typhimurium* and *S. enteritidis*.

Eggs remain a common source because of vertical transovarial transmission within an infected poultry flock. Poultry itself has become a significant source of *Salmonella* infection. Fruits, vegetables, meats, and ice cream are other reported food associations.

Populations at greatest risk are infants, older adults, and the immunocompromised, but also those with inflammatory bowel disease, hemoglobinopathies, and endovascular prosthetic devices. Patients older than 60 years have the highest rate of hospitalization and highest case-fatality rate. Antibiotic treatment should be considered for these high-risk groups because bacteremia may occur in 2% to 14% of cases. Unfortunately, increasing resistance to the usual antibiotics (cephalosporins, aminoglycosides, and fluoroquinolones) has made therapy more challenging.

Campylobacter

Campylobacter is the second most common identified organism in foodborne disease. Over one million cases are estimated to occur annually. After a 2- to 5-day incubation period, acute dysentery ensues. Nearly two thirds of patients will have fever, and one half will have bloody diarrhea. Illness may last 1 week and then resolve spontaneously. Immunocompromised patients may experience life-threatening sepsis and therefore should receive aggressive therapy.

Age-related biphasic peaks of *Campylobacter* infection occur in infancy and early adulthood. Young men are more often affected because of poor food handling knowledge. Almost all human illness is caused by one species, *Campylobacter jejuni*. Poultry is the overwhelming source. Additional food sources include raw milk, water, and ice cream. When treatment is deemed necessary, a macrolide is preferred or a fluoroquinolone antibiotic can be used, but once again increasing drug resistance may present a therapeutic challenge. Macrolide resistance remains less than 5% but quinolone resistance may be as high as 20%. Regions of southeast Asia have strains of *Campylobacter* that are resistant to both macrolide and quinolone antibiotics. Antibiotic-resistant strains are associated with more invasive disease and increased mortality. Guillain-Barré syndrome may be an unusual delayed sequela of infection with *Campylobacter*.

Shigella

Although less common than *Salmonella* or *Campylobacter*, *Shigella* is a significant cause of foodborne disease. Shigella is responsible for 10% to 20% of cases of bacterial foodborne illness each year in the United States. After 2 to 4 days of incubation, it produces an invasive dysentery syndrome that often includes fever and bloody diarrhea. Shiga toxins are frequently elaborated. Duration is typically 5 to 7 days. Fruits, vegetables, and shellfish are common food associations. Third-generation cephalosporins and fluoroquinolones are the antibiotics of choice; however, drug resistance may be encountered. Long-term sequelae include reactive arthritis and HUS.

STEC O157:H7

STEC O157:H7 infection was initially associated with ground beef. Multiple other food associations have been recognized, such as unpasteurized apple cider, milk and dairy products, juices, and lettuce. In addition, STEC O157:H7 has been associated

with non-foodborne illness after contact with cattle and swimming in contaminated lakes. Crump and colleagues have described an outbreak among a group after they visited a dairy farm.

An estimated 60,000 to 70,000 cases occur annually, resulting in approximately 2000 hospitalizations and 60 to 70 deaths. The average incubation period is 4 to 8 days. Symptoms include abdominal cramps with bloody diarrhea but little or no fever. The diarrhea usually resolves within 1 week. Antibiotics appear to play no role in treatment, because the illness is the result of a Shiga toxin produced by the organism. Five to 10 days after the diarrheal illness, HUS develops. It is more common in the young (<5 years old) and older adults. Manifestations of HUS may include hemolytic anemia, thrombocytopenia, and acute renal failure. Neurologic sequelae (*e.g.*, seizures or stroke) may be additional late complications.

Listeria

Listeriosis is caused by *Listeria monocytogenes*. It is a much less common cause of foodborne disease, with approximately 2500 cases annually. However, it has the highest hospitalization and mortality rates of all foodborne diseases, with approximately 500 deaths each year. It strikes more often at the extremes of age, attacking the young and older adults, as well as those who are immunocompromised, causing a more severe illness in this population. Pregnant women are also at increased risk of infection. Manifestations appear to vary by host-related factors. Older adults and immunocompromised patients often present with sepsis and meningitis, whereas immunocompetent patients develop febrile gastroenteritis. Pregnant women may experience a flulike illness, but granulomatosis infantisepticum may afflict the fetus, resulting in bacteremia, meningitis, or both in the newborn infant.

Data from the CDC have suggested that Latin Americans may have a higher incidence of listeriosis. Latin American women of childbearing age and their infants have an 11-fold increased risk of infection. The reason for this finding is unclear and remains under investigation.

Listeriosis has been associated with delicatessen meats, hot dogs, soft cheeses, and unpasteurized milk and dairy products. Queso fresco, an ethnic homemade soft cheese produced from unpasteurized milk, has been associated with listeriosis in the Hispanic population.

Illness follows a 1- to 2-day incubation period. Clinical symptoms include fever, gastrointestinal upset, and subsequent diarrhea. When treatment is needed, ampicillin appears to be the most effective antibiotic.

Vibrio

Vibrio foodborne disease tends to be seasonal, with a peak incidence in late summer and early autumn. Consumption of raw seafood from the southern United States coast is the most common food association. *V. parahaemolyticus* and *V. vulnificus* are the

most frequent species isolated. They are halophilic and cold-tolerant organisms, which allow *Vibrio* to survive in conditions that may normally retard or prevent food contamination.

A clinical syndrome of watery diarrhea, abdominal cramping, nausea, vomiting, and fever occurs 1 to 4 days after ingestion. The illness is usually self limited, with resolution in about 3 days. Persons with liver disease may develop a severe sepsis syndrome, bullous cellulitis, or both, with 50% mortality. *Vibrio* cellulitis and wound infections are occupational risks for fishermen and oyster shuckers. Appropriate antibiotic treatment includes tetracycline or ceftriaxone.

Yersinia

Yersiniosis is an uncommon cause of foodborne disease in the United States. It has been associated with the consumption of raw pork, unpasteurized milk and dairy products, and contaminated water. The preparation, handling, or consumption of chitterlings has been associated with *Yersinia* infections. Young African American children are disproportionately affected by this holiday food tradition.

The incubation period is 4 to 7 days and is followed by fever, abdominal pain, and bloody diarrhea. The abdominal pain may mimic that of appendicitis. Additional manifestations include carditis, joint pain, and sepsis. Although most cases resolve spontaneously, severe cases may require therapy with doxycycline, a fluoroquinolone, aminoglycoside, or trimethoprim-sulfamethoxazole.

Parasites

Parasites are an uncommon form of foodborne illness. The most frequent causes include *Cryptosporidium* spp. and *Giardia lamblia*, which have been associated with contaminated water. Additional foodborne diseases include cyclosporiasis, trichinosis, toxoplasmosis, and amebiasis. Cyclosporiasis has been previously linked to imported raspberries. Trichinosis was traditionally linked to pork but can be contracted through other sources, such as inadequately cooked wild game. Toxoplasmosis has been most often associated with undercooked meat and amebiasis is associated with contaminated water.

Cryptosporidiosis may be difficult to treat. Response has been noted with nitazoxanide, paromomycin, or azithromycin. Metronidazole is the usual treatment for giardiasis. Prolonged treatment with trimethoprim-sulfamethoxazole may be necessary to cure cyclosporiasis.

Toxins

Foodborne disease caused by toxins may have a variety of presentations that include gastrointestinal symptoms, neurologic manifestations, or both. Preformed heat-stable enterotoxins associated with *Staphylococcus aureus* and *Bacillus cereus* have an acute onset of nausea, vomiting, and diarrhea within 1 to 6 hours of ingestion. Fever is not a

common component of this self-limited syndrome. Symptoms resolve rapidly, often within 12 hours.

Clostridium perfringens has a slower onset of illness, occurring approximately 12 hours after ingestion, because the heat-labile enterotoxin is produced in vivo after consumption of contaminated food. Cramping and diarrhea are the major manifestations, with resolution of symptoms in about 24 hours.

Botulinus toxin is considered the most potent lethal substance known. It is produced by *Clostridium botulinum*. Illness occurs 18 to 36 hours after ingestion of the source food. Home-canned foods have been the traditional sources. The onset of illness is heralded by nausea, vomiting, and diarrhea, followed by constipation. A descending paralysis then occurs. Antitoxins are available but only prevent further progression of paralysis because they neutralize circulating toxin and have no effect on bound toxin. Foodborne botulism carries a 5% to 10% mortality rate. If the individual survives, many months may be required before recovery.

The onset of paresthesias within minutes to a few hours of food ingestion should alert the clinician to the possibility of niacin, monosodium glutamate, fish, or shellfish poisoning. Marine bacteria present on the surface of some fish produce inhibitors of histamine degradation, resulting in high levels of histamine. When they are consumed, scombroid poisoning (histamine fish poisoning) may occur. The fish most often associated with scombroid poisoning are tuna, mackerel, skipjack, bonito, and mahi-mahi. The syndrome resembles a histamine reaction, with flushing, headache, nausea, vomiting, cramping, and burning in the mouth and throat. Poisoning by ciguatera fish such as grouper and snapper produces nausea, vomiting, and diarrhea as well as paresthesias of the lips, tongue, and throat. Shellfish poisoning causes a similar syndrome except that muscle weakness, paralysis, or amnesia may occur in severe cases. The neurologic manifestations resolve in hours to a few days.

Mushroom poisoning can produce various clinical syndromes. Depending on the toxin involved, symptoms may range from parasympathetic hyperactivity to hallucinations or hepatic and renal failure, in the case of amatoxins or phallotoxins. Onset is rapid, within 2 hours of ingestion, and resolution of symptoms occurs in approximately 24 hours. Organ failure may follow after an additional 1 to 2 days. Without emergent liver transplantation, acute hepatic failure rapidly leads to death.

Viruses

Hepatitis A and Norwalk virus are the two most commonly identified viral sources of foodborne disease. Many additional cases of foodborne disease occur as a result of unidentified viruses. Hepatitis A is often associated with shellfish and infected food handlers. In addition, green onions were determined to be the source of a widespread outbreak in a restaurant chain in 2003.

The high morbidity and overall relatively low mortality of foodborne disease could be significantly reduced. Proper knowledge of food handling, storage, and preservation

could have a significant impact on the occurrence of this common problem. Improved conditions in mass production and processing of foods have produced tangible results. New methods of sterilization, such as irradiation, represent avenues of future progress.

Additional information on foodborne illness can be found on the CDC web site. This site reviews many of the common syndromes in an educational case scenario format. Several useful tables list causative agents, incubation periods, and major manifestations.

FOOD-BORNE INFECTIONS AND INTOXICATIONS

BACILLUS CEREUS – FOODBORNE INTOXICATION

Found

Widely distributed in nature; can be isolated from meats, milk, vegetables, and fish.

Transmission

Bacteria produce a toxin that causes illness. Vomiting-type outbreaks have usually been associated with rice products and other starchy foods such as potatoes, pasta, and cheese products. Sauces, puddings, soups, casseroles, pastries, and salads have also been implicated in outbreaks.

Symptoms

Food poisoning is characterized by nausea and vomiting 0.5 to six hours after the ingestion of a contaminated food product. In more severe cases, abdominal cramps and diarrhea might occur with symptoms lasting up to 24 hours.

CAMPYLOBACTER JEJUNI – FOODBORNE INFECTION

Found

Widely distributed in nature; can be isolated from meats, milk, vegetables, and fish.

Transmission

Bacteria produce a toxin that causes illness. Vomiting-type outbreaks have usually been associated with rice products and other starchy foods such as potatoes, pasta, and cheese products. Sauces, puddings, soups, casseroles, pastries, and salads have also been implicated in outbreaks.

Symptoms

Food poisoning is characterized by nausea and vomiting 0.5 to six hours after the ingestion of a contaminated food product. In more severe cases, abdominal cramps and diarrhea might occur with symptoms lasting up to 24 hours.

CAMPYLOBACTER JEJUNI – FOODBORNE INFECTION

Found

Intestinal tracts of animals, birds, raw milk, untreated water, and sewage sludge.

Transmission

Contaminated water, raw milk, and raw or undercooked meat, poultry, or shellfish.

Symptoms

Fever, headache, and muscle pain followed by diarrhea (sometimes bloody), abdominal pain, and nausea that appear two to five days after eating; may last seven to 10 days.

CLOSTRIDIUM BOTULINUM – FOODBORNE INTOXICATION

Found

Widely distributed in nature; soil and water on plants and intestinal tracts of animals and fish. Grows only in little or no oxygen.

Transmission

Bacteria produce a toxin that causes illness. Improperly canned foods, garlic in oil, vacuum-packed and tightly wrapped food.

Symptoms

Toxins affect the nervous system. Symptoms usually appear in 18 to 36 hours, but can sometimes appear as few as four hours or as many as eight days after eating. Double vision, droopy eyelids, trouble speaking and swallowing, and difficulty breathing may occur. Can be fatal in three to 10 days if not treated.

CLOSTRIDIUM PERFRINGENS

Found

Soil, dust, sewage, and intestinal tracts of animals and humans. Grows only in little or no oxygen.

Transmission

Called "the cafeteria germ" because many outbreaks result from food left for long periods in steam tables or at room temperature. Bacteria destroyed by cooking, but some toxin-producing spores may survive.

Symptoms

Diarrhea and gas pains may appear eight to 24 hours after eating; usually last about 1 day, but less severe symptoms may persist for one to two weeks.

ESCHERICHIA COLI 0157:H7 – FOODBORNE INFECTION

Found

Intestinal tracts of some mammals, raw milk, unchlorinated water; one of several strains of E. coli that can cause human illness.

Transmission

Contaminated water, raw milk, raw or rare ground beef, unpasteurized apple juice or cider, uncooked fruits and vegetables, person-to-person.

Symptoms

Diarrhea or bloody diarrhea, abdominal cramps, nausea, and malaise; can begin two to five days after food is eaten, lasting about eight days. Some, especially the very young, have developed Hemolytic Uremic Syndrome (HUS) that causes acute kidney failure. A similar illness, thrombotic thrombocytopenic purpura (TTP), may occur in older adults.

HEPATITIS A VIRUS – FOODBORNE INFECTION

Found

Hepatitis A is widely distributed throughout the world, occurring in both epidemic and sporadic cases. Hepatitis A is primarily transmitted person to person by the fecal-oral route, but common source transmission does occur.

Transmission

Hepatitis A virus is excreted in feces of infected people and can produce clinical disease when a susceptible individual consumes contaminated water or foods. Cold cuts and sandwiches, fruits, fruit juices, milk and milk products, vegetables, salads, shellfish, and iced drinks all can be considered vehicles for the transmission of Hepatitis A.

Symptoms

Hepatitis A is usually a mild illness characterized by sudden onset of fever, malaise, nausea, anorexia, and abdominal discomfort, followed by several days of jaundice.

LISTERIA MONOCYTOGENES – FOODBORNE INFECTION

Found

Some studies suggest that 1% to 10% of humans may be intestinal carriers of Listeria Monocytogenes. It has been found in at least 37 mammalian species, both domestic and

feral, as well as at least 17 species of birds and possibly some species of fish and shellfish. It can be isolated from soil, silage, and other environmental sources

Transmission

Raw milks, pasteurized fluid milk, cheeses, ice cream, raw vegetables, fermented raw-meat sausages, raw and cooked poultry, raw meats, and raw and smoked fish.

Symptoms

Some studies suggest that 1% to 10% of humans may be intestinal carriers of Listeria monocytogenes.

It has been found in at least 37 mammalian species, both domestic and feral, as well as at least 17 species of birds, and possibly some species of fish and shellfish. It can be isolated from soil, silage, and other environmental sources.

LISTERIA MONOCYTOGENES

Found

Intestinal tracts of humans and animals, milk, soil, leaf vegetables, and processed foods; can grow slowly at refrigerator temperatures.

Transmission

Soft cheese, raw milk, improperly processed ice cream, raw leafy vegetables, meat, and poultry. Illness caused by bacteria that do not produce toxin.

Symptoms

Fever, chills, headache, backache, sometimes abdominal pain and diarrhea; 12 hours to three weeks; may later develop more serious illness in at-risk patients (meningitis or spontaneous abortion in pregnant women); sometimes just fatigue.

NORWALK VIRUS GROUP – FOODBORNE INFECTION

Found

The virus has been identified in clams and oysters by radio immunoassay. It is typically shed in the feces of humans.

Transmission

Norwalk gastroenteritis is transmitted by the fecal-oral route via contaminated water and foods. Shellfish and salad ingredients are the foods most often implicated in Norwalk outbreaks. Ingestion of raw or insufficiently steamed clams and oysters poses a high risk for infection with Norwalk virus.

SALMONELLA (OVER 2,300 TYPES)

Found

Intestinal tract and feces of animals; Salmonella enteritidis in raw eggs.

Transmission

Raw or undercooked eggs, poultry, and meat; raw milk and dairy products; seafood and food handlers.

Symptoms

Stomach pain, diarrhea, nausea, chills, fever, and headache usually appear eight to 72 hours after eating; may last one to two days.

SHIGELLA (OVER 30 TYPES)

Found

Human intestinal tract; rarely found in other animals.

Transmission

Person-to-person by fecal-oral route; fecal contamination of food and water. Most outbreaks result from food, especially salads, prepared and handled by workers using poor personal hygiene techniques.

Symptoms

Disease referred to as "shigellosis" or bacillary dysentery. Diarrhea containing blood and mucus, fever, abdominal cramps, chills, and vomiting; 12 to 50 hours from ingestion of bacteria; can last a few days to two weeks.

STAPHYLOCOCCUS AUREUS – FOODBORNE INTOXICATION

Found

On the skin, infected cuts, pimples, noses, and throats.

Transmission

From people to food through improper food handling. Multiply rapidly at room temperature to produce a toxin that causes illness.

Symptoms

Severe nausea, abdominal cramps, vomiting, and diarrhea can occur one to six hours after eating; recovery within two to three days—longer if severe dehydration occurs.

VIBRIO PARAHAEMOLYTICUS AND OTHER MARINE VIBRIO SPP.-FOOD-BORNE INFECTION

Found

Both pathogenic and non-pathogenic forms of the organism can be isolated from marine and estuarine environments and from fish and shellfish dwelling in these environments.

Transmission

Infections with this organism have been associated with the consumption of raw, improperly cooked, or cooked, recontaminated fish and shellfish.

Symptoms

Diarrhea, abdominal cramps, nausea, vomiting, headache, fever, and chills may be associated with infections caused by this organism.

SALMONELLA

Salmonella is the second most common intestinal infection in the United States. More than 7,000 cases of *Salmonella* were confirmed in 2009; however the majority of cases go unreported. The Centers for Disease Control and Prevention estimates that over 1 million people in the U.S. contract *Salmonella* each year, and that an average of 20,000 hospitalizations and almost 400 deaths occur from *Salmonella*poisoning, according to a 2011 report.

Salmonella infection usually occurs when a person eats food contaminated with the feces of animals or humans carrying the bacteria. *Salmonella*outbreaks are commonly associated with eggs, meat and poultry, but these bacteria can also contaminate other foods such as fruits and vegetables. Foods that are most likely to contain *Salmonella* include raw or undercooked eggs, raw milk, contaminated water, and raw or undercooked meats.

Salmonella is generally divided into two categories. Non-typhoidal *Salmonella* is the most common form, and is carried by both humans and animals. Most serotypes of *Salmonella*, such as *Salmonella* Javiana and *Salmonella* Enteritidis cause non-typhoidal *Salmonella*.

Typhoidal *Salmonella*, which causes typhoid fever, is rare, and is caused by *Salmonella* Typhi, which is carried only by humans.

SYMPTOMS OF SALMONELLA INFECTION

Symptoms of *Salmonella* infection, or Salmonellosis, range widely, and are sometimes absent altogether. The most common symptoms include diarrhea, abdominal cramps, and fever.

Typical Symptoms of *Salmonella* infection: Appear 6 to 72 hours after eating contaminated food and last for 3 to 7 days without treatment.

- Diarrhea
- Abdominal Cramps
- Fever of 100°F to 102°F

Additional symptoms:

- Bloody diarrhea
- Vomiting
- Headache
- Body Aches

Typhoid Fever Symptoms: Symptoms of typhoid fever appear between 8 and 14 days after eating contaminated food and last anywhere from 3 to 60 days. They include a fever of 104°F, weakness, lethargy, abdominal pain, coughing, nosebleeds, delirium, and enlarged organs. Typhoid fever is a serious illness that can result in death.

COMPLICATIONS OF SALMONELLA

Complications of *Salmonella* poisoning are more likely to occur among young children and people age 65 or older. Possible complications include:

Reactive Arthritis: Reactive arthritis is thought to occur in 2 to 15 percent of *Salmonella* patients. Symptoms include inflammation of the joints, eyes, or reproductive or urinary organs. On average, symptoms appear 18 days after infection.

Focal Infection: A focal infection occurs when *Salmonella* bacteria takes root in body tissue and causes illnesses such as arthritis or endocartitis. It is caused by typhoidal *Salmonella* only.

SALMONELLA TREATMENT

Salmonella infections generally last 3 to 7 days, and often do not require treatment. People with severe dehydration may need rehydration through an IV.

Antibiotics are recommended for those at risk of invasive disease, including infants under three months old. Typhoid fever is treated with a 14-day course of antibiotics.

Unfortunately, treatment of *Salmonella* has become more difficult as it has become more resistant to antibiotics. Finding the right antibiotic for a case of *Salmonella* is crucial to treating this bacterial infection.

PREVENTION OF SALMONELLA INFECTION

These safety measures can help prevent *Salmonella* poisoning:

- Wash your hands before preparing food and after handling raw meats
- Cook meat and eggs thoroughly until they reach an internal temperature of 160°F (71°C)
- Do not eat foods containing raw eggs or milk, such as undercooked French toast

- Avoid cooking raw meat in the microwave, as it may not reach a high enough internal temperature to kill Salmonella bacteria and may be unevenly cooked
- Avoid bringing uncooked meat into contact with food that will not be cooked (*i.e.* salad)
- Wash hands with soap after handling reptiles or animal feces
- Always wash your hands after going to the bathroom

SALMONELLOSIS

Salmonellosis is a symptomatic infection caused by bacteria of the *Salmonella* type. The most common symptoms are diarrhea, fever, abdominal cramps, and vomiting. This typically occurs half to three days after exposure with symptoms lasting four to seven days. Occasionally more significant disease can result in dehydration. The old, young, and others with a weak immune systems are more likely to develop severe disease. Specific types of *Salmonella* can result in typhoid fever or paratyphoid fever.

There are two species of *Salmonella*: *Salmonella bongori* and *Salmonella enterica* with many subtypes. Infection is usually spread via contaminated meat, eggs, or milk. Other foods may spread the disease if they have come into contact with manure. A number of pets may also carry the infection and spread the infection including, cats, dogs, and reptiles. Diagnosis is by a stool test.

Efforts to prevent the disease include proper preparation and cooking of food. Mild disease typically does not require specific treatment. More significant cases may need the treatment of electrolyte problems and the replacement of fluids by intravenous. In those at high risk or in whom the disease has spread outside the intestines, antibiotics are recommended.

Salmonellosis is one of the most common causes of diarrhea globally. In 2015, 90,300 deaths occurred from non-typhoidal and 178,000 deaths from typhoidal salmonellosis. In the United States about 1.2 million cases and 450 deaths occur from non–typhoidal salmonellosis a year. In Europe it is the second most common foodborne disease after campylobacteriosis.

SIGNS AND SYMPTOMS

Enteritis

After a short incubation period of a few hours to one day, the bacteria multiply in the intestinal lumen, causing an intestinal inflammation. Most people with salmonellosis develop diarrhea, fever, vomiting, and abdominal cramps 12 to 72 hours after infection. Diarrhea is often mucopurulent (containing mucus or pus) and bloody. In most cases, the illness lasts four to seven days, and most people recover without treatment. In some cases, though, the diarrhea may be so severe that the patient becomes dangerously dehydrated and must be taken to a hospital. At the hospital, the patient may receive

intravenous fluids to treat the dehydration, and may be given medications to provide symptomatic relief, such as fever reduction. In severe cases, the *Salmonella* infection may spread from the intestines to the blood stream, and then to other body sites, and can cause death, unless the person is treated promptly with antibiotics.

In otherwise healthy adults, the symptoms can be mild. Normally, no sepsis occurs, but it can occur exceptionally as a complication in the immunocompromised. However, in people at risk such as infants, small children, and the elderly, *Salmonella* infections can become very serious, leading to complications. In infants, dehydration can cause a state of severe toxicity. Extraintestinal localizations are possible, especially *Salmonella* meningitis in children, osteitis, etc. Children with sickle-cell anemia who are infected with *Salmonella* may develop osteomyelitis. Treatment of osteomyelitis, in this case, will be to use fluoroquinolones (ciprofloxacin, levofloxacin, etc., and nalidixic acid).

Those whose only symptom is diarrhea usually completely recover, but their bowel habits may not return to normal for several months.

Typhoid Fever

Typhoid fever occurs when *Salmonella* bacteria enter the lymphatic system and cause a systemic form of salmonellosis. Endotoxins first act on the vascular and nervous apparatus, resulting in increased permeability and decreased tone of the vessels, upset thermal regulation, vomiting, and diarrhea. In severe forms of the disease, enough liquid and electrolytes are lost to upset the water-salt metabolism, decrease the circulating blood volume and arterial pressure, and cause hypovolemic shock. Septic shock may also develop. Shock of mixed character (with signs of both hypovolemic and septic shock) are more common in severe salmonellosis. Oliguria and azotemia develop in severe cases as a result of renal involvement due to hypoxia and toxemia.

Long-term

Salmonellosis is associated with later irritable bowel syndrome and inflammatory bowel disease. Evidence however does not support it being a direct cause of the latter.

A small number of people afflicted with salmonellosis experience reactive arthritis, which can last months or years and can lead to chronic arthritis. In sickle-cell anemia, osteomyelitis due to *Salmonella* infection is much more common than in the general population. Though *Salmonella* infection is frequently the cause of osteomyelitis in sickle-cell anemia patients, it is not the most common cause, which remains to be *Staphylococcus* infection. Those infected may become asymptomatic carriers, but it is relatively uncommon, with shedding observed in only 0.2 to 0.6% of cases after a year.

CAUSES

- Contaminated food, often having no unusual look or smell
- Poor kitchen hygiene, especially problematic in institutional kitchens and restaurants because this can lead to a significant outbreak

- Excretions from either sick or infected but apparently clinically healthy people and animals (especially dangerous are caregivers and animals)
- Polluted surface water and standing water (such as in shower hoses or unused water dispensers)
- Unhygienically thawed poultry (the meltwater contains many bacteria)
- An association with reptiles (pet tortoises, snakes, iguanas, and aquatic turtles) is well described.
- Amphibians such as frogs

Salmonella bacteria can survive for some time without a host; thus, they are frequently found in polluted water, with contamination from the excrement of carrier animals being particularly important.

The European Food Safety Authority highly recommends that when handling raw turkey meat, consumers and people involved in the food supply chain should pay attention to personal and food hygiene.

An estimated 142,000 Americans are infected each year with *Salmonella* Enteritidis from chicken eggs, and about 30 die. The shell of the egg may be contaminated with *Salmonella* by feces or environment, or its interior (yolk) may be contaminated by penetration of the bacteria through the porous shell or from a hen whose infected ovaries contaminate the egg during egg formation.

Nevertheless, such interior egg yolk contamination is theoretically unlikely. Even under natural conditions, the rate of infection was very small (0.6% in a study of naturally contaminated eggs and 3.0% among artificially and heavily infected hens).

PREVENTION

The FDA has published guidelines to help reduce the chance of food-borne salmonellosis. Food must be cooked to 68–72 °C (145–160 °F), and liquids such as soups or gravies must be boiled. Freezing kills some *Salmonella*, but it is not sufficient to reliably reduce them below infectious levels. While *Salmonella* is usually heat-sensitive, it does acquire heat resistance in high-fat environments such as peanut butter.

Vaccine

Antibodies against non-typhoidal *Salmonella* were first found in Malawi children in research published in 2008. The Malawian researchers have identified an antibody that protects children against bacterial infections of the blood caused by non-typhoidal *Salmonella*. A study at Queen Elizabeth Hospital in Blantyre found that children up to two years old develop antibodies that aid in killing the bacteria. This could lead to a possible *Salmonella* vaccine for humans. A recent study has tested a vaccine on chickens which offered efficient protection against salmonellosis.

Vaccination of chickens against *Salmonella* essentially wiped out the disease in the United Kingdom. A similar approach has been considered in the United States, but the Food and Drug Administration decided not to mandate vaccination of hens.

Industrial Hygiene

Since 2011, Denmark has had zero cases of human salmonella poisoning. The country eradicated salmonella without vaccines and antibiotics by focusing on eliminating the infection from "breeder stocks", implementing various measures to prevent infection, and taking a zero-tolerance policy towards salmonella in chickens.

TREATMENT

Electrolytes may be replenished with oral rehydration supplements (typically containing salts sodium chloride and potassium chloride).

Appropriate antibiotics, such as ceftriaxone, may be given to kill the bacteria but are not necessary in most cases. Azithromycin has been suggested to be better at treating typhoid in resistant populations than both fluoroquinolone drugs and ceftriaxone. Antibiotic resistance rates are increasing throughout the world, so health care providers should check current recommendations before choosing an antibiotic.

EPIDEMIOLOGY

In the mid- to late 20th century, *Salmonella enterica* serovar Enteritidis was a common contaminant of eggs. Depending on the region, this is less common now with the advent of hygiene measures in egg production, and the vaccination of laying hens to prevent *Salmonella* colonization. Various *Salmonella* serovars (strains) also cause severe diseases in animals.

United States

About 142,000 people in the United States are infected each year with *Salmonella* Enteritidis from chicken eggs, and about 30 die.

In 2010, an analysis of death certificates in the United States identified a total of 1,316 *Salmonella*-related deaths from 1990 to 2006. These were predominantly among older adults and those who were immunocompromised. The U.S. government reported as many as 20% of all chickens were contaminated with *Salmonella* in the late 1990s, and 16.3% were contaminated in 2005.

The United States has struggled to control salmonella infections, with the rate of infection rising from 2001 to 2011. In 1998, the USDA moved to close plants if salmonella was found in excess of 20 percent, which was the industry's average at the time, for three consecutive tests. Texas-based Supreme Beef Processors, Inc. sued on the argument that Salmonella is naturally occurring and ultimately prevailed when a federal appeals court affirmed a lower court. These issues were highlighted in a proposed Kevin's Law (formally proposed as the Meat and Poultry Pathogen Reduction and Enforcement Act of 2003), of which components were included the Food Safety Modernization Act passed in 2011, but that law applies only to the FDA and not the USDA. The USDA proposed a regulatory initiative in 2011 to Office of Management and Budget.

Europe

Since July 2012, an outbreak of salmonellosis occurred in Northern Europe caused by *Salmonella thompson*. The infections were linked to smoked salmon from the manufacturer Foppen, where the contamination had occurred. Most infections were reported in the Netherlands, over 1060 infections with this subspecies have been confirmed, as well as four mortalities.

A case of widespread infection was detected mid-2012 in seven EU countries. Over 400 people had been infected with *Salmonella enterica* serovar Stanley (*S.* Stanley) that usually appears in the regions of Southeast Asia. After several DNA analyses seemed to point to a specific Belgian strain, the "Joint ECDC/E FSA Rapid Risk Assessment" report detected turkey production as the source of infection.

In Germany, food poisoning infections must be reported. Between 1990 and 2005, the number of officially recorded cases decreased from about 200,000 to about 50,000 cases.

Elsewhere

In March 2007, around 150 people were diagnosed with salmonellosis after eating tainted food at a governor's reception in Krasnoyarsk, Russia. Over 1,500 people attended the ball on March 1 and fell ill as a consequence of ingesting *Salmonella*-tainted sandwiches.

About 150 people were sickened by *Salmonella*-tainted chocolate cake produced by a major bakery chain in Singapore in December 2007.

HISTORY

Both salmonellosis and the *Salmonella* genus of microorganisms derive their names from a modern Latin coining after Daniel E. Salmon (1850–1914), an American veterinary surgeon. He had help from Theobald Smith, and together they found the bacterium in pigs.

Four-inch regulation

The "Four-inch regulation" or "Four-inch law" is a colloquial name for a regulation issued by the U.S. FDA in 1975, restricting the sale of turtles with a carapace length less than four inches (10 cm).

The regulation was introduced, according to the FDA, "because of the public health impact of turtle-associated salmonellosis". Cases had been reported of young children placing small turtles in their mouths, which led to the size-based restriction.

SHIGELLA

Shigella is the bacterium that causes the disease shigellosis, also known as bacillary dysentery. *Shigella* is one of the most easily transmitted bacterial diarrheas, since it can

occur after fewer than 100 bacteria are ingested. While reported cases of *Shigella* range between 14,000 and 20,000 annually, with the majority of these cases occurring between July and October. *Shigella Sonnei* is the most common type of *Shigella*. It accounts for over two-thirds of cases of shigellosis in the United States.

Shigella bacteria are generally transmitted through a fecal-oral route. Foods that come into contact with human or animal waste can transmit *Shigella*. Thus, handling toddlers' diapers, eating vegetables from a field contaminated with sewage, or drinking pool water are all activities that can lead to shigellosis.

SYMPTOMS OF SHIGELLA FOOD POISONING

Symptoms of *Shigella* poisoning most commonly develop one to three days after exposure to *Shigella* bacteria, and usually go away within five to seven days. It is also possible to get *Shigella* but experience no symptoms, and still be contagious to others, a condition known as being asymptomatic.

Common *Shigella* Food Poisoning Symptoms

- Diarrhea: Diarrhea ranges from mild to severe. It is bloody in 25 to 50 percent of cases and usually contains mucus
- Fever
- Stomach cramps
- Rectal spasms

COMPLICATIONS FROM SHIGELLA

Complications from shigellosis can include severe dehydration, seizures in small children, rectal bleeding, and invasion of the blood stream by the bacteria. Young children and the elderly are at the highest risk of death. The following is a list of specific complications caused by *Shigella*.

Proctitis and Rectal Prolapse: The bacteria that causes shingellosis can also cause inflammation of the lining of the rectum or rectal prolapse.

Reactive Arthritis: Approximately 3 percent of patients with *Shigella* infection, most often those with *Shigella flexneri*, develop Reactive Arthritis. It occurs when the immune system attempts to combat *Shigella* but instead attacks the body. Symptoms of Reactive Arthritis include inflammation of the joints, eyes, or reproductive or urinary organs. On average, symptoms appear 18 days after infection.

Toxic Megacolon: In this rare complication, the colon is paralyzed and unable to pass bowel movements or gas. Symptoms of Toxic Megacolon include abdominal pain and swelling, fever, weakness, and disorientation. If this complication goes untreated and the colon ruptures, the patient's condition can be life-threatening.

Hemolytic Uremic Syndrome, or HUS: *Shigella* rarely results in HUS, which is more commonly a complication of Shiga toxin-producing E. coli infections. HUS can lead to kidney failure.

DIAGNOSIS OF SHIGELLA

A *Shigella* infection is diagnosed through laboratory testing of a stool sample.

SHIGELLA FOOD POISONING TREATMENT

A *Shigella* infection usually goes away on its own in five to seven days, although bowel movements may continue to be abnormal for up to a month following infection. Antibiotics, however, can shorten the course of the illness. A doctor can prescribe antibiotics after testing a stool sample for the presence of *Shigella* bacteria.

Some strains of shigellosis are resistant to antibiotics, meaning that antibiotics might not always be an effective treatment. Antidiarrheal medication should be avoided, as it can actually make the illness worse.

PREVENTING A SHIGELLA INFECTION

Frequent hand washing is key to preventing *Shigella*, since individuals can carry *Shigella* without noticing symptoms, and *Shigella* bacteria can remain active for weeks after illness.

Steps for Preventing the Spread of *Shigella* Infection

- If a child in diapers has shigellosis, wash your hands after changing their diaper and wipe down the changing area with disinfectant
- People with *Shigella* should not prepare food for others for at least two days after diarrhea has stopped
- Drink only treated or boiled water while traveling and only eat fruits you peel yourself
- Only swim in pools maintaining a chlorine level of 0.5 parts per million and stay clear of pools where children not yet toilet trained are swimming

SHIGELLOSIS

Shigellosis is a type of diarrhea caused by a bacterial infection with *Shigella*. Symptoms generally start one to two days after exposure and include diarrhea, fever, abdominal pain, and pain with passing stool. Blood may be present in the stool. Symptoms typically last five to seven days. Complications can include post infectious arthritis, sepsis, seizures, and hemolytic uremic syndrome.

Shigellosis is caused by four specific types of *Shigella*. These are typically spread by exposure to infected feces. This can occur via contaminated food, water, or hands. Contamination may be spread by flies or when changing diapers. Diagnosis is by stool culture.

Prevention is by properly washing the hands. There is no vaccine. Shigellosis usually resolves without specific treatment. Sufficient fluids by mouth and rest is recommended. Bismuth subsalicylate may help with the symptoms; however, medications that slow the bowels such as loperamide are not recommended. In severe cases antibiotics may

be used but resistance is common. Commonly used antibiotics include ciprofloxacin or azithromycin.

Globally shigellosis occurs in at least 80 million people and results in about 700,000 deaths a year. Most cases occur in the developing world. Young children are most commonly affected. Outbreaks of disease may occur in childcare settings and schools. It is also relatively common among travelers. In the United States about half a million cases occur a year.

SIGNS AND SYMPTOMS

Signs and symptoms may range from mild abdominal discomfort to full-blown dysentery characterized by cramps, diarrhea, with slimy-consistent stools, fever, blood, pus, or mucusin stools or tenesmus. Onset time is 12 to 96 hours, and recovery takes 5 to 7 days.

Infections are associated with mucosal ulceration, rectal bleeding, and drastic dehydration. Reactive arthritis and hemolytic uremic syndrome are possible sequelae that have been reported in the aftermath of shigellosis.

Shigella can be transmitted through food, including salads (potato, tuna, shrimp, macaroni, and chicken), raw vegetables, milk and dairy products, and meat. Contamination of these foods is usually through the fecal-oral route. Fecally contaminated water and unsanitary handling by food handlers are the most common causes of contamination. Apart from hand-to-mouth infection, shigellosis is transmitted through fomites, water and mechanical vectors like houseflies.

The most common neurological symptom includes seizures.

DIAGNOSIS

The diagnosis of shigellosis is made by isolating the organism from diarrheal fecal sample cultures. *Shigella* species are negative for motility and are generally not lactose fermenters, but *S. sonnei* can ferment lactose. They typically do not produce gas from carbohydrates (with the exception of certain strains of *S. flexneri*) and tend to be overall biochemically inert. *Shigella* should also be urea hydrolysis negative. When inoculated to a triple sugar iron slant, they react as follows: K/A, gas -, and H_2S -. Indole reactions are mixed, positive and negative, with the exception of *S. sonnei*, which is always indole negative. Growth on Hektoen enteric agar produces bluish-green colonies for *Shigella* and bluish-green colonies with black centers for *Salmonella*.

PREVENTION

Simple precautions can be taken to prevent getting shigellosis: wash hands before handling food and thoroughly cook all food before eating. The primary prevention methods are improved sanitation and personal and food hygiene, but a low-cost and efficacious vaccine would complement these methods.

Since shigellosis is spread very quickly among children, keeping infected children out of daycare for 24 hours after their symptoms have disappeared, will decrease the occurrence of shigellosis in daycares.

Vaccine

Currently, no licensed vaccine targeting *Shigella* exists. Several vaccine candidates for *Shigella* are in various stages of development including live attenuated, conjugate, ribosomal, and proteosome vaccines. *Shigella* has been a longstanding World Health Organization target for vaccine development, and sharp declines in age-specific diarrhea/dysentery attack rates for this pathogen indicate that natural immunity does develop following exposure; thus, vaccination to prevent the disease should be feasible. Shigellosis is resistant to many antibiotics used to treat the disease, so vaccination is an important part of the strategy to reduce morbidity and mortality.

TREATMENT

Treatment consists mainly of replacing fluids and salts lost because of diarrhea. Replacement by mouth is satisfactory for most people, but some may need to receive fluids intravenously. Antidiarrheal drugs (such as diphenoxylate or loperamide) may prolong the infection and should not be used.

Antibiotics

Antibiotics should only be used in severe cases or for certain populations with mild symptoms (elderly, immunocompromised, food service industry workers, child care workers). For *Shigella*-associated diarrhea, antibiotics shorten the length of infection, but they are usually avoided in mild cases because many *Shigella* strains are becoming resistant to common antibiotics. Furthermore, effective medications are often in short supply in developing countries, which carry the majority of the disease burden from *Shigella*. Antidiarrheal agents may worsen the sickness, and should be avoided.

In most cases, the disease resolves within four to eight days without antibiotics. Severe infections may last three to six weeks. Antibiotics, such as trimethoprim-sulfamethoxazole, ciprofloxacin may be given when the person is very young or very old, when the disease is severe, or when the risk of the infection spreading to other people is high. Additionally, ampicillin (but not amoxicillin) was effective in treating this disease previously, but now the first choice of drug is pivmecillinam.

EPIDEMIOLOGY

Insufficient data exist, but it is estimated to have caused the death of 34,000 children under the age of five in 2013, and 40,000 deaths in people over five years of age. *Shigella*also causes about 580,000 cases annually among travelers and military personnel from industrialized countries.

An estimated 500,000 cases of shigellosis occur annually in the United States. Infants, the elderly, and the critically ill are susceptible to the most severe symptoms of disease, but all humans are susceptible to some degree. Individuals with acquired immune deficiency syndrome (AIDS) are more frequently infected with *Shigella*. Shigellosis is a more common and serious condition in the developing world; fatality rates of shigellosis epidemics in developing countries can be 5–15%.

Orthodox Jewish communities (OJCs) are a known risk group for shigellosis; *Shigella sonnei* is cyclically epidemic in these communities in Israel, with sporadic outbreaks occurring elsewhere in among these communities. "Through phylogenetic and genomic analysis, we showed that strains from outbreaks in OJCs outside of Israel are distinct from strains in the general population and relate to a single multidrug-resistant sublineage of *S. sonnei* that prevails in Israel. Further Bayesian phylogenetic analysis showed that this strain emerged approximately 30 years ago, demonstrating the speed at which antimicrobial drug–resistant pathogens can spread widely through geographically dispersed, but internationally connected, communities."

LISTERIA FOOD POISONING

WHAT IS LISTERIA AND HOW DOES IT CAUSE FOOD POISONING?

Listeria (pronounced liss-STEER-e-uh) is a gram-positive rod-shaped bacterium that can grow under either anaerobic (without oxygen) or aerobic (with oxygen) conditions. Of the six species of *Listeria*, only *L. monocytogenes*(pronounced maw-NO-site-aw-JUH-neez) causes disease in humans. These bacteria multiply best at 86-98.6 degrees F (30-37 degrees C), but also multiply better than all other bacteria at refrigerator temperatures, something that allows temperature to be used as a means of differentiating *Listeria* from other contaminating bacteria.

Called an "opportunistic pathogen," *Listeria* is noted to cause an estimated 2,600 cases per year of severe invasive illness. Perhaps not surprisingly then, "foodborne illness caused by *Listeriamonocytogenes* has raised significant public health concern in the United States, Europe, and other areas of the world." As one noted expert observed, summarizing the history of these bacteria and their significance for public health:

Although L. monocytogenes was recognized as an animal pathogen over 80 years ago, the first outbreak confirming an indirect transmission from animals to humans was reported only in 1983, in Canada's Maritime provinces. In that outbreak, cabbages, stored in the cold over the winter, were contaminated with Listeria through exposure to infected sheep manure. A subsequent outbreak in California in 1985 confirmed the role of food in disseminating listeriosis. Since then Listeria has been implicated in many outbreaks of food-borne illness, most commonly from exposure to contaminated dairy products and prepared meat products, including turkey and deli meats, pâté, hot dogs and seafood and fish.

Given its widespread presence in the environment and food supply, the ingestion of *Listeria* has been described as an "exceedingly common occurrence."

HOW COMMON ARE LISTERIA INFECTIONS?

Listeria bacteria are found widely in the environment in soil, including in decaying vegetation and water, and may be part of the fecal flora of a large number of mammals, including healthy human adults. According to the FDA, "studies suggest that 1-10% of humans may be intestinal carriers of *Listeria*." Another authority notes that the "organism has been isolated from the stool of approximately 5% of healthy adults." Overall, seasonal trends show a notable peak in total *Listeria* cases and related-deaths from July through October.

Ingested by mouth, *Listeria* is among the most virulent foodborne pathogens, with up to 20% of clinical infections resulting in death. These bacteria primarily cause severe illness and death in persons with immature or compromised immune systems. Consequently, most healthy adults can be exposed to *Listeria*with little to no risk of infection and illness.

A study published in 1995 projected *Listeria* infection-rates to the U.S. population, suggesting that an estimated 1,965 cases and 481 deaths occurred in 1989 compared with an estimated 1,092 cases and 248 deaths in 1993, a 44% and 48% reduction in illness and death, respectively. In comparison, a USDA study published in 1996 estimated that there had been 1,795-1860 *Listeria*-related cases in 1993, and 445-510 deaths, with 85-95% of these attributable to the consumption of contaminated food. Listeriosis-related mortality rates decreased annually by 10.7% from 1990 through 1996, and by 4.3% from 1996 through 2005.

Among adults 50 years of age and older, infection rates were estimated to have declined from 16.2 per 1 million in 1989 to 10.2 per 1 million in 1993. Perinatal disease decreased from 17.4 cases per 100,000 births in 1989 to 8.6 cases per 100,000 births in 1993. Neo-natal infections are often severe, with a mortality rate of 25-50%.

According to the CDC's National Center for Zoonotic, Vector-Borne, and Enteric Diseases:

Listeriosis was added to the list of nationally notifiable diseases in 2001. To improve surveillance, the Council of State and Territorial Epidemiologists has recommended that all L. monocytogenes *isolates be forwarded to state public health laboratories for subtyping through the National Molecular Subtyping Network for Foodborne Disease Surveillance (PulseNet). All states have regulations requiring health care providers to report cases of listeriosis and public health officials try to interview all persons with listeriosis promptly using a standard questionnaire about high risk foods. In addition, FoodNet conducts active laboratory- and population-based surveillance.*

In 2006, public health officials from 48 states reported 1,270 foodborne disease outbreaks, with a confirmed or suspect source in 884 of the outbreaks (70%). Only one of the outbreaks with a confirmed source was attributed to *Listeria*, with this outbreak

involving eleven hospitalizations and one death. The next year, of 17,883 lab-confirmed infections, the CDC attributed 122 to *Listeria*. In 2009, there were 158 confirmed *Listeria* infections, representing an incidence-rate of.34 cases for every 100,000 persons in the United States. Such data revealed an incidence-rate of 0.27 cases per 100,000 persons, a decrease of 42% compared with 1996—1998. But, according to CDC's Technical Information web site, it is estimated that there are 1,600 cases of *Listeria* infection annually in the United States, based on data through 2008.

The 2009 numbers represented a reported 30% decrease in the number of infections compared to the 1996—1998 rates of infection. Although the nature and degree of underreporting is subject to dispute, all agree that the confirmed cases represent just the tip of the iceberg. Indeed, one study estimates the annual incidence rate for *Listeria* to be around 1,795-1,860 cases per 100,000 persons, with 445-510 of the cases ending in death.

Finally, in a study of FoodNet laboratory-confirmed invasive cases—where infection is detected in blood, cerebrospinal fluid, amniotic fluid, placenta or products of conception—the number of listeriosis cases decreased by 24% from 1996 through 2003. During this same period, pregnancy-associated disease decreased by 37%, while cases among those fifty years old and older decreased by 23%.

THE PREVALENCE OF LISTERIA IN FOOD AND THE ENVIRONMENT

LISTERIA BACTERIA ARE COMMON IN NATURE.

Listeria is a common presence in nature, found widely in such places as water, soil, infected animals, human and animal feces, raw and treated sewage, leafy vegetables, effluent from poultry and meat processing facilities, decaying corn and soybeans, improperly fermented silage, and raw (unpasteurized) milk.

Foods commonly identified as sources of *Listeria* infection include improperly pasteurized fluid milk, cheeses (particularly soft-ripened varieties, such as traditional Mexican cheeses, Camembert and ricotta), ice cream, raw vegetables, fermented raw-meat sausages, raw and cooked poultry, and cooked, ready-to-eat (RTE) sliced meats—often referred to as "deli meats". One study found that, over a five-year period of testing, in multiple processing facilities, *Listeriamonocytogenes* was isolated from 14% of 1,080 samples of smoked finfish and smoked shellfish.

Ready-to-eats foods have been found to be a notable and consistent source of *Listeria*. For example, a research-study done by the *Listeria* Study Group found that *Listeria monocytogenes* grew from at least one food specimen in the refrigerators of 64% of persons with a confirmed *Listeria* infection (79 of 123 patients), and in 11% of more than 2000 food specimens collected in the study. Moreover, 33% of refrigerators (26 of 79) contained foods that grew the same strain with which the individual had been infected,

a frequency much higher than would be expected by chance. A widely cited USDA study that reviewed the available literature also summarized that:

In samples of uncooked meat and poultry from seven countries, up to 70 percent had detectable levels of Listeria. *Schuchat found that 32 percent of the 165 culture-confirmed listeriosis cases could be attributed to eating food purchased from store delicatessen counters or soft cheeses. In Pinner microbiologic survey of refrigerated foods specimens obtained from households with listeriosis patients, 36 percent of the beef samples and 31 percent of the poultry samples were contaminated with* Listeria.

The prevalence of *Listeria* in ready-to-eat meats has not proven difficult to explain. As one expert in another much-cited article has noted:

The centralized production of prepared ready-to-eat food products...increases the risk of higher levels of contamination, since it requires that foods be stored for long periods at refrigerated temperatures that favour the growth of Listeria. *During the preparation, transportation and storage of prepared foods, the organism can multiply to reach a threshold needed to cause infection.*

The danger posed by the risk of *Listeria* in ready-to-eat meats has prompted the USDA to declare the bacterium an adulterant in these kinds of meat products and, as a result, to adopt a zero-tolerance policy for the presence of this deadly pathogen.

A USDA Baseline Data Collection Programme done in 1994 documented *Listeria* contamination on 15.0% of broiler-chicken carcasses. Subsequent USDA data collection did not test for the prevalence of *Listeria* in chicken or in turkeys.

LISTERIA TYPICALLY SPREADS TO PEOPLE THROUGH CONTAMINATED FOOD OR WATER, BUT CAN ALSO BE TRANSMITTED FROM MOTHER TO FETUS.

Except for the transmission of mother to fetus, human-to-human transmission of *Listeria* is not known to occur. Infection is caused almost exclusively by the ingestion of the bacteria, most often through the consumption of contaminated food. The most widely-accepted estimate of foodborne transmission is 85-95% of all *Listeria* cases.

The infective dose—that is, the amount of bacteria that must be ingested to cause illness—is not known. In an otherwise healthy person, an extremely large number of *Listeria* bacteria must be ingested to cause illness—estimated to be somewhere between 10–100 million viable bacteria (or colony forming units "CFU") in healthy individuals, and only 0.1–10 million CFU in people at high risk of infection. Even with such a dose, a healthy individual will suffer only a fever, diarrhea, and related gastrointestinal symptoms..

The amount of time from infection to the onset of symptoms—typically referred to as the incubation period—can vary to a significant degree. Symptoms of *Listeria* infection can develop at any time from 2 to 70 days after eating contaminated food. According to one authoritative text:

The incubation period for invasive illness is not well established, but evidence from a few cases related to specific ingestions points to 11 to 70 days, with a mean of 31 days. In one report, two pregnant women whose only common exposure was attendance at a party developed Listeria*bacteremia with the same uncommon enzyme type; incubation periods for illness were 19 and 23 days.*

Adults can get listeriosis by eating food contaminated with *Listeria*, but babies can be born with listeriosis if their mothers eat contaminated food during pregnancy. The mode of transmission of *Listeria* to the fetus is either transplacental via the maternal blood stream or ascending from a colonized genital tract. Infections during pregnancy can cause premature delivery, miscarriage, stillbirth, or serious health problems for the newborn.

Incidence of *Listeria* infection in HIV-positive individuals is higher than in the general population. One study found that:

The estimated incidence of listeriosis among HIV-infected patients in metropolitan Atlanta was 52 cases per 100,000 patients per year, and among patients with AIDS it was 115 cases per 100,000 patients per year, rates 65–145 times higher than those among the general population. HIV-associated cases occurred in adults who were 29–62 years of age and in postnatal infants who were 2 and 6 months of age.

Pregnant women make up around 30% of all infection cases, while accounting for 60% of cases involving the 10- to 40-year age group.

THE ELDERLY, PREGNANT WOMEN AND ANYONE IMMUNOCOMPROMISED IS MOST AT RISK FOR CONTRACTING LISTERIA.

Several segments of the population are at increased risk and need to be informed so that proper precautions can be taken. The body's defence against *Listeria* is called "cell-mediated immunity" because the success of defending against infection depends on our cells (as opposed to our antibodies), especially lymphocytes called "T-cells." Therefore, individuals whose cell-mediated immunity is suppressed are more susceptible to the devastating effects of listeriosis, including especially HIV-infected individuals, who have been found to have a *Listeria*-related mortality of 29%.

Pregnant women naturally have a depressed cell-mediated immune system. In addition, the immune systems of fetuses and newborns are very immature and are extremely susceptible to these types of infections. Other adults, especially transplant recipients and lymphoma patients, are given necessary therapies with the specific intent of depressing T-cells, and these individuals become especially susceptible to *Listeria* as well. According to the CDC and other public health organizations, individuals at increased risk for being infected and becoming seriously ill with *Listeria* include the following groups:

- *Pregnant women:* They are about 20 times more likely than other healthy adults to get listeriosis. About one-third of listeriosis cases happen during pregnancy.

- *Newborns:* Newborns rather than the pregnant women themselves suffer the serious effects of infection in pregnancy.
- Persons with weakened immune systems
- Persons with cancer, diabetes, or kidney disease
- *Persons with AIDS:* They are almost 300 times more likely to get listeriosis than people with normal immune systems.
- Persons who take glucocorticosteroid medications (such as cortisone)
- The elderly

THE INFECTION CAUSED BY LISTERIA CAN VARY FROM MILD TO SEVERE

When a person is infected and develops symptoms of *Listeria* infection, the resulting illness is called listeriosis. Only a small percentage of persons who ingest *Listeria* fall ill or develop symptoms. For those who do develop symptoms as a result of their infection, the resulting illness is either mild or quite severe, in what is sometimes referred to as a "bimodal distribution of severity."

On the mild end of the spectrum, listeriosis usually consists of the sudden onset of fever, chills, severe headache, vomiting, and other influenza-type symptoms. Along these same lines, the CDC notes that infected individuals may develop fever, muscle aches, and sometimes gastrointestinal symptoms such as nausea or diarrhea. When present, the diarrhea usually lasts 1-4 days (with 42 hours being average), with 12 bowel movements per day at its worst.

Most healthy adults and children who consume contaminated food experience only mild to moderate symptoms. The infection is usually self-limited, since, in healthy hosts, exposure to Listeria *stimulates the production of tumour necrosis factor and other cytokines, which activate monocytes and macrophages to eradicate the organism. Few people with normal immune function go on to have more severe, life-threatening forms of listeriosis, characterized by septic shock, meningitis and encephalitis.*

As already noted, when pregnant, women have a mildly impaired immune system that makes them susceptible to *Listeria* infection. If infected, the illness appears as an acute fever, muscle pain, backache, and headache. Illness usually occurs in the third trimester, which is when immunity is at its lowest. Infection during pregnancy can lead to premature labour, miscarriage, infection of the newborn, or even stillbirth. Twenty-two percent of such infections result in stillbirth or neo-natal death.

Newborns may present clinically with early-onset (less than 7 days) or late-onset forms of infection (7 or more days). Those with the early-onset form are often diagnosed in the first 24 hours of life with sepsis (infection in the blood). Early-onset listeriosis is most often acquired through trans-placental transmission. Late-onset neo-natal listeriosis is less common than the early-onset form. Clinical symptoms may be subtle and include irritability, fever and poor feeding. The mode of acquisition of late-onset listeriosis is poorly understood.

COMPLICATIONS OF LISTERIA INFECTION

Blood infection and meningitis are both complications of Listeria infection. Death is the most severe consequence of listeriosis.

For those persons who suffer a *Listeria* infection that does not resolve on its own, the complications (or *sequelae*) can be many. The most common is septicemia (bacterial pathogens in the blood, also known as bacteremia), with meningitis being the second most common. Other complications can include inflammation of the brain or brain stem (encephalitis), brain abscess, inflammation of the heart-membrane (endocarditis), and localized infection, either internally or of the skin.

Death is the most severe consequence of listeriosis, and it is tragically common. For example, based on 2009 FoodNet surveillance data, 89.2% of *Listeria*patients ended up in the hospital, the highest hospitalization rate for pathogenic bacterial infection. In persons 50 years of age and older, there was a 17.5% fatality rate—also the highest relative to other pathogens.

Listeria infection is diagnosed through blood or stool cultures. Spinal fluid can also be tested for Listeria.

Because there are few symptoms that are unique to listeriosis, doctors must consider a variety of potential causes for infection, including viral infections (like flu), and other bacterial infections that may cause sepsis or meningitis.

Early diagnosis and treatment of listeriosis in high-risk patients is critical, since the outcome of untreated infection can be devastating. This is especially true for pregnant women because of the increased risk of spontaneous abortion and preterm delivery. Depending on the risk group, rates of death from listeriosis range from 10% to 50%, with the highest rate among newborns in the first week of life.

Methods typically used to identify diarrhea-causing bacteria in stool cultures interfere or limit the growth of *Listeria*, making it less likely to be identified and isolated for further testing. On the other hand, routine methods are effective for isolating *Listeria* from spinal fluid, blood, and joint fluid. Magnetic-resonance imaging (MRI) is used to confirm or rule out brain or brain stem involvement.

TREATMENT FOR LISTERIA INFECTION

Listeria infections typically resolve without treatment, but antibiotics may be necessary to treat some cases.

Listeriosis is usually a self-limited illness—which means that a majority of infected individuals will improve without the need for medical care. But for those patients with a high fever, a stool culture and antibiotic-treatment may be justified for otherwise healthy individuals. Although there have been no studies done to determine what drugs or treatment duration is best, ampicillin is generally considered the "preferred agent." There is no consensus on the best approach for patients who are allergic to penicillins.

Invasive infections with *Listeria* can be treated with antibiotics. When infection occurs during pregnancy, antibiotics given promptly to the pregnant woman can often

prevent infection of the fetus or newborn. Babies with listeriosis receive the same antibiotics as adults, although a combination of antibiotics is often used until physicians are certain of the diagnosis.

MYCOTOXIN

A mycotoxin (from the Greek μυκης *mykes*, "fungus" and τοξικον *toxikon*, "poison") is a toxic secondary metabolite produced by organisms of the fungus kingdom and is capable of causing disease and death in both humans and animals. The term 'mycotoxin' is usually reserved for the toxic chemical products produced by fungi that readily colonize crops. One mold species may produce many different mycotoxins, and several species may produce the same mycotoxin.

PRODUCTION

Most fungi are aerobic (use oxygen) and are found almost everywhere in extremely small quantities due to the minute size of their spores. They consume organic matter wherever humidity and temperature are sufficient. Where conditions are right, fungi proliferate into colonies and mycotoxin levels become high. The reason for the production of mycotoxins is not yet known; they are not necessary for the growth or the development of the fungi. Because mycotoxins weaken the receiving host, the fungus may use them as a strategy to better the environment for further fungal proliferation. The production of toxins depends on the surrounding intrinsic and extrinsic environments and these substances vary greatly in their toxicity, depending on the organism infected and its susceptibility, metabolism, and defence mechanisms.

MAJOR GROUPS

Aflatoxins are a type of mycotoxin produced by *Aspergillus* species of fungi, such as *A. flavus* and *A. parasiticus*. The umbrella term aflatoxin refers to four different types of mycotoxins produced, which are B_1, B_2, G_1, and G_2. Aflatoxin B_1, the most toxic, is a potent carcinogen and has been directly correlated to adverse health effects, such as liver cancer, in many animal species. Aflatoxins are largely associated with commodities produced in the tropics and subtropics, such as cotton, peanuts, spices, pistachios, and maize.

Ochratoxin is a mycotoxin that comes in three secondary metabolite forms, A, B, and C. All are produced by *Penicillium* and *Aspergillus* species. The three forms differ in that Ochratoxin B (OTB) is a non-chlorinated form of Ochratoxin A (OTA) and that Ochratoxin C (OTC) is an ethyl ester form Ochratoxin A. *Aspergillus ochraceus* is found as a contaminant of a wide range of commodities including beverages such as beer and wine. *Aspergillus carbonarius* is the main species found on vine fruit, which releases its toxin during the juice making process. OTA has been labeled as a carcinogen and a nephrotoxin, and has been linked to tumors in the human urinary tract, although research in humans is limited by confounding factors.

Citrinin is a toxin that was first isolated from *Penicillium citrinum*, but has been identified in over a dozen species of *Penicillium* and several species of *Aspergillus*. Some of these species are used to produce human foodstuffs such as cheese (*Penicillium camemberti*), sake, miso, and soy sauce (*Aspergillus oryzae*). Citrinin is associated with yellowed ricedisease in Japan and acts as a nephrotoxin in all animal species tested. Although it is associated with many human foods (wheat, rice, corn, barley, oats, rye, and food coloured with Monascus pigment) its full significance for human health is unknown. Citrinin can also act synergistically with Ochratoxin A to depress RNA synthesis in murine kidneys.

Ergot Alkaloids are compounds produced as a toxic mixture of alkaloids in the sclerotia of species of *Claviceps*, which are common pathogens of various grass species. The ingestion of ergot sclerotia from infected cereals, commonly in the form of bread produced from contaminated flour, cause ergotism, the human disease historically known as St. Anthony's Fire. There are two forms of ergotism: gangrenous, affecting blood supply to extremities, and convulsive, affecting the central nervous system. Modern methods of grain cleaning have significantly reduced ergotism as a human disease, however it is still an important veterinary problem. Ergot alkaloids have been used pharmaceutically.

Patulin is a toxin produced by the *P. expansum*, *Aspergillus*, *Penicillium*, and *Paecilomyces* fungal species. *P. expansum* is especially associated with a range of moldy fruits and vegetables, in particular rotting apples and figs. It is destroyed by the fermentation process and so is not found in apple beverages, such as cider. Although patulin has not been shown to be carcinogenic, it has been reported to damage the immune system in animals. In 2004, the European Community set limits to the concentrations of patulin in food products. They currently stand at 50 µg/kg in all fruit juice concentrations, at 25 µg/kg in solid apple products used for direct consumption, and at 10 µg/kg for children's apple products, including apple juice.

Fusarium toxins are produced by over 50 species of *Fusarium* and have a history of infecting the grain of developing cereals such as wheat and maize. They include a range of mycotoxins, such as: the fumonisins, which affect the nervous systems of horses and may cause cancer in rodents; the trichothecenes, which are most strongly associated with chronic and fatal toxic effects in animals and humans; and zearalenone, which is not correlated to any fatal toxic effects in animals or humans. Some of the other major types of *Fusarium* toxins include: beauvercin and enniatins, butenolide, equisetin, and fusarins.

OCCURRENCE

Although various wild mushrooms contain an assortment of poisons that are definitely fungal metabolites causing noteworthy health problems for humans, they are rather arbitrarily excluded from discussions of mycotoxicology. In such cases the distinction is based on the size of the producing fungus and human intention. Mycotoxin exposure

is almost always accidental whereas with mushrooms improper identification and ingestion causing mushroom poisoning is commonly the case. Ingestion of misidentified mushrooms containing mycotoxins may result in hallucinations. The cyclopeptide-producing *Amanita phalloides* is well known for its toxic potential and is responsible for approximately 90% of all mushroom fatalities. The other primary mycotoxin groups found in mushrooms include: orellanine, monomethylhydrazine, disulfiram-like, hallucinogenic indoles, muscarinic, isoxazole, and gastrointestinal (GI)-specific irritants. The bulk of this chapter is about mycotoxins that are found in microfungi other than poisons from mushrooms or macroscopic fungi.

In Indoor Environments

Buildings are another source of mycotoxins and people living or working in areas with mold increase their chances of adverse health effects. Molds growing in buildings can be divided into three groups — primary, secondary, and tertiary colonizers. Each group is categorized by the ability to grow at a certain water activity requirement. It has become difficult to identify mycotoxin production by indoor molds for many variables, such as (i) they may be masked as derivatives (ii) they are poorly documented and (iii) the fact that they are likely to produce different metabolites on building materials. Some of the mycotoxins in the indoor environment are produced by *Alternaria*, *Aspergillus* (multiple forms), *Penicillium*, and *Stachybotrys*. *Stachybotrys chartarum* contains a higher number of mycotoxins than other molds grown in the indoor environment and has been associated with allergies and respiratory inflammation. The infestation of *S. chartarum* in buildings containing gypsum board, as well as on ceiling tiles, is very common and has recently become a more recognized problem. When gypsum board has been repeatedly introduced to moisture, *S. chartarum* grows readily on its cellulose face. This stresses the importance of moisture controls and ventilation within residential homes and other buildings. The negative health effects of mycotoxins are a function of the concentration, the duration of exposure and the subject's sensitivities. The concentrations experienced in a normal home, office or school are often too low to trigger a health response in occupants.

In the 1990s, public concern over mycotoxins increased following multimillion-dollar toxic mold settlements. The lawsuits took place after a study by the Center for Disease Control(CDC) in Cleveland, Ohio, reported an association between mycotoxins from *Stachybotrys* spores and pulmonary hemorrhage in infants. However, in 2000, based on internal and external reviews of their data, the CDC concluded that because of flaws in their methods, the association was not proven. *Stachybotrys* spores in animal studies have been shown to cause lung hemorrhaging, but only at very high concentrations.

One study by the Center of Integrative Toxicology at Michigan State University investigated the causes of Damp Building Related Illness (DBRI). They found that *Stachybotrys* is possibly an important contributing factor to DBRI. So far animal models

indicate that airway exposure to *S. chartarum* can evoke allergic sensitization, inflammation, and cytotoxicity in the upper and lower respiratory tracts. Trichothecene toxicity appears to be an underlying cause of many of these adverse effects. Recent findings indicate that lower doses (studies usually involve high doses) can cause these symptoms.

Some toxicologists have used the Concentration of No Toxicological Concern (CoNTC) measure to represent the airborne concentration of mycotoxins that are expected to cause no hazard to humans (exposed continuously throughout a 70–yr lifetime).

The resulting data of several studies have thus far demonstrated that common exposures to airborne mycotoxins in the built indoor environment are below the CoNTC, however agricultural environments have potential to produce levels greater than the CoNTC.

In Food

Mycotoxins can appear in the food chain as a result of fungal infection of crops, either by being eaten directly by humans or by being used as livestock feed.

In 2004 in Kenya, 125 people died and nearly 200 others were treated after eating aflatoxin-contaminated maize. The deaths were mainly associated with homegrown maize that had not been treated with fungicides or properly dried before storage. Due to food shortages at the time, farmers may have been harvesting maize earlier than normal to prevent thefts from their fields, so that the grain had not fully matured and was more susceptible to infection.

Spices are susceptible substrate for growth of mycotoxigenic fungi and mycotoxin production. Red chilli, black pepper, and dry ginger were found to be the most contaminated spices.

In Animal Food

There were outbreaks of dog food containing aflatoxin in North America in late 2005 and early 2006, and again in late 2011.

Mycotoxins in animal fodder, particularly silage, can decrease the performance of farm animals and potentially kill them. Several mycotoxins reduce milk yield when ingested by dairy cattle.

In Dietary Supplements

Contamination of medicinal plants with mycotoxins can contribute to adverse human health problems and therefore represents a special hazard. Numerous natural occurrences of mycotoxins in medicinal plants and herbal medicines have been reported from various countries including Spain, China, Germany, India, Turkey and from the Middle East. In a 2015 analysis of plant-based dietary supplements, the highest mycotoxin concentrations were found in milk thistle-based supplements, at up to 37 mg/kg.

HEALTH EFFECTS

Some of the health effects found in animals and humans include death, identifiable diseases or health problems, weakened immune systems without specificity to a toxin, and as allergens or irritants. Some mycotoxins are harmful to other micro-organisms such as other fungi or even bacteria; penicillin is one example. It has been suggested that mycotoxins in stored animal feed are the cause of rare phenotypical sex changes in hens that causes them to look and act male.

In Humans

Mycotoxicosis is the term used for poisoning associated with exposures to mycotoxins. The symptoms of mycotoxicosis depend on the type of mycotoxin; the concentration and length of exposure; as well as age, health, and sex of the exposed individual. The synergistic effects associated with several other factors such as genetics, diet, and interactions with other toxins have been poorly studied. Therefore, it is possible that vitamin deficiency, caloric deprivation, alcohol abuse, and infectious disease status can all have compounded effects with mycotoxins. In turn, mycotoxins have the potential for both acute and chronic health effects via ingestion, skin contact, and inhalation. These toxins can enter the blood stream and lymphatic system; they inhibit protein synthesis, damage macrophage systems, inhibit particle clearance of the lung, and increase sensitivity to bacterial endotoxin.

MITIGATION

Mycotoxins greatly resist decomposition or being broken down in digestion, so they remain in the food chain in meat and dairy products. Even temperature treatments, such as cooking and freezing, do not destroy some mycotoxins.

Removal

In the feed and food industry it has become common practice to add mycotoxin binding agents such as montmorillonite or bentonite clay in order to effectively adsorb the mycotoxins. To reverse the adverse effects of mycotoxins, the following criteria are used to evaluate the functionality of any binding additive:

- Efficacy of active component verified by scientific data
- A low effective inclusion rate
- Stability over a wide pH range
- High capacity to absorb high concentrations of mycotoxins
- High affinity to absorb low concentrations of mycotoxins
- Affirmation of chemical interaction between mycotoxin and adsorbent
- Proven *in vivo* data with all major mycotoxins
- Non-toxic, environmentally friendly component

Since not all mycotoxins can be bound to such agents, the latest approach to mycotoxin control is mycotoxin deactivation. By means of enzymes (esterase, de-epoxidase),

yeast(*Trichosporon mycotoxinvorans*), or bacterial strains (Eubacterium BBSH 797 developed by Biomin), mycotoxins can be reduced during pre-harvesting contamination. Other removal methods include physical separation, washing, milling, nixtamalization, heat-treatment, radiation, extraction with solvents, and the use of chemical or biological agents. Irradiation methods have proven to be effective treatment against mold growth and toxin production.

Regulations

Many international agencies are trying to achieve universal standardization of regulatory limits for mycotoxins. Currently, over 100 countries have regulations regarding mycotoxins in the feed industry, in which 13 mycotoxins or groups of mycotoxins are of concern. The process of assessing a need for mycotoxin regulation includes a wide array of in-laboratory testing that includes extracting, clean-up and separation techniques. Most official regulations and control methods are based on high-performance liquid techniques (*e.g.*, HPLC) through international bodies. It is implied that any regulations regarding these toxins will be in co-ordinance with any other countries with which a trade agreement exists. Many of the standards for the method performance analysis for mycotoxins is set by the European Committee for Standardization (CEN). However, one must take note that scientific risk assessment is commonly influenced by culture and politics, which, in turn, will affect trade regulations of mycotoxins.

Food-based mycotoxins were studied extensively worldwide throughout the 20th century. In Europe, statutory levels of a range of mycotoxins permitted in food and animal feed are set by a range of European directives and EC regulations. The U.S. Food and Drug Administration has regulated and enforced limits on concentrations of mycotoxins in foods and feed industries since 1985. It is through various compliance programmes that the FDA monitors these industries to guarantee that mycotoxins are kept at a practical level. These compliance programmes sample food products including peanuts and peanut products, tree nuts, corn and corn products, cottonseed, and milk. There is still a lack of sufficient surveillance data on some mycotoxins that occur in the U.S.

USE IN FICTION

A fictional use of a mycotoxin occurs in William Gibson's seminal novel *Neuromancer* (1984). A "Russian war-time mycotoxin" is administered to Case, the novel's protagonist.

Mycotoxins are used as the basis for the infection in the 2013 video game *The Last of Us* for the PlayStation 3 and its remastering for PlayStation 4. A warning sign in one of the abandoned cities in the game reads "MYCOTOXINS" with fine print seeming to list the signs and symptoms of the game's fictional human infection. (In reality, biological toxins, while poisonous, do not cause an "infection".)

FOOD MYCOTOXINS

Unavoidable, natural contaminants in foods may have either chemical or biological origin. Mycotoxins—toxic secondary metabolites of fungi—are biological in origin. Despite efforts to control fungal contamination, toxigenic fungi are ubiquitous in nature and occur regularly in worldwide food supplies due to mold infestation of susceptible agricultural products, such as cereal grains, nuts, and fruits. Thousands of mycotoxins exist, but only a few present significant food safety challenges. The natural fungal flora associated with foods is dominated by three genera—Aspergillus, Fusarium, and Penicillium, which except for the Fusarium plant pathogens, may include commensals as well as pathogens. The chemical structures of mycotoxins produced by these fungi are very diverse, as are the characteristics of the mycotoxicoses they can cause.

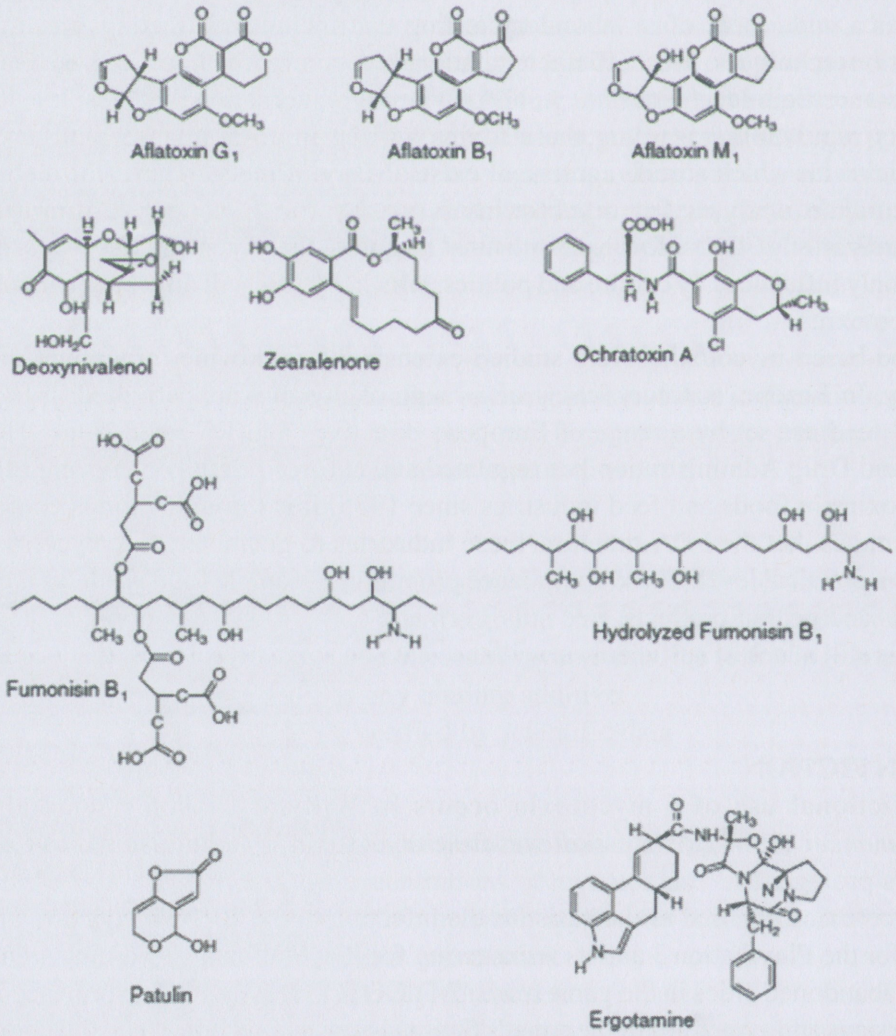


Fig. Chemical structures of mycotoxins found in foods

Ergotism is the oldest identified mycotoxicosis in humans. This mycotoxin represents a group of alkaloids that grow on the heads of grasses, such as wheat and rye. Ergot was responsible for a disease of the Middle Ages known as "St. Anthony's Fire," so named for the burning sensation caused in victims' limbs. The Spartans apparently suffered an ergot epidemic in 430 B.C. and European epidemics date back as far as 857 A.D.. Ergotism has also been associated with the Salem witch trials in the 1600s in Massachusetts. More recent outbreaks, associated with economic upheaval and war, have occurred in Russia, Ireland (1929), France (1953), and Ethiopia (1978). Although ergot poisoning continues to pose a challenge for the livestock industry, the toxin is less of a challenge for the food industry because current food quality control procedures screen out ergot-infected grains.

Of the thousands of existing mycotoxins, a few hundred are associated with food and only a handful present food safety challenges to the farm-to-fork food continuum. At the farm level, mold growth can result in reduced crop yields and livestock productivity stemming from illness or death due to consumption of contaminated feed. In food manufacturing, destruction of mycotoxins by conventional food processing is difficult because they are typically highly resistant and detection is complicated due to limitations in analytical methodology.

In the marketplace, mycotoxins can be a hurdle to international trade, leading to increased regulation of foods and feeds that may contain them and removal from the market of commodities not meeting regulatory limits.

Table. Guidance and regulations on mycotoxins in food and feed

Country/Region	Mycotoxin	Food/Feed	Action Level
United States	Patulin	Apple juice, apple juice concentrate, and apple juice products	50 ppb
	Fumonisin $B_1 + B_2 + B_3$	Dagermed dry milled corn products	2 ppm
		Whole or partially degermed dry milled corn products	4 ppm
		Dry milled corn bran	4 ppm
		Cleaned corn intended for mesa production	4 ppm
		Cleaned corn intended for popcorn	3 ppm
		Corn and corn by-products intended for:	
		Equids and rabbits	5 ppm
		Swine and catfish	20 ppm
		Breeding ruminants, poultry, and mink (includes lactating dairy cattle and hens laying eggs for human consumption)	30 ppm
		Ruminants ≥ 3-mo old being raised for slaughter and mink for pel production	60 ppm
		Poultry being raised for slaughter	100 ppm
		All other species or classes of livestock and pet animals	10 ppm

	Aflatoxin $B_1 + B_2 + G_1 + G_2$	Brazil nuts, pistachio nuts, peanuts, and peanut products	20 ppb
	Aflatoxin M_1	Milk	0.5 ppb
	Aflatoxin $B_1 + B_2 + G_1 + G_2$	Corn and peanut products intended for:	
		Finishing beef cattle	300 ppb
		Finishing swine ≥ 100 lb	200 ppb
		Breeding beef cattle, breeding swine, or mature poultry	100 ppb
		Corn, peanut products, and other animal feeds and feed ingrediments but excluding cottonseed meal, intended for immature animals	100 ppb
		Corn, peanut products, cottonseed meal, and other animal feed ingredients intended for dairy animals, for animal species, or when the intended use in unknown	20 ppb
		Cottonseed meal for beef cattle, swine, poultry	300 ppb
	DON	Finished wheat products	1 ppm
European Union	Ochratoxin A	Raw cereal grains	5 ppb
		All products derived form cereals	3 ppb
		Dried vine fruit (currants, raisins, sultanas)	10 ppb
	Patulin	Apple juice and other foods derived from apples	50 ppb
		Solid apple products, for example, purees, compotes	25 ppb
		Apple juice and soild apple products intended for infant foods	10 ppb
	Aflatoxin B_1	Spices (Capsicum and Piper spp., nutmeg, ginger, and turmeric)	5 ppb
	Aflatoxin $B_1 + B_2 + G_1 + G_2$	Spices (Capsicum and Piper spp., nutmeg, ginger, and turmeric)	10 ppb
	Aflatoxin B_1	Groundnuts, nuts, dried fruit, and processed products there of intended for direct consumption or as an ingredient	2 ppb

Table. Guidance and regulations on mycotoxins in food and feed

Country/Region	Mycotoxin	Food/Feed	Action Level
		Groundnuts to be subjected to sorting or other physical treatment before human consumption or use as ingredient	8 ppb
		Nuts and dried fruit to be subjected to sorting or other physical treatment before human consumption or use as ingredient	5 ppb
		Cereals and processed products thereof	2 ppb

		intended for direct consumption or as an ingredient	
	Aflatoxin $B_1 + B_2 + G_1 + G_2$	Groundnuts, nuts, dried fruit, and processed products thereof intended for direct consumption or as an ingredient	4 ppb
		Groundnuts to be subjected to sorting or other physical treatment before human consumption or use as ingredient	15 ppb
		Nuts and dried fruit to be subjected to sorting or other physical treatment before human consumption or use as ingredient	10 ppb
		Cereals and processed products thereof intended for direct consumption or as an ingredient	4 ppb
	Aflatoxin M_1	Milk (raw, for manufacture of milk-based products, and heat-treated)	0.05 ppb
Codex Alimentarius Commission	Patulin	Apple juice and apple juice ingredients in other beverages	50 ppb
	Aflatoxin $B_1 + B_2 + G_1 + G_2$	Peanuts intended for further processing	15 ppb
	Aflatoxin M_1	Milk	0.5 ppb

When present in foods in sufficiently high levels, these fungal metabolites can have toxic effects that range from acute (for example, liver or kidney deterioration), to chronic (for example, liver cancer), mutagenic, and teratogenic; and resulting symptoms range from skin irritation to immunosuppression, birth defects, neurotoxicity, and death. Aflatoxin B1 (AFB1), fumonisins, and patulin are suspected human carcinogens. Deoxynivalenol and other trichothecenes as well as AFB1 are likely to exert immunosuppressive effects, and fumonisin B1 (FB1) may contribute to neural tube defects.

Renal dysfunction due to ochratoxin A exposure (suspected in Balkan endemic nephropathy) is also a potentially significant problem, especially as this could exacerbate impaired renal function in individuals with diabetes, a burgeoning worldwide epidemic that is highly likely to grow. There is also uncertainty related to the effects of chronic, low-level, long-term exposure to single and/or multiple mycotoxins, which may be the case even for those individuals consuming a diverse diet (Lopez-Garcia and others 1999).

Environmental factors affect mycotoxin presence in raw and stored commodities. Data on optimal temperature and water activity for toxin production by Aspergillus, Penicillium, and Fusarium spp. in culture are provided in Table 2. Traditionally, control of mycotoxin contamination of foods has been attempted through control of water activity, pH, and quality control of incoming ingredients. Novel control avenues are emerging, including availability of genetically modified grains with increased insect

resistance and, thus, lowered rates of fungal infection; improved management of grain ingredients; and inclusion of controls for mycotoxins in food manufacturing Hazard Analysis and Critical Control Point (HACCP) plans.

Table. Examples of optimal conditions for mycotoxin production

Microorganism (mycotoxin)	Temp (°C)	A_w
Aspergillus flavus, A_1 parasiticus (aflatoxin)	33	0.99
Aspergillus ochraceus (ochratoxin)	30	0.98
Penicillium verrucosum (ochratoxin)	25	0.90 to 0.98
Aspergillus carbonarius (ochratoxin)	15 to 20	0.85 to 0.90
Fusarium verticilloides, F_1 proliferatum (fumonisin)	10 to 30	0.93
Fusarium verticillioides, F. proliferatum (DON)	11	0.90
Fusarium graminearum (zearalenone)	25 to 30	0.98
Penicillium expansum (patulin)	0 to 25	0.95 to 0.99

[a]The majority of data generated on environmental optima for mycotoxin production was obtained from cultures rather than actual field or storage environments.

Genotyping techniques have shed new light on mycotoxin-producing fungi and provided the foundation for advances in detection methodology. Historically, fungi have been identified on the basis of traditional taxonomic characteristics (for example, morphological features); more recently, the tools of molecular biology have enabled genetic analysis and classification on the basis of nucleic acid sequence. Since analytical methods for detecting mycotoxins have become more prevalent, sensitive, and specific, surveillance of foods for mycotoxin contamination has become more common. Information from surveys that have been conducted around the world with a diversity of mycotoxins detected.

This Scientific Status Summary addresses mycotoxins on the basis of key characteristics or scientific advances unique to each toxin. Since the publication of the previous Summary (IFT 1986) on this topic, a new type of mycotoxin—the fumonisins—produced by Fusarium spp. has been isolated, and much has been accomplished in the areas of toxicology, detection, and control of mycotoxins. This Summary focuses on the scientific advances made after 1986.

MYCOTOXINS IMPACTING FOOD PRODUCTION AND MANUFACTURING

PATULIN

Apricots, grapes, peaches, pears, apples, olives, cereals, and low-acid fruit juices (notably apple, grape, and pear) are the commodities most commonly infected by the pathogens that produce patulin. Patulin is not found in intact fruit because it is damage to the surface of fruit that makes it vulnerable to Penicillium infection (Sewram and

others 2000). Thus, the critical point for controlling fruit quality is the point at which the fruit enters the processing line.

Recent studies have determined that patulin is not carcinogenic, thereby causing a decline in research interest (Wouters and Speijers 1996). Hence, most of the patulin toxicity research conducted since 1995 has focused on genotoxicity.

Historically, apple juice has been a product of high concern with regard to patulin contamination. Therefore, many of the investigations on patulin stability during food processing have focused on apple juice. Bissessur and others (2001) reported that filtration to clarify juices and concentrates reduced patulin levels up to 40%. Lipowska (1990) observed that patulin was unstable during fermentation of apple juice to cider and was completely destroyed by treatment with 0.125% sulfur dioxide. However, findings pertaining to the effect of heat on the toxin vary. Although Woller and Majreus (1982) reported no loss of patulin in thermal processing of apple juice, Wheeler and others (1987) reported partial patulin destruction using high temperature-short time pasteurization, and Kadakal and Nas (2003) reported a 25% loss in naturally contaminated apple juices during pasteurization or evaporation conditions (70 to 100 °C). It is thought that the pH of the apple juices lends heat stability to patulin, accounting for the variability in results. Because of this, it is important to assess the effectiveness of conditions specific to each process before implementing a process control measure.

OCHRATOXIN

Ochratoxin is present in a large variety of foods because it is produced by several fungal strains of the Penicillium and Aspergillus species that have varied physiologies and ecologies. The presence of chlorine in its structure makes it unique. Ochratoxin is considered to be nephrotoxic, teratogenic, and immunotoxic, and has been classified by the IARC as a Class 2B carcinogen, probable human carcinogen.

Ochratoxin A, the main toxin in this group, is found in wheat, corn, and oats having fungal infection and in cheese and meat products of animals consuming ochratoxin-contaminated grains (Aish and others 2004). A. ochraceus is found on dry foods such as dried and smoked fish, soybeans, garbanzo beans, nuts, and dried fruit. A. carbonarius is the major pathogen in grapes and grape product including raisins, wines, and wine vinegars. Although reported to occur in foods around the world, the main regions of concern are Europe and, for some foods, Africa. The Joint Expert Committee on Food Additives of the Food and Agriculture Organization of the United Nations and the World Health Organization presented data indicating that cereals, wine, grape juice, coffee, and pork are the major sources of human ochratoxin exposure, at levels of 58%, 21%, 7%, 5%, and 3% of total ochratoxin intake, respectively. Levels reported range from 100 to 700 ng/kg in cereals, 30 to 9000 ng/L in European wines, 170 to 1300 ng/kg in coffee, and 150 to 2900 ng/kg in pork (Sage and others 2004). Ochratoxin presence in European wines is a relatively recent concern, with red wines typically containing higher ochratoxin levels than rosé or white wines.

Because of the large variety of food matrices in which ochratoxin has been found, there is no universally suitable method of analysis. Differences in extraction conditions and clean-up are as varied as the foods. Analysis is typically accomplished by high performance liquid chromatography, although liquid chromatography—mass spectrometry— is an important secondary confirmation technique.

The impact of processing on ochratoxin A-contaminated foods is not very well understood. Polishing and milling of wheat (to remove outer layers for white flour production) lowered ochratoxin levels; however, no effect was seen for whole-wheat flours. Chelkowski and others (1981) reported equal distribution of ochratoxin A into the bran and flour fractions upon dry milling of wheat and barley. Van der Stegen and others (2001) reported that ochratoxin was relatively stable during heat processing; however, toxin levels were reduced 70% to 96% during coffee bean roasting, and Heilmann and others (1999) reported similar reductions during decaffeination. Wet milling of corn resulted in reductions of ochratoxin levels in germ and grits of 96% and 49%, respectively. And McKenzie and others (1997) reported that ozonolysis is effective in destroying ochratoxin in aqueous model systems.

ZEARALENONE

A myco-estrogen, zearalenone, has attracted recent attention due to concerns that environmental estrogens have the potential to disrupt sex steroid hormone functions. Occasional outbreaks of zearalenone mycotoxicosis in livestock are known to cause infertility. Alternatively, derivatives of zearalenone are used in some livestock feeds for growth promotion (for example, Ralgro® in beef cattle), as alternatives to the more potent and controversial synthetic estrogen, diethylstilbestrol.

This toxin is found almost entirely in grains and in highly variable amounts ranging from a few nanograms per gram to thousands of nanograms per gram. The appearance of mold on grain plants cannot be relied upon to warn of toxin production because Fusarium-infected grain does not necessarily appear visibly moldy in the presence of high concentrations of mycotoxins. The average human intake of zearalenone was estimated to be approximately 0.02 μg/kg bw/d on the basis of limited data obtained in Canada, the United States, and Scandinavian countries, but it is likely that intakes are greater in countries from the regions of the world having less well-controlled grain storage systems.

Genotoxicity is a reported concern with respect to zearalenone. Although this estrogenic compound showed no mutagenicity in Ames tests (1 to 500 μg zearalenone/agar plate), the substance induced chromosomal anomalies in some lymphocyte, oocyte, and kidney cell cultures when present within a range of 0.1 to 20 μM. This dose range is difficult to extrapolate to likely human exposures because no human bioavailability estimates are available. With estimated human intake of approximately 1 to 2 μg per person, however, occurrence of blood or tissue concentrations remotely close to 0.1 M (approximately 30 μg/L) seems extremely unlikely.

A related fungal metabolite, α-zearalenol, which has about 3-fold more estrogenic potency than zearalenone, was recently shown to inhibit atherogenesis, lowering plasma LDL-cholesterol and limiting aortic plaque formation in ovariectomized rabbits fed a high dose of cholesterol. The effective estrogenic dose of μ-zearalenol was >0.5 mg/kg/d for 12 wk. Except as a potential pharmaceutical, such a large dose is of little practical value. Common human exposure levels for zearalenone or related compounds would not be expected to exert such health benefits.

AFLATOXINS

Aflatoxins may contaminate many crops including peanuts, corn, cottonseed, Brazil nuts, pistachios, spices, copra (dried coconut), and figs with widespread contamination in hot and humid regions of the world. These mycotoxins occur in several chemical forms, designated aflatoxin B_1, B_2, G_1, G_2, and M_1. "B" and "G" refer to the blue or green fluorescence observed upon exposure of the toxin to ultraviolet irradiation. M_1 is the predominant metabolite of AFB1 in milk from lactating humans and animals that consume AFB1-contaminated food or feed. According to the IARC, there is sufficient evidence to conclude that AFB1 and mixtures of B_1, G_1, and M_1 are proven human carcinogens, thereby warranting Group 1 carcinogen status. M_1 and B_2 are designated as Group 2B probable human carcinogens.

AFB1 is metabolized by the liver through the cytochrome P450 enzyme system to the major carcinogenic metabolite AFB1-8,9-epoxide (AFBO), or to less mutagenic forms such as AFM1, Q1, or P1. There are several pathways that AFBO can take, one resulting in cancer, another in toxicity, and others in AFBO excretion. The exo-form of AFBO readily binds to cellular macromolecules including genetic material, for example, proteins and DNA, to form adducts. It is the formation of DNA-adducts, such as with N7-guanine, that leads to gene mutations and cancer. One such mutation is suspected to occur in the human p53 tumor suppression gene at codon 249 (AGG, Eaton and Gallagher 2004). Studies have shown that AFBO induces conversions from G (guanine) to T (thymine) at the 3rd nucleotide of the codon, making it a mutational "hotspot." This mutation has been found with greater frequency among patients with hepatocellular carcinomas in areas of high-risk aflatoxin exposure. The AFB1-N7-guanine adduct is excreted in the urine of those infected. Urinary excretion not only serves as evidence that humans have the necessary biochemical pathways for carcinogenesis, but also provides a reliable biomarker for exposure to AFB1.

Inhibition of AFBO formation (through disruption of the cytochrome P450 system) and/or adduct formation are important strategies for prevention of these damaging mutations. In animal models, metabolic detoxification of AFBO is facilitated by induction of glutathione S-transferase (GST). This enzyme catalyzes the reaction that binds glutathione to AFBO and renders it non-carcinogenic. It is interesting to note that mice, which are resistant to aflatoxin carcinogenesis, have GST activity levels 3 to 5 times higher than rats, which are susceptible—and humans have lower GST activity than

rats. Synthetic dithiolthione compounds, such as oltipraz (an FDA approved antischistosomal drug), and antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and ethoxyquin, are among the most effective against aflatoxin carcinogenesis (Bammler and others 2000, IARC 1993a, b, Kwak and others 2001).

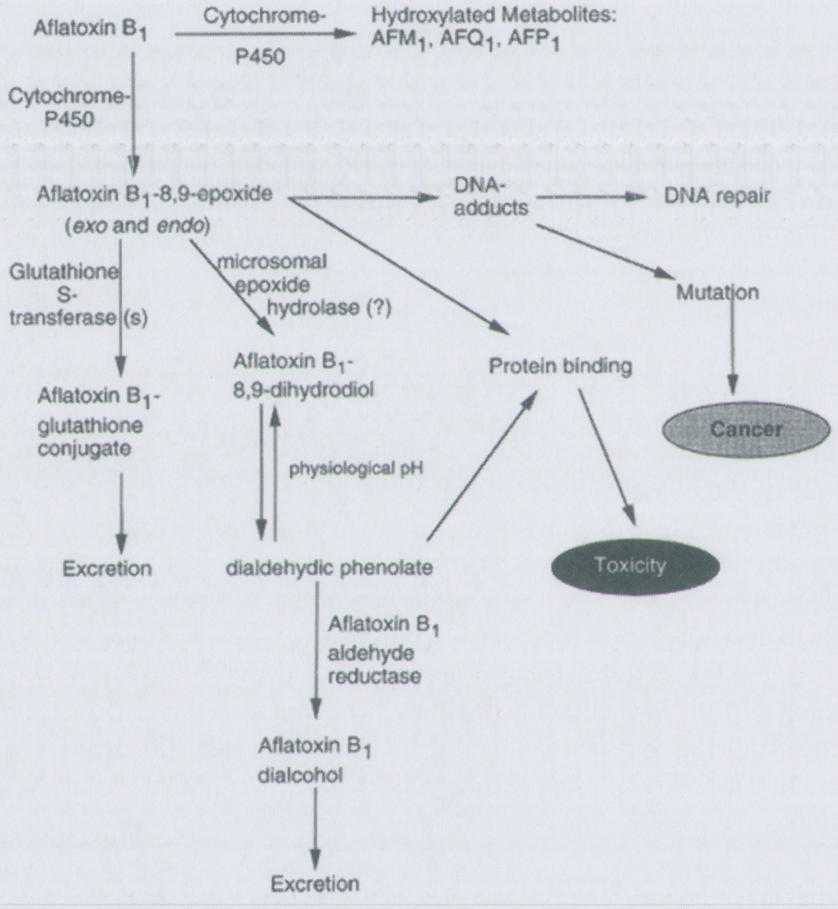


Fig. Overview of biotransformation pathways for aflatoxin B_1

Human clinical trials in China showed that a daily dose (125 mg/d) of oltipraz significantly increased excretion of AFB1-mercapturate, a derivative of GST reaction with AFB1 (Kwak and others 2001); chlorophyllin has also been shown to protect against human AFB1 toxicity. It remains to be seen if long-term administration of oltipraz could lessen human risk for AFB1 carcinogenesis; reduction of aflatoxin intake, however, would result in reduced liver cancer rates.

Simultaneous hepatitis B and AFB1 infections commonly occur in regions with high rates of hepatocellular carcinoma (HCC). A cohort study of more than 18000 individuals in China clearly showed a relative risk (measure of how much a particular risk factor [for example, AFB1] influences the risk of a specified outcome [for example, HCC])

for HCC of 3.4 in subjects who showed AFB1 exposure (urinary AFB1-N7-guanine; due to AFB1 exposure, a person is 3.4 times more likely to develop HCC), whereas relative risk for subjects positive for hepatitis B antigen was 7.3; combination of hepatitis B and AFB1 exposure increased relative risk for HCC to 59 (Qian and others 1994). Thus, AFB1 is an independent and possibly strongly potentiating factor for human HCC.

Human aflatoxicoses continue to be an occasional, serious problem. For example, a severe outbreak was reported in Kenya in 2002 (CDC 2004). Half of the maize food samples tested in districts associated with this outbreak had AFB1 levels >20 ppb (the action level for AFB1 in Kenya), with 3% to 12% of samples, depending on the district, containing >1000 ppb and some samples containing as much as 8000 ppb AFB1. This outbreak had at least a 39% incidence of death (317 cases with 125 deaths) resulting from acute hepatotoxicity.

Immunotoxicity seems a likely effect of human AFB1 exposure due to the numerous animal studies in which lymphocyte (T-cell, macrophage, natural killer cell, and B-cell) immune functions were suppressed or perturbed by this mycotoxin. Immunoglobulin A (IgA) response to some vaccine challenges was suppressed in Gambian children with detectable AFB1-albumin adducts (a complex formed between the toxin and the biological material, in this case a protein, that may either be repaired or mutate, in which case it could lead to cancer as discussed above). Decreased human growth was associated with increasing AFB1-albumin adduct formation in African children. Vitamin A and zinc status were not related to AFB1 exposure. This suggests that AFB1 exacerbates protein calorie malnutrition and thereby growth suppression; suppressed immune function is a likely correlate to AFB1 infection.

Some food processing methods have been shown to result in reduction or elimination of aflatoxins. Roasting peanuts resulted in greater reductions of chemically detectable aflatoxins than boiling (Njapau and others 1998). Fermentation of wheat flour dough reduced detectable aflatoxin by approximately 50%, while baking of the dough resulted in lesser reductions ranging from 0 to 25% (Scott 1991). Traditional non-alkaline toasting and boiling processes to produce pinole (a meal of ground corn and beans) from aflatoxin-contaminated corn were reported to significantly reduce chemically detectable aflatoxin (Mendez-Albores and others 2004a). High-temperature (121 °C) alkaline treatment of contaminated corn prior to frying resulted in very low levels of chemically detectable aflatoxin (Camoou-Arriola and Price 1989). Alkaline processing or nixtamalization (the traditional process of cooking corn in lime water to produce nixtamal that is then ground to form masa) of corn also resulted in significant reductions of aflatoxin. Although Cazzaniga and others (2001) reported that extrusion processing (up to 180 °C) of corn did not achieve substantial destruction of aflatoxin, Cheftel (1989) reported significant reductions in detectable aflatoxin during extrusion of rice flours; differences in results may be due to differences in extruder design. McKenzie and others (1997) reported that treatment with ozone destroyed AFB1 and G1 in aqueous model systems; and Prudente

and King (2002) reported 92% reduction in contaminated corn, with no reformation of the mycotoxin post-treatment. There are reports of reformation or reactivation of aflatoxins postprocess. For example, initial loss of detectable aflatoxin was followed by detection upon acidification of the masa flour. The researchers speculated that this acidification could happen after consumption of nixtamalized aflatoxin-contaminated corn (Mendez-Albores and others 2004b).

TRICHOTHECENES

Approximately 180 trichothecenes are known to exist, but only a few are significant to human health. This Summary focuses on deoxynivalenol (DON), the most prevalent of the trichothecenes in human foods, although related mycotoxins such as 3-acetyl DON, T-2 toxin, and nivalenol also occur with some regularity. The biosynthetic pathway for trichothecene production is known for several Fusarium species (Desjardins and others 1993); 11 genes involved in the trichothecene pathway have been cloned. These findings allow researchers to pursue traditional plant breeding and transgenic approaches to mycotoxin control.

Inhibition of protein synthesis is thought to be the fundamental mechanism of trichothecene toxicity. Ehrlich and Daigle (1987) showed that DON and T-2 toxin caused polyribosomal breakdown in mammalian cell lines. 3-acetyl DON had similar lethality to DON in vivo because it was converted to DON; however, the addition of a hydroxyl group at the C-4 position, as in nivalenol, decreased lethal dose in mice by 6-fold compared with DON (Thompson and Wannemacher 1986).

More recently, elucidation of DON toxicity mechanisms has focused on differential responses of mRNA and translation products following DON exposure of mice. Cell signaling pathways are activated by 1 mg DON/kg bw, through gene induction and activation of several nitrogen-activated protein kinases. DON ($\geq$ 100 ng/mL) activates hematopoetic cell kinase and double-stranded RNA-activated protein kinase, which leads to apoptosis (programmed cell death). The way in which symptoms relate to these molecular events remains to be clarified. Numerous studies have shown that DON is immunotoxic in animal models. Host resistance assays offer the most definitive assessment of such effects. Male BALB/c mice given 2 ppm DON (in water) 2 wk prior to and concurrent with oral intubation of Salmonella enteritidis (3 $\times$ 106 CFU) had increased bacterial counts postinfection, indicating that their immune systems were repressed by DON exposure. Although human DON exposure may be within the range of doses shown to be immunotoxic in rodents, human exposures and responses to this toxin are ill defined. Meky and others (2003) showed that a small number of urine samples from humans in a high risk region (with greater wheat and corn food intake) had 37 ng DON/mL (14 to 94 ng/mL range), whereas samples from a low-risk region had 12 ng DON/mL (4 to 18 ng/mL range), a significant difference.

Several thousand people were affected by gastrointestinal distress in an incident in the Kashmir Valley of India in 1987. Ninety-seven reported feelings of fullness and

mild to moderate abdominal pain within 15 min to 1 h after consuming their breakfast or evening snack (consisting of locally produced or homemade wheat bread). Other reported symptoms included throat irritation (63%), diarrhea (39%), vomiting (7%), blood in the stools (5%), and facial rash (2%). Increased incidence of upper respiratory tract infections was reported in children who had consumed the wheat bread for more than a week. Illnesses subsided when consumption of the bread ceased. Samples of flours and wheat in the local markets contained DON (11/17 had toxin levels of 0.346 to 8.38 μg/g), nivalenol (2/19 had levels of 0.03 to 0.1 μg/g), T-2 toxin (4/19 had levels of 0.55 to 4 μg/g), and 3-acetyl DON (4/19 had levels of 0.6 to 2.4 μg/g), but were negative for aflatoxins and ergot alkaloids. These results provide solid evidence for the potential health implications of fairly low exposure to the toxin and emphasize the need for more work to define human risk from this common foodborne contaminant. The need to define the role of DON in impairment of human immune function is further emphasized given the growing number of epidemics of severe infectious illnesses (for example, HIV) and world population of immune-impaired individuals (young children and the elderly).

Two AOAC® Official Methods—thin layer and gas chromatography (GC) assays—exist for DON quantification. High-performance liquid chromatography methods have been peer-reviewed, but are not yet approved by AOAC International. Despite the availability of approved methods, variability in sampling and testing procedures presents difficulties for precise determinations. Inexpensive, rapid assays for DON are not standardized or widely available. Development of molecular imprint polymer technology for DON detection is promising in that once the polymer matrix is formed, it may be regenerated by solvent washing and used repeatedly, compared with immunoaffinity columns, which cannot be regenerated. Because prevention of DON contamination seems highly unlikely, and detoxification methods, discussed below, are far from practical at this point, DON detection deserves greater attention within the food science community.

The Council for Agricultural Science and Technology estimated that the annual US cost due to DON contamination of human food crops is $637 million. The CAST model included 727 samples of wheat and corn foods from data gathered from FDA and private surveys conducted during 1995 to 1997. Food losses were based on samples with >1 μg/g DON. DON contamination was greater than 1 μg/g in 6.9% of corn samples and 12.4% of wheat samples.

Edwards (2004) reviewed the environmental conditions that favour DON accumulation in food crops. Minimal tillage, nitrogen fertilizers, application of azoxystrobin (fungicide) or glyphosate (herbicide), and production of grains where maize had been grown the previous year were the main risk factors associated with increased DON accumulation. Biological and insect control shows promise, in laboratory environments, for reducing DON contamination levels, but little or no progress has been made in the field.

Current food processing techniques do not significantly contribute to DON remediation, either by reduction or detoxification, in human or animal foods. The combination of high pH (10.0) and high heat (100 °C for 60 min and 120 °C for 30 min) treatment of DON in an aqueous buffer solution produced partial to complete destruction. Treatment of wheat and corn with approved food additives, such as dry and aqueous sulfite gas and ozone, has also been investigated.

Aqueous sodium bisulfite had the greatest reductive effect by reaction with DON to produce acid-stable sulfonate adduct (DON-S); however, this adduct was hydrolyzed to release DON under alkaline conditions. Upon bread baking, the toxin levels increased by 50 to 75% due to alkaline hydrolysis of the DON sulfonate adduct. DON levels in corn were reduced by as much as 95% by autoclaving at 121 °C for 1 h with 8.33% aqueous sodium bisulfite. This corn was mixed with a basal diet and fed successfully to pigs, indicating that this treatment may be a viable option depending on the end use of the contaminated grain.

Removing DON from feed barley by an abrasive dehulling (pearling) process was shown to significantly reduce toxin levels. Naturally contaminated (at various levels) barley was pearled for 15 s to consistently leave 34% of the initial concentration of the toxin and 85% of the grain mass. Longer treatment resulted in significant grain losses, but suitable scale-up remains a hurdle to commercial feasibility. Grain milling partitioned DON (and zearlenone) to the various kernel fractions (bran > shorts > flour). Zearlenone was reduced below 1 ppm in all of the 27 flour samples; however, 3 of 27 flour samples contained DON levels greater than 1 ppm. FDA advisory information suggests that DON levels above 1 ppm are not acceptable for use in products for human consumption. Reduction effectiveness depended upon the extent of penetration of the fungi into the kernel (Trigo-Stockli and others 1996), thereby limiting the practical implications of this method to control DON levels in milled products. Other methods investigated without success include alkaline processing and high temperature (autoclaving) and high pressure processing (extrusion). Ultimately, continued vigilance is necessary to screen potentially contaminated grains and properly dispose of lots with DON levels higher than allowed for specific purposes.

FUMONISINS

Fumonisins are produced by the maize pathogens, Fusarium verticillioides (formerly F. moniliforme) and F. proliferatum, and at very low levels by Alternaria in black end stem rot in tomatoes, asparagus, and garlic. Maize-containing foods are the major fumonisin concern for the food industry. At least 15 related fumonisin compounds have been identified; the fumonisin B (FB) group is predominant. The Fusarium species comprise a very complicated genus. Traditional phenotypic taxonomy based on morphology of the Fusarium species can be done by well-trained specialists; because the morphology of many of the species is very similar and leads to misidentification, this approach has its limitations, however.

The fumonisins are highly water-soluble and unlike all other food mycotoxins because they do not have an aromatic structure or a unique chromophore for easy analytical detection. They are primary amines (carbon group substitution at only 1 of the 3 bonding positions) with 2 tricarballylic groups, which contribute to their water-solubility. Study of metabolic pathways is in progress. Fumonisin synthesis is known to involve acetate precursors and alanine and several of the genes involved in fumonisin synthesis have been identified as a cluster on chromosome 1 in F. verticillioides.

Fumonisin B1 (FB1) is the agent responsible for leukoencephalomalacia (related to necrotic lesions in the cerebrum) in horses and pulmonary edema in swine. Hepatotoxicity (liver damage) and nephrotoxicity (kidney damage) have also been reported in connection with fomonisin intoxication. Equine leukoencephalomalacia was reported in horses in veterinary medical literature in 1902, but the causative agents were not understood until 1990. Several major outbreaks of these diseases were reported in 1989 and 1990 in the United States when the concentration of fumonisins in midwestern maize was quite high. The fumonisins are weakly carcinogenic among different rodent species (Gelderblom and others 1993, Voss and others 1995) and are probable human carcinogens, associated with increased incidence of esophageal cancers in South Africa and China (IARC 1993a, b). Marasas and others (2004) suggested that fumonisin consumption is a risk factor in neural tube and related birth defects. Fumonisins are known to disrupt sphingolipid concentrations and synthesis, which may explain the different etiologies of fumonisin toxicity in livestock, experimental animals, and humans. Altered plasma sphingosine/sphinganine (blood serum compounds) ratios serve as biomarkers of fumonisin exposure.

Fumonisin content in the US corn was relatively high between 1988 and 1991, but has been low (<0.5 µg/g) in recent years. There are a few reports of high fumonisin levels (up to 150 µg/g) in homegrown corn consumed in China and South Africa. Most commercial foods, however, contain 500 ng/g or less due to low fumonisin levels in corn and ingredient quality control.

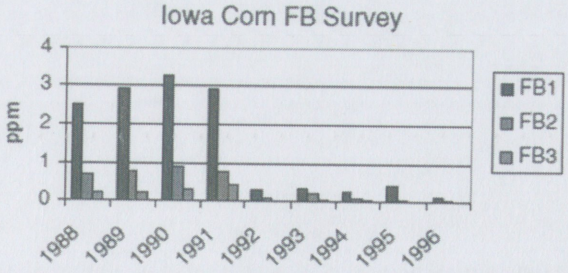


Fig. Fumonisin concentrations in ppm (ig/g) in Iowa corn elevator samples during 1988 to 1996

Grain sorting and sizing has not been shown to reduce fumonisin levels in corn. Although corn screenings (small broken pieces of corn kernels) are partly the result of fungal action on the kernels, removal of the screenings did not significantly reduce fumonisin levels. Because screenings can account for up to 25% of the corn in commerce,

this approach for reducing fumonisin levels is not economically viable either. Wet milling of contaminated corn (to produce starch) partitioned fumonisins to all fractions (gluten > fibre > steep water > germ) except the starch fraction. Fraction yields were not different between fumonisin-contaminated corn and the control. Dry milling of contaminated corn partitioned fumonisin to all fractions, with the bran (pericarp) containing the highest levels (bran > germ > flour > flaking grits) for white, yellow, and blue corn. If levels are reduced sufficiently, the corn may be subjected to decontamination and/or used in lower-risk products.

Fermentation of fumonisin-contaminated corn to produce ethanol resulted in reduced ethanol yields and did not significantly degrade the toxin. However, distillation of the ethanol resulted in a fumonisin-free alcohol with fumonisins remaining in the distillers' solids. Ozonolysis of FB resulted in conversion to 3-keto-FB; however, toxicity was not reduced. Ammoniation has also been investigated without success; treatment of FB-containing culture material did not reduce its toxicity to rats.

The effects of a variety of heat/chemical processing operations on fumonisin content have been investigated and the fumonisins have proven extremely stable. Jackson and others (1996) investigated stability of 5 ppm in aqueous model systems at pH 4, 7, and 10. They found that FB was most stable under neutral conditions and least stable at pH 4; however, at temperatures above 175 °C FB content was reduced by over 90% regardless of pH, suggesting that high temperature processing may be effective against FB in some instances. However, gaps remain in our understanding of thermal effects due to reactions of other food ingredients with the putative toxic structural moiety of fumonisin, the primary amine group. The primary amine group is key to detection in chromatographic and immunological analytical methods and can be derivatized with acids and/or react with reducing sugars (Maillard reaction) during heat processing, preventing these forms from being detected. The amine group can readily participate in non-enzymatic browning with a variety of reducing sugars and produces an array of typical Maillard products and FB-glucose and FB-fructose adducts, which have been shown to be non-carcinogenic in rat studies (Lu Z and others 1997, Liu and others 2001, Lu Y and others 2002) and lacking acute toxicity in swine studies (Fernandez-Surumay and others 2005). Fumonisin concentrations are lowered during extrusion processing and the remaining low levels of Maillard reaction products are thought to be detoxified because naturally occurring N-acetyl-fumonisin was shown to be non-toxic, and it is presumed that the fumonisin-glucose adducts are likewise non-toxic.

Further investigations of heat application to reduce FB levels included baking and frying, both of which were shown to produce some reduction in fumonisin levels. Corn-based batter was baked (to make muffins) at 175 °C and 200 °C for 20 min, reducing FB levels by approximately 15% to 30%, with increasing losses as temperature increased. Losses were greatest at the surface of the muffins, which was attributed to greater heat penetration as the baking temperature was raised. Frying of masa (to make chips) at temperatures up to 170 °C for 6 min did not produce significant FB losses; frying at 190 °C

for 15 min was required to reduce FB levels by 67%. A more recent study revealed up to 80% reduction in production of fried corn chips; very little of this reduction was the result of frying, however; reduction was due to nixtamilization and rinsing.

Alkaline processing has been shown to be effective in reducing fumonisin levels and activity. The ester bonds of FB are hydrolyzed to release its tricarballylic groups and yield aminopentol. Overall levels of both FB and hydrolyzed fumonisin (HFB) were reduced approximately 50% by the traditional nixtamilization process; however both FB and HFB remained in the masa and cooked tortillas in a 1:1 mol/L ratio, suggesting that the cooking, steeping, and rinsing process was effective in reducing toxin content, but that baking to produce tortillas did not result in further reduction. Other studies of this process (pilot, commercial, and traditional scale processes) have yielded some variation to these results, but most of all exhibited significant reduction of toxicity. HFB is more bioavailable than fumonisin, but less toxic to mice and rats (Hendrich and others 1993, Voss and others 1998); masa production, therefore, is capable of significantly reducing toxicity of fumonisins.

CO-CONTAMINATION

In addition to add to the complex nature of mycotoxin contamination, there is also the possibility for multiple toxins to be present in the same plant. Various combinations of the above compounds have been identified, with work by Lopez-Garcia (1998) indicating that their behaviour in such cases is altered. Information on co-contamination is limited, thereby elevating the challenge faced throughout the farm-to-fork continuum.

MYCOTOXIN CONTROL STRATEGIES

The preceding sections contained discussions of potential chemical and physical (processing) measures to control mycotoxin contamination of foods and food products.

GOOD AGRICULTURAL PRACTICES (GAPS)/GOOD MANUFACTURING PRACTICES (GMPS)

The first line of defence against the introduction of mycotoxins is at the farm level and starts with implementation of good agricultural practices to prevent infection. Preventive strategies should be implemented from pre- through postharvest. Preharvest strategies include maintenance of proper planting/growing conditions (for example, soil testing, field conditioning, crop rotation, irrigation), antifungal chemical treatments (for example, proprionic and acetic acids), and adequate insect and weed prevention. Harvesting strategies include use of functional harvesting equipment, clean and dry collection/transportation equipment, and appropriate harvesting conditions (low moisture and full maturity). Postharvest measures include use of drying as dictated by moisture content of the harvested grain, appropriate storage conditions, and use of transport vehicles that are dry and free of visible fungal growth. While implementation of these

precautions go a long way towards reducing mycotoxin contamination of foods, they alone do not solve the problem and should be an integral part of an integrated HACCP-based management system (Lopez-Garcia and others 1999)

HACCP

Inclusion of mycotoxin control in HACCP plans, an important aspect of an overall management approach, should include strategies for prevention, control, and quality from farm-to-fork. In the food industry, postharvest control of mycotoxins has been addressed via HACCP plans, which include use of approved supplier schemes. Implementation at preharvest stages of the food system needs more attention. Such action provides a critical front-line defence to prevent introduction of contaminants into the food and feed supplies. Preharvest HACCP programmes have been documented for controlling aflatoxin in corn and coconuts in Southeast Asia, peanuts and peanut products in Africa, nuts in West Africa, and patulin in apple juice and pistachio nuts in South America (FAO/IAEA 2001).

Aldred and Magan (2004) outlined a number of HACCP schemes for wheat-based commodities and Lopez-Garcia and others (1999) provided guidance for development of an integrated mycotoxin management programme. The effective use of an HACCP-based postharvest hurdle approach to nearly eliminate aflatoxins from peanuts.

Table. HACCP-based reduction of aflatoxins postharvest a, b

Technology	Aflatoxin Level (µg/kg)	% Reduction	% Cumulative Reduction
Farmer's stock	217	–	–
Belt separator	140	35	35
Shelling plant[c]	100	29	54
Colour sorting[c]	30	70	86
Gravity table[c]	25	16	88
Blanching/colour sorting	2.2	91	99.0
Re-colour sorting[c]	1.6	27	99.3

[a]Results were obtained from processing of a 40000 kg lot of contaminated peanuts.
[b]From park and liang 1993.
[c]Data based on medium-category peanuts only.

BIOLOGICAL CONTROL MEASURES

DON levels have been shown to be reduced in the field and in storage without intervention, as discussed by Karlovsky (1999).

Such findings include:

- Degradation mechanisms resulting in reduced mycotoxin levels in the field. Limited research on DON has suggested the possibility that the mycotoxin may be metabolized by corn enzymes; and

- Decline in DON levels in grains stored at –18 °C to 4 °C and trichothecenes at temperatures greater than 0 °C.

Karlovsky explained that such reductions in mycotoxin levels have proven to be inconsistent and decreased levels of mycotoxin in the field do not substantiate the occurrence of biological degradation.

The potential for using microorganisms to detoxify mycotoxins has shown promise. Exposure of DON to microbes contained in the contents of the large intestines of chickens completely transformed it in vitro to de-epoxy-DON (He and others 1992), which is 24 times less toxic than DON itself. Similar findings were demonstrated with the microflora of cow intestines.

TRANSGENIC APPROACHES

Current research efforts are focusing on methods to prevent infection at the preharvest stage with emphasis on mechanisms by which the affected plants may inhibit growth of molds or destroy mycotoxins that they produce. Traditional grain-breeding strategies to select for preferred genetic traits have been conducted for many years. There has been limited success with this approach to Fusarium graminearum and Aspergillus flavus. There are hybrids currently in use that limit mycotoxin production; however, the potential to reach unacceptable levels remains.

Fumonisin production has received less attention from researchers; however, quantitative trait loci (QTL) have been mapped. Unfortunately, QTL accounted for less than half the variance in Fusarium phenotype and despite improved resistance, unacceptable levels are still possible. Traditional methods are plagued by many hurdles, however, including inconsistent, labour-intensive inoculation techniques, lack of single genes and resistant control genotypes, and the financial implications of evaluating results. Duvick (2001) pointed out that visible symptoms of plant mold can be selected for using traditional breeding techniques, but many of the mycotoxin-producing fungi surface with no visible signs.

Genetic modification of mold-susceptible plants holds great promise for controlling this food safety issue. Articles by Karlovsky (1999), Duvick (2001), and Munkvold (2003) review a variety of approaches that are being or have been pursued. One such approach involves increasing production of compounds (for example, antifungal proteins or secondary metabolites, such as hydroxamic acids, phenolics, stilbenes) that reduce infection by the microorganism. This may be accomplished by introducing a novel gene to express the target compound. Another option is to enhance expression of such a compound by the existing gene, thereby capitalizing on the plant's own defence mechanisms. For example, enzymes that catalyze production of antifungals could be targeted for expression. Alternatively, genetic engineering methods to increase production of enzymes that degrade mycotoxins are also being pursued. Transgenic maize has been patented for fumonisin-degrading corn for swine consumption. Efforts are also under way to engineer plants to produce compounds that disrupt mycotoxin synthesis.

For example, enhanced expression of an α-amylase inhibitor in Aspergillus spp. could result in significantly reduced aflatoxin levels.

Another avenue for reducing mycotoxin levels would be to reduce insect injury to plant kernels. Insects play an important role in the proliferation of mold growth in the field and in storage.

Resistance developed through the use of several Bt (Bacillus thermophilus) genes in corn, wheat, and other cereal grains to minimize insect damage has led to effective reduction in Fusarium ear rot (F. verticillioides and F. proliferatum) mycotoxin levels in grain. Munkvold (2003) cited 19 reports on Bt hybrids, with 12 of these demonstrating reduced mycotoxin production compared to the parent corn. It is important to note, however, that this approach is not a long-term solution for fumonisin production because Fusarium spp. can enter the kernels regardless of insect injury. Additionally, reductions of aflatoxin production in the Bt hybrids were not observed.

BIOTERRORISM

Because a number of mycotoxins, which may be lethal in relatively low doses, may be cultured and grown on a wide variety of grains, the possibility of deliberate mycotoxin contamination of commodities and/or foods should be recognized by the food industry when developing defence plans. The impact of an intentional act of mycotoxin contamination could be severe, with potential public health outcomes involving high mortality and devastating economic consequences stemming from the corresponding impact on the health care system, public fear, and avoidance of affected products. Prior to September 11, 2001, there was little concern pertaining to defence against intentional contamination. Because of this, grain storage and delivery systems, as well as food manufacturing plant security systems, deserve attention and crisis plans should be in place to deal with possible biological and chemical terrorism incidents. Where appropriate, these efforts should include mycotoxins.

RISK ASSESSMENT

Risk assessment of human health hazards associated with mycotoxins must rely on extrapolation from toxicity data obtained in animal models and human exposure assessments. Exposure assessments are quite sketchy at best, given that there is no publicly accessible ongoing systematic surveillance for human mycotoxin exposures. There are some interesting recent examples of attempts to perform such extrapolations and comparisons. Advances in the statistical estimation of uncertainty make extrapolations increasingly relevant. For example, Eriksen and others (2000) based an extrapolation of zearalenone risk on a no-observed effect level (NOEL) of 40 μg/kg/d in pigs (during a 15-d study), for estrogenic effects. Pigs were the most sensitive species, so although it is not clear to what extent humans and pigs are equivalent in their response, this estimate errs on the side of safety. The NOEL for zearalenone was divided by a

safety factor of 80 to derive an acceptable daily intake (ADI) of 0.5 μg/kg for humans. No rationale was given for the choice of safety factor, but, depending on the world region, this ADI is 8 to 31 times greater than estimated human exposures. Since this estimate was done, the term ADI is being replaced by the term reference dose (RfD). Kodell and Gaylor (1999) have provided evidence-based extrapolation factors, combining data across hundreds of studies of toxic effects of nongenotoxic agents and deriving best estimates of major sources of variability in experiments (including interspecies, inter-individual, and duration of toxic exposure). In the example of zearalenone, based on the NOEL in pigs and a combined factor of 46 for inter-individual and interspecies variability (95% confidence estimate), a revised estimate of human RfD would be 0.87 μg zearalenone/kg/d.

Kuiper-Goodman and others (1996) performed a risk assessment for fumonisins based on human exposure data from Canada and the extant toxicity literature on these mycotoxins. Because fumonisins are almost exclusively found in corn, this is a somewhat simpler case than for most other mycotoxins. Based on 361 corn food samples analyzed over 4 y, human fumonisin intake was estimated to be <0.089 μg/kg bw/d. This dose was 1700-fold less than the lowest noel obtained from animal studies (a 4.4-y study of 9 vervet monkeys showing a noel of 0.15 mg/kg bw/d). The authors concluded that human fumonisin intakes in Canada were very unlikely to pose health risks. A more recent 2-y rodent carcinogenicity study confirms this finding, with a noel of >0.2 mg/kg bw/d with altered sphingosine/sphinganine ratios as a toxic endpoint. The NOEL in this study for cancer (renal carcinogenesis in male rats only) was 0.6 mg/kg bw/d. Kuiper-Goodman (2004) recently reviewed mycotoxin risk assessment and risk management and the efforts of countries to harmonize regulations.

Due to the variation in mycotoxin content of human foods across world regions and seasons, and the continually improving toxicological data sets for mycotoxins, increasingly sophisticated models will be developed to assess human health risk from these foodborne toxins. Progress in the science of risk assessment is allowing a greater level of certainty regarding risk, but toxin interactions and emerging human epidemics of various chronic and infectious diseases will continue to pose major challenges in this field.

FOOD SAFETY IMPLICATIONS

Public awareness of issues surrounding mycotoxins is increasing. Karlovsky (1999) provides 3 explanations for this phenomenon. First, analytical chemistry is increasingly able to quantify the presence of toxins in a growing number of food commodities. Second, new and improved bioassays for toxicological studies on specific targets have surpassed the abilities of less sophisticated methods and allowed identification of negative health effects where previously none had been found. Third, the availability of routine testing methods that are both efficient and affordable has allowed for in-house monitoring, resulting in greater numbers of identified contaminations.

The variability in mycotoxin contamination and the potential for novel mycotoxicoses to emerge make the prospects for ongoing significant human mycotoxicoses likely, especially in low-income countries in which surveillance is less available because of economical and technological constraints. The human health consequences of acute aflatoxicosis alone range from death to exacerbated malnutrition, devastating to the affected populations.

In view of ongoing epidemics of immunosuppressive diseases, including HIV infection and chronic protein calorie malnutrition, the additional immunosuppression possible from mycotoxins deserves more attention. Very little is known about the effects of long-term low-level exposure, especially with regard to co-contamination with multiple mycotoxins. Also, due to the heterogeneity of mycotoxin contamination and the potential for sampling regions with elevated toxin levels ("hot spots"), consistent sampling and analysis is difficult. Thus, development of low-tech, inexpensive methods for mycotoxin surveillance is a world health imperative. With several novel approaches being developed, such as molecular imprint polymers and immuno- and bio-assays, adoption of such methods is within reach. The prevention of mycotoxin contamination of human foods could have a significant effect on public health in low-income countries, and deserves significant attention. The food industry should take the lead in these efforts, because it will lead to improved economic sustainability of the industry, enhanced food safety efforts, enhanced international trade efforts, and improved public health.

MICROBIAL FOOD WEB

The microbial food web refers to the combined trophic interactions among microbes in aquatic environments. These microbes include viruses, bacteria, algae, heterotrophic protists(such as ciliates and flagellates).

In aquatic environments, microbes constitute the base of the food web. Single celled photosynthetic organisms such as diatoms and cyanobacteria are generally the most important primary producers in the open ocean. Many of these cells, especially cyanobacteria, are too small to be captured and consumed by small crustaceans and planktonic larvae. Instead, these cells are consumed by phagotrophic protists which are readily consumed by larger organisms. Viruses can infect and break open bacterial cells and (to a lesser extent), planktonic algae (a.k.a. phytoplankton). Therefore, viruses in the microbial food web act to reduce the population of bacteria and, by lysing bacterial cells, release particulate and dissolved organic carbon (DOC). DOC may also be released into the environment by algal cells. One of the reasons phytoplankton release DOC termed "unbalanced growth" is when essential nutrients (*e.g.* nitrogen and phosphorus) are limiting. Therefore, carbon produced during photosynthesis is not used for the synthesis of proteins (and subsequent cell growth), but is limited due of a lack of the nutrients necessary for macromolecules. Excess photosynthate, or DOC is then released, or exuded.

The microbial loop describes a pathway in the microbial food web where DOC is returned to higher trophic levels via the incorporation into bacterial biomass.

PHYCOTOXIN

Phycotoxins (from Greek, *phykos*, "seaweed"; and *toxikon*, "toxin") are complex allelopathic chemicals produced by eukaryotic and prokaryotic algal secondary metabolic pathways. More simply, these are toxic chemicals synthesized by photosynthetic organisms.

These metabolites are (in most cases) not harmful to the producer but may be toxic to either one or many members of the marine food web. This page focuses on phycotoxins produced by marine microalgae; however, freshwater algae and macroalgae are known phycotoxin producers and may exhibit analogous ecological dynamics. In the pelagic marine food web, phytoplankton are subjected to grazing by macro- and micro-zooplankton as well as competition for nutrients with other phytoplankton species. Marine bacteria try to obtain a share of organic carbon by maintaining symbiotic, parasitic, commensal, or predatoryinteractions with phytoplankton. Other bacteria will degrade dead phytoplankton or consume organic carbon released by viral lysis. The production of toxins is one strategy that phytoplankton use to deal with this broad range of predators, competitors, and parasites. Smetacek suggested that "planktonic evolution is ruled by protection and not competition. The many shapes of plankton reflect defence responses to specific attack systems". Indeed, phytoplankton retain an abundance of mechanical and chemical defence mechanisms including cell walls, spines, chain/colony formation, and toxic chemical production. These morphological and physiological features have been cited as evidence for strong predatory pressure in the marine environment. However, the importance of competition is also demonstrated by the production of phycotoxins that negatively impact other phytoplankton species. Flagellates (especially dinoflagellates) are the principle producers of phycotoxins; however, there are known toxigenic diatoms, cyanobacteria, prymnesiophytes, and raphidophytes. Because many of these allelochemicals are large and energetically expensive to produce, they are synthesized in small quantities. However, phycotoxins are known to accumulate in other organisms and can reach high concentrations during algal blooms. Additionally, as biologically active metabolites, phycotoxins may produce ecological effects at low concentrations. These effects may be subtle, but have the potential to impact the biogeographic distributions of phytoplankton and bloom dynamics.

POTENTIAL ECOLOGICAL EFFECTS

Anti-grazing effects

Phycotoxins may prevent grazing by several mechanisms: grazer death, infertility, or deterrence.

Some evidence of anti-grazing effects:

1. Teegarden found that three different species of copepods were able to distinguish between a saxitoxin-producing Alexandrium sp. and morphologically similar non-toxigenic Alexandrium sp. by chemosensory means. These three different copepod species grazed predominantly on the non-toxigenic Alexandrium spp. and avoided the saxitoxin-producer. However, the effect of saxitoxin deterrence varied per copepod species. This implies that saxitoxin producing Alexandrium sp. have an advantage over non-toxigenic dinoflagellates.
2. Miralto et al. reported a low hatching success of eggs laid by copepods that fed on diatoms containing polyunsaturated aldehydes. When ingested by copepods, these aldehydes appear to arrest embryonic development. This has the potential to decrease the future population of copepods and promote the survival of copepods which do not eat as many diatoms.

Anti-microbial Effects

Phycotoxins production may be useful to ward off parasitic or algicidal heterotrophic bacteria.

Some evidence of anti-microbial effects:

1. Bates et al. was able to enhance domoic acid production in Pseudo-nitzschia multseries with the re-introduction of bacteria. Additionally, P. multiseries cultures which were completely axenic (bacteria-free), produce less domoic acid than P. multiseries cultures which have contained bacteria for several generations.
2. Sieburth found acrylic acid inhibited gut microflora in penguins. High concentrations of acrylic acid were ingested by penguins via their euphasid diet, which had been feeding on Phaeocystis. The antimicrobial effect of acrylic acid was verified by Slezak et al. who concluded that acrylic acid will inhibit bacterial production in situations where phytoplankton form aggregates (*i.e.* marine snow or Phaeocystis blooms). However, acrylic acid production may also serve to keep bacteria away from the phytoplankton in more dilute concentrations.

Competitive Effects

Since many different species of phytoplankton compete for a limited number of nutrients, it's possible that phycotoxin production is used as a method to either kill competitors or to keep other phytoplankton out of the producer's nutrients space.

Some evidence of competitive effects:

1. Graneli showed that Prymnesium spp. will produce phycotoxins which kill competitors under nitrogen or phosphorus limitation.
2. Fistarol et al. found that Alexandrium spp. produce toxins which decrease the growth rate of other phytoplankton and change community composition.
3. Prince et al. showed that chemical exudates from the dinoflagellate Karenia

brevis decreased the growth rate and sometimes killed competitor species by decreasing their photosynthetic efficiency and increasing membrane permeability.

LIST OF KNOWN PHYCOTOXINS AND MECHANISMS OF ACTION

Most characterized phycotoxins have some economic or health impact on humans. Other well-studied phycotoxins are potential or existing pharmaceuticals or have some use in cellular research. Therefore, our level of knowledge on individual toxins does not necessarily reflect their ecological relevance. Additionally, the mode of action and level of toxicity are effects that have been documented in macroorganisms (typically mice).

These modes of action may be different in the pelagic marine environment. However, it is unlikely that the synthesis of complex and energetically expensive chemicals should be conserved over evolutionary time if they do not confer some advantage on the producer.

Even if we do not yet know the effect of many toxins in their natural environment, their mere presence and impressive diversity indicates that they do serve some ecological purpose. It should be noted that the phytoplankton species listed below do not encompass the entire range of known toxigenic species. There exists experimental evidence for phytoplankton species that have inhibitory effects on grazers or other phytoplankton species, but their toxins have not been identified.

TYPES OF TOXINS

Excreted Toxins

Excreted toxins may help deter predators and bacteria which are drawn in by phytoplankton waste products. Phytoplankton are known to excrete waste metabolites into the surrounding environment. This is a potential source of reduced nutrients and carbon for bacteria and may act as a signal for predators which can detect and follow kairomonegradients in their environment.

Excreted toxins would seem most advantageous to the individual cell in their ability to keep predators and/or parasitic and algicidal bacteria at a distance. However, continuous toxin production and excretion carries a metabolic cost. For excreted toxins to be effective, they must have a low molecular weight to rapidly diffuse in the marine environment and to be energetically cheap to produce. However, excreted toxins may not actually repel larger motile predators because molecular diffusivity is slow and turbulence at the millimeter scale is large in water. Excreted phycotoxins may act as repellents if their signal registers at the same speed as other signals that potential grazers can detect (kairomones), assuming both are encountered by a predator at the same time. Additionally, excreted toxins may be effective method of keeping harmful bacteria and other phytoplankton competitors outside of the phycotoxin producer's microzone of nutrients.

Contact Toxins

Contact toxins are effective if they impact the grazer or harmful bacterium immediately after contact with the phytoplankton producer. These toxins are located at the cell surface and are typically classified as glycoproteins, glycolipids, or polypeptides. These toxins would have to be highly specific to their target receptors to be effective.

Post-ingestion Toxins

In order for these types of toxins to take effect, post-ingestion toxin producers have to be consumed by a grazer. Post-ingestion toxins, also known as suicide toxins, are not beneficial to individual cells because unlike terrestrial plants, phytoplankton do not have sacrificial tissue. However, if internal toxins do result in the death, decrease growth rate, infertility, or deterrence of a predator the remaining representatives of the plankton community may benefit. Community defence is most beneficial in a clonal population where toxigenic species are abundant, for example during a monospecific phytoplankton bloom.

Chemical Defence Signal Mechanisms

Table modified from Wolfe (2000)

	Excreted Toxins	Contact Toxins	Post-ingestion Toxins
Molecules	Small molecules but varied structures; organic and amino acids, sugars, short-chain lipids and derivatives	Glycoproteins, glycolipids, polypeptides	Varied: toxicants or toxins
Toxin properties	Aqueous solubility, diffusivity, lability, toxicity	Specificity, toxicity	Toxicity or concentration
Toxin location	Aqueous environment	Cell surface	Cell interior
Effect or mode of action	Negative kinesis/taxis: repellent	Release following capture: deterrent	Subsequent inhibition of feeding or toxicity reduced digestibility or growth efficiency
Benefit level	Individual or population, including competitors	Individual	Genetically similar population

DETECTION METHODS

It is technically difficult to identify and characterize a metabolite that is produced in low concentrations and is secreted into a fluid that contains a diversity of other metabolites.

Allelopathy is very difficult to observe in the field (with the exception of harmful algal blooms) because phycotoxin production may be induced by a variety of environmental factors and may create a cascade of biotic and physical events, which are difficult to separate from direct allelopathic effects of one species on another. There

are six points (similar in logic to Koch's postulates) that must be established to rigorously prove that one species is chemically inhibiting another in an ecological system

1. A pattern of inhibition of one species [...] by another must be shown.
2. The putative aggressor [species] must produce a toxin.
3. There must be a mode of toxin release from the [species] into the environment.
4. There must be a mode of toxin transport and/or accumulation in the environment.
5. The afflicted [species] must have some means of toxin uptake.
6. The observed pattern of inhibition cannot be explained solely by physical factors or other biotic factors, especially competition and herbivory:
7. Concentrations which impact the target species must be environmentally realistic given rates of transport and diffusion in the aquatic environment.

Few (if any) studies on phytoplankton toxins have attempted to rigorously meet all of these criteria. All methods of detecting phycotoxins involve extraction of the candidate toxin from a phytoplankton culture; therefore, it's important to determine whether the toxin is secreted into the media or stored in the phytoplankton cell. It's also important to know whether the target organism must be present to induce toxin synthesis.

Most commonly, the presence of a phycotoxin is verified by bioassay-guided fractionation. The sample must be fractionated, or separated from the other metabolites and chemicals in the media using chromatography. These different fractions may be then tested on the target species to determine which sample causes the expected allelopathic symptom(s). This approach is useful for rapidly isolating an allelochemical whose structure is not known. However, bioassays have the potential to generate false positives. This may occur if the bioassay is not controlled properly. For example, in a mixed batch culture the target species may die or have reduced growth rates due to competition for nutrients, dissolved inorganic carbon, or pH levels which are too low for the target species.

Developments in genomics, transcriptomics, proteomics, and metabolomics are now yielding large volumes of biochemical data. "Metabolic profiling" allows for comparison between biologically active and inactive samples and identification of compounds present at low concentrations using mass spectrometry. These samples may then be compared by principal component analysis. Characterization of the compounds present in the active sample (but not in the inactive sample) may then be identified and characterized using standard methods in mass spectroscopy. Isotope labeling may also be used to identify the pathways used in phycotoxin biosynthesis.

4

Food Processing

Food Processing could be defined as the process of transforming food items into usable forms. It might include the processing of raw material through various chemical and physical process into food.

Different activities involved in this process include cooking, mincing, liquefaction, canning, pickling, emulsification, and macerating.

OBJECTIVES OF FOOD PROCESSING

Food Technology is one of the known vast domains. It deals with the production process to make food. Food processing is done to achieve certain goals like the ones stated below:

- To boost the shelf life of food articles.
- To prevent contamination of food.
- For transport and food storage.
- To turn food products into the ones that appeal to customers.

There are certain criteria that have to be compiled for the apt processing of food, right from the possibility of a pest or a bacteria to invade and multiply on foods to the biological activity of foods.

FOOD PRESERVATION

Food preservation is a process employed to prevent the growth of fungi, bacteria, and many other microorganisms. It involves the process of slowing down the oxidation of fats that would lead to rancidity. There are several food preservation methods that

are designed specifically to preserve food. Some of the selected few preservation methods are stated below:

Drying

It is one of the traditional techniques that are employed to decompose food products. Exposure of food particles to sunlight to dry them is one such method done naturally. This process would result in the evaporation of moisture content from food thus preventing microorganisms from invading the food. Moisture from food could be removed also by using hot air

Cooling

It is a technique of preserving food by slowing down the growth of microorganisms and action of an enzyme that is responsible for rotting of food. Some of the food products such as meat, dairy products, and fish could be stored in a refrigerator thus increasing the shelf-life of the products.

Freezing

It is one of the regular processes that has been under use domestically and commercially to preserve a wide range of foods. Rapid freezing might have an adverse effect on the texture of food.

Heating

The majority of microorganisms and spores could be destroyed by applying sufficient heat to food items. One of the known examples includes boiling of milk.

Pickling

It is a process of preserving food in an edible and antimicrobial liquid. Pickling could be categorized into two types, namely fermentation and thermal pickling.

In fermentation pickling, bacteria present in a liquid produces organic agents which would act as preservation agents.

In chemical pickling, the food is preserved in an edible liquid that destroys microorganisms and bacteria.

HISTORY

Food processing dates back to prehistoric ages, with crude processing methods that included slaughtering, fermenting, sun drying, preserving with salt, and various means of cooking (such as roasting, smoking, steaming, and oven baking). Salt-preservation was especially common for foods that constituted the diets of warriors and sailors, up until the introduction of canning methods. Evidence for the existence of these methods exists in the writings of the ancient Greek, Chaldean, Egyptian, and Roman civilizations, as well as archaeological evidence from Europe, North and South America, and Asia.

These tried and tested processing techniques remained essentially the same until the advent of the Industrial Revolution. Examples of ready-meals also exist from the period before the Industrial Revolution, such as the Cornish pasty and Haggis.

Modern food processing technology was largely developed in the nineteenth and twentieth centuries, to serve military needs. In 1809, Nicolas Appert invented a vacuum bottling technique that would supply food for French troops, and this contributed to the development of tinning and then canning by Peter Durand in 1810. Although initially expensive and somewhat hazardous due to the lead used in cans, canned goods later became a staple around the world. Pasteurization, discovered by Louis Pasteur in 1862, was a significant advance in ensuring the microbiological safety of food.

In the twentieth century, World War II, the space race, and the rising consumer society in developed countries (including the United States) contributed to the growth of food processing with such advances as spray drying, juice concentrates, freeze drying, and the introduction of artificial sweeteners, colouring agents, and preservatives such as sodium benzoate. In the late twentieth century, products such as dried instant soups, reconstituted fruits and juices, and self-cooking meals (such as "Meal, Ready-to-Eat," or MRE, field rations) were developed.

In Western Europe and North America, the second half of the twentieth century witnessed a rise in the pursuit of convenience, as food processors marketed their products especially to middle-class working wives and mothers. Frozen foods (often credited to Clarence Birdseye) found their success in the sales of juice concentrates and "TV dinners." Processors utilized the perceived value of time to appeal to the postwar population, and this same appeal contributes to the success of convenience foods today.

FOOD PROCESSING METHODS

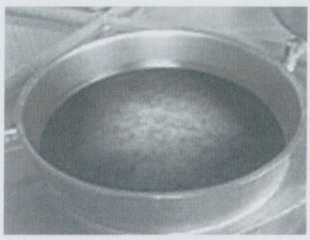


Fig. Beer fermenting at a brewery.

Common food processing techniques include:

- Removal of unwanted outer layers, such as potato peeling or the skinning of peaches
- Chopping or slicing, such as to produce diced carrots
- Mincing and macerating
- Liquefaction, such as to produce fruit juice
- Fermentation, as in beer breweries
- Emulsification

- Cooking, by methods such as baking, boiling, broiling, frying, steaming, or grilling
- Mixing
- Addition of gas such as air entrainment for bread or gasification of soft drinks
- Proofing
- Spray drying
- Pasteurization
- Packaging

PERFORMANCE PARAMETERS FOR FOOD PROCESSING

When designing processes for the food industry, the following performance parameters may be taken into account:

- Hygiene, measured, for instance, by the number of microorganisms per ml of finished product
- Energy consumption, measured, for instance, by "ton of steam per ton of sugar produced"
- Minimization of waste, measured, for instance, by the "percentage of peeling loss during the peeling of potatoes"
- Labour used, measured, for instance, by the "number of working hours per ton of finished product"
- Minimization of cleaning stops, measured, for instance, by the "number of hours between cleaning stops"

BENEFITS

More and more people live in the cities far away from where food is grown and produced. In many families, the adults are work from home and therefore there is little time for the preparation of food based on fresh ingredients. The food industry offers products that fulfill many different needs: from peeled potatoes that simply need to be boiled at home to fully prepared ready meals that can be heated up in the microwave oven in a few minutes.

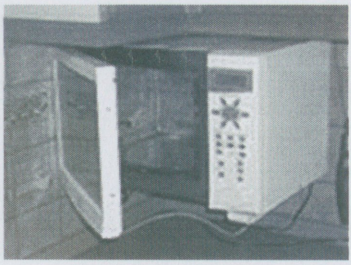


Fig. Microwave oven

Benefits of food processing include toxin removal, preservation, easing marketing and distribution tasks, and increasing food consistency. In addition, it increases seasonal

availability of many foods, enables transportation of delicate perishable foods across long distances, and makes many kinds of foods safe to eat by de-activating spoilage and pathogenic micro-organisms. Modern supermarkets would not be feasible without modern food processing techniques, long voyages would not be possible, and military campaigns would be significantly more difficult and costly to execute.

Modern food processing also improves the quality of life for allergy sufferers, diabetics, and other people who cannot consume some common food elements. Food processing can also add extra nutrients such as vitamins.

Processed foods are often less susceptible to early spoilage than fresh foods, and are better suited for long distance transportation from the source to the consumer. Fresh materials, such as fresh produce and raw meats, are more likely to harbour pathogenic microorganisms (for example, Salmonella) capable of causing serious illnesses.

DRAWBACKS

In general, fresh food that has not been processed other than by washing and simple kitchen preparation, may be expected to contain a higher proportion of naturally occurring vitamins, fibre and minerals than the equivalent product processed by the food industry. Vitamin C, for example, is destroyed by heat and therefore canned fruits have a lower content of vitamin C than fresh ones.



Fig. Tate and Lyle brand Corn Syrup being moved by tank car.

Food processing can lower the nutritional value of foods. Processed foods tend to include food additives, such as flavourings and texture enhancing agents, which may have little or no nutritive value, and some may be unhealthy. Some preservatives added or created during processing, such as nitrites or sulfites, may cause adverse health effects.

Processed foods often have a higher ratio of calories to other essential nutrients than unprocessed foods, a phenomenon referred to as "empty calories." Most junk foods are processed, and fit this category.

High quality and hygiene standards must be maintained to ensure consumer safety, and failure to maintain adequate standards can have serious health consequences.

Processing food is a very costly process, thus increasing the prices of foods products.

TRENDS IN MODERN FOOD PROCESSING

Health

- Reduction of fat content in final product, for example, by using baking instead of deep-frying in the production of potato chips
- Maintaining the natural taste of the product, for example, by using less artificial sweetener

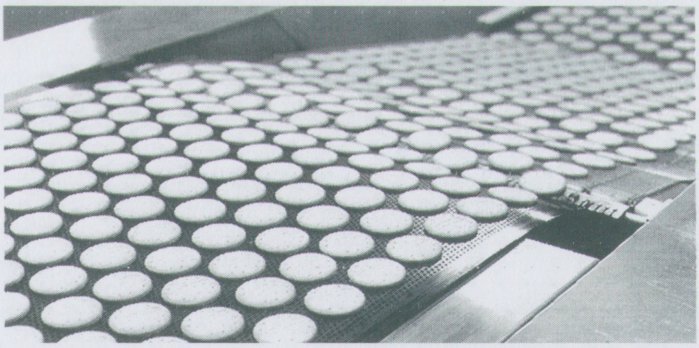
Hygiene

The rigorous application of industry and government endorsed standards to minimize possible risk and hazards. In the U.S., the standard adopted is HACCP.

Efficiency

- Rising energy costs lead to increasing usage of energy-saving technologies, for example, frequency converters on electrical drives, heat insulation of factory buildings, and heated vessels, energy recovery systems
- Factory automation systems (often Distributed control systems) reduce personnel costs and may lead to more stable production results

COMMON METHODS USED IN FOOD PROCESSING



Food processing is the technique which converts raw food items into well-cooked and preserved eatables. For processing, the best quality of raw materials is used by the industry, which caters to our daily consumption. But do you know how they do all the hard work? Following are some techniques and methods that are used to convert raw food into processed food:

DRYING

This is perhaps the oldest method used by humans to preserve or process their food. Drying reduces the water content in the product, which in turn reduces the likelihood of bacterial growth. When it comes to process cereal grains like wheat, maize, oats, rice, barley, grams and rye etc., drying process is used.

Preservation

This includes heating (or boiling) in order to destroy micro-organisms, oxidation, toxic inhibition, dehydration or drying, osmotic inhibition, freezing, a sort of cold pasteurization which destroys pathogens and various combinations of all these methods.

Smoking

Many foods such as meat, fish and others are processed, preserved and flavoured by the use of smoke mostly in big smoke houses. The food processing technique is quite simple, and the combination of smoke with the aroma of hydro-carbons generated from the smoke processes the food enhances the taste.

Freezing

This is the most common technique used in modern world to preserve or process the food both on commercial and domestic basis. A wide range of products can be frozen to process at the same time with the help of huge cold storage facilities.

Salting

Salt sucks out the moisture from the food, hence is used in food processing. Meat is the best example of the food processed by salting as nitrates are used very frequently to treat meat.

Vacuum Packs

Here, the food is packed in airtight bags and bottles in a vacuum area. An air-tight environment doesn't provide oxygen needed by germs especially bacteria to survive. This method is very commonly used for preserving processed nuts.

Sugaring

In this method fruits such as apples, peaches and plums are cooked with sugar until they are crystallized and then it is stored dry.

Pickling

In this method of food processing, the food is cooked in chemicals and materials (which are fit for human and animal consumption) which destroy micro-organisms. Usually, these include brine, vinegar, ethanol, vegetable oil and many other types of oils. Pickling is very commonly seen in vegetables such as cabbage and peppers.

These are some of the frequently used methods of preserving or food processing. These methods are performed under strict guidelines and regulations so as to achieve maximum efficiency and preservation.

This Food Safety Month, get familiar with the various aspects of Food Safety like Food Storage, Food Processing, Personal Hygiene, Packaging and Labelling and Cleaning and Sanitation.

AGROPROCESSING INDUSTRY: DEFINITION AND DIMENSIONS

TYPES OF AGROPROCESSING

A common and traditional definition of agroprocessing industry refers to the subset of manufacturing that processes raw materials and intermediate products derived from the agricultural sector. Agroprocessing industry thus means transforming products originating from agriculture, forestry and fisheries.

Indeed, a very large part of agricultural production undergoes some degree of transformation between harvesting and final use. The industries that use agricultural, fishery and forest products as raw materials comprise a very varied group. They range from simple preservation (such as sun drying) and operations closely related to harvesting to the production, by modern, capital-intensive methods, of such articles as textiles, pulp and paper.

The food industries are much more homogeneous and are easier to classify than the non-food industries since their products all have the same end use. Most preservation techniques, for example, are basically similar over a whole range of perishable food products, whether they be fruit, vegetables, milk, meat or fish. In fact, the processing of the more perishable food products is to a large extent for the purpose of preservation.

Non-food industries, in contrast to the food industries, have a wide variety of end uses. Almost all non-food agricultural products require a high degree of processing. Much more markedly than with the food industries, there is usually a definite sequence of operations, leading through various intermediate products before reaching the final product. Because of the value added at each of these successive stages of processing, the proportion of the total cost represented by the original raw material diminishes steadily. A further feature of the non-food industries is that many of them now increasingly use synthetics and other artificial substitutes (especially fibres) in combination with natural raw materials.

Another useful classification of agroprocessing industry is in upstream and downstream industries. Upstream industries are engaged in the initial processing of agricultural commodities. Examples are rice and flour milling, leather tanning, cotton ginning, oil pressing, saw milling and fish canning. Downstream industries undertake further manufacturing operations on intermediate products made from agricultural materials. Examples are bread, biscuit and noodle making, textile spinning and weaving; paper production; clothing and footwear manufacturing; and rubber manufactures.

A further specification is related to the nature of the production process which, in many cases, can range from craft to industrial organization. For example, in some developing countries the same good may be produced both by handloom weavers

working in their own home and by large textile factories that have sophisticated machinery and complex systems of organization and that produce a range of industrial products for the domestic and external markets. In such cases, it can be misleading to define agroprocessing industry just on the basis of the goods produced because only the second method of production mentioned has industrial characteristics.

Today, however, it is becoming even more difficult to provide a precise demarcation of what should be considered an agro-industrial activity: the impact of innovation processes and new technologies suggests a widening of the range of agro-industry inputs that could be considered, including biotechnological and synthetic products, for example. This implies that agro-industry today continues to process simple agricultural goods while also transforming highly sophisticated industrial inputs that are often the result of considerable investments in research, technology and innovation.

Corresponding to this growing complexity of inputs is an increasing range of transformation processes, characterized by physical and chemical alteration and aimed at improving the marketability of raw materials according to the final end use.

All these factors – the growing complexity of inputs, the impact of innovation processes and new technologies, the sophistication and the growing range of the transformation processes – makes it increasingly difficult to draw a clear distinction between what should be considered strictly industry and what can be classified as agro-industry.

Table. Share of agro-industries in total manufacturing value added[1] in selected country groups, 1980 and 1994[2]

Country groups	Food, beverages, tobacco (3.1)		Textiles, clothing, leather, footwear (3.2)		Wood products, furniture (3.3)		Paper & products, printing (3.4)		Rubber products (3.5.5)		All agro-industry (3.1-3.4, 3.5.5)	
	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994
Industrialized countries	13.3	12.6	8.3	5.7	3.6	3.1	7.9	8.9	1.2	1.1	34.3	31.4
EC	11.9	13.5	8.5	6.0	3.7	3.4	6.8	7.6	1.3	1.1	32.2	31.6
Japan	11.3	9.4	7.2	4.3	4.4	2.3	8.8	9.2	1.4	1.2	33.1	26.4
North America	13.7	11.9	6.4	4.8	2.8	3.0	11.4	11.3	1.0	1.1	35.3	32.1
Eastern Europe and CIS	20.8	20.5	14.4	13.7	2.7	3.2	2.2	1.8	1.4	1.1	41.5	40.3
Developing countries	18.2	17.7	15.2	11.4	2.8	2.2	4.3	4.6	1.5	1.7	42.0	37.6
NIEs[3]	15.1	14.5	15.0	10.8	2.4	1.6	4.5	5.0	1.6	1.8	38.6	33.7
Second-generation NIEs[4]	23.5	19.7	16.2	13.0	3.2	3.8	3.3	3.8	2.0	2.2	48.2	42.5

Note: ISIC classifications in parentheses. [1] At constant 1990 prices. [2] 1993 for developing countries. [3] NIEs = Argentina, Brazil, Mexico, former Yugoslavia, Hong Kong, India, the Republic of Korea, Singapore and Taiwan Province of China. [4] Second-generation NIEs = Morocco, Tunisia, Chile, Turkey, Indonesia, Malaysia, the Philippines and Thailand.

According to the traditional classification of the UN International Standard Industrial Classification of All Economic Activities (ISIC), which is quite rigid but useful for statistical purposes, agro-industrial production is present in many manufacturing sectors: 3.1 Manufacture of Food, Beverages and Tobacco; 3.2 Textile, Wearing Apparel and Leather Industries; 3.3 Manufacture of Wood and Wood Products, Including Furniture; 3.4 Manufacture of Paper and Paper products, Printing and Publishing; 3.5.5 Manufacture of rubber products. Although this chapter is about all these areas of agro-industry, it often focuses on the particularly important group of food, beverages and tobacco.

AGROPROCESSING INDUSTRY IN FIGURES

The contribution of agro-industries to total manufacturing value added (MVA) in selected country groups in 1980 and 1993-94, based on the broad ISIC classification outlined above.

Even in the most advanced economies, these industries represent a large part of total industrial activity. In industrialized countries, while primary agriculture accounts for a very small proportion of total output, the various industries derived from agricultural transformation represented nearly one-third of total MVA in 1994. The share is even higher (37.6 percent) in developing countries, where agro-industry is often the main industrial activity and a major contributor to production, export earnings and employment.

However, the share of agro-industries has dropped by around three to four percentage points in both developing and industrialized countries since 1980, slightly more in the former and slightly less in the latter.

The major component of agro-industrial activities in both industrialized and developing countries is composed of the food, beverages and tobacco industry, which accounted in 1994 for about 13 percent of total MVA in the industrialized countries and 18 percent in the developing countries, although the share has also been declining in both groups.

As regards the distribution of world value added in the various branches of agro-industry, the share of the developing countries has increased significantly in all branches, reaching close to one-third of the world total in tobacco, footwear and textiles and also rising considerably in the cases of beverages and leather between 1980 and 1994.

Among the industrialized countries, a strong advance was made by the European Community (EC) in food products, beverages, tobacco and leather which, however, went along with relative declines in most other agro-industrial branches. North America strengthened its market dominance in wood and paper products, and also increased significantly its share in the rubber and textile industries.

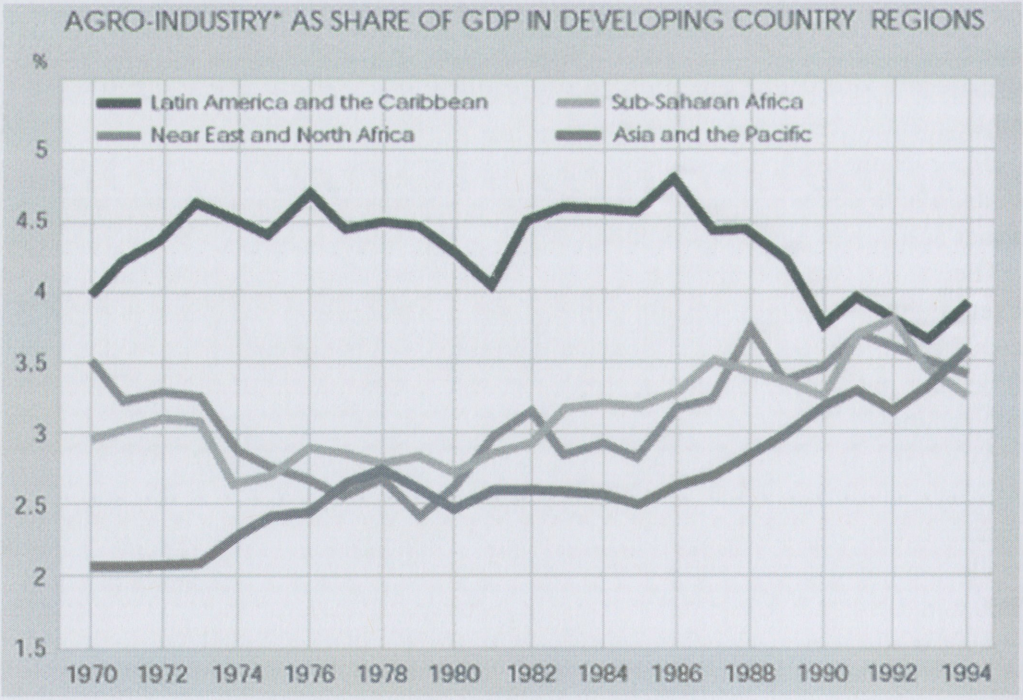
By contrast, steep relative declines occurred in Eastern Europe and the CIS, where problems of economic transition imposed a heavy toll on, *inter alia*, agro-industrial activity.

Shares in output in this region declined for all branches, from around three percentage points for footwear, wood products and tobacco, to up to nine or ten points for food, beverages, textiles and leather.

The overall gains in contribution to output by the developing countries were reflected in the faster rates of expansion of their industries compared with those of the industrialized countries during 1980-94. Their rate of growth exceeded those of industrial and transition economies for all branches of industrial activity during the 1980s, and again in 1990-94.

Rubber and paper were particularly buoyant throughout the period, as was the beverage industry in 1990-94.

The food, beverages and tobacco industries combined are by far the most important component of agro-industrial activities in both developed and developing countries, and also account for a sizeable share of their overall economic output. In the case of the developing countries, food, beverages and tobacco manufacturing account for about 3 to 4 percent of GDP, the share in the various regions showing a remarkable convergence over the past decades.



Latin America and the Caribbean stands apart from the other regions, however. While the economic weight of the subsector has been historically greater in this region, it has tended to lose relative importance since the mid-1980s, in contrast to the other regions where it has tended to increase. Most notable is the steady rise in Asia and the Pacific throughout much of the 1970s and 1980s, a trend which has continued also in the 1990s.

Table. Distribution of world[1] value added by branch of agro-industry, 1980 and 1993[2]

Branch	Industrialized countries and economies in transition					Developing(ISIC)		
	Year	All	EU	Japan	North America	Eastern Europe and CIS	All	NIEs	World[1]
Food (3.1.1/2)	1980	85.5	28.0	14.8	22.3	16.3	14.5	7.4	100.0
	1994	82.0	32.3	13.7	24.7	6.9	18.0	9.0	100.0
Beverages (3.1.3)	1980	79.3	32.6	10.4	18.6	14.0	20.7	11.1	100.0
	1994	73.2	36.3	8.8	19.2	4.8	26.8	13.6	100.0
Tobacco (3.1.4)	1980	73.7	33.7	3.2	29.3	5.8	26.3	12.2	100.0
	1994	66.8	35.9	2.8	23.4	2.8	33.2	14.7	100.0
Textiles (3.2.1)	1980	78.1	29.3	14.4	14.0	17.9	21.9	13.2	100.0
	1994	71.3	29.7	11.4	19.0	8.8	28.7	16.5	100.0
Wearing apparel (3.2.2)	1980	81.5	34.2	11.1	21.7	11.6	18.5	10.9	100.0
	1994	76.0	29.3	10.3	25.9	7.4	24.0	12.6	100.0
Leather (3.2.3)	1980	76.7	34.6	9.9	12.0	18.9	23.3	15.3	100.0
	1994	72.2	39.1	10.4	11.5	9.1	27.8	18.1	100.0
Footwear (3.2.4)	1980	74.1	42.1	4.4	13.1	11.7	25.9	17.6	100.0
	1994	69.3	41.8	6.4	8.5	9.2	30.7	20.0	100.0
Wood products (3.3.1)	1980	89.6	33.5	22.1	19.4	7.6	10.4	4.9	100.0
	1994	87.8	34.4	14.7	27.5	4.3	12.2	4.0	100.0
Paper (3.4.1)	1980	90.4	33.1	12.7	35.0	6.1	9.6	6.3	100.0
	1994	88.3	33.5	13.4	36.5	1.5	11.7	7.7	100.0
Rubber (3.5.5)	1980	84.9	36.3	17.2	17.6	11.3	15.1	10.1	100.0
	1994	78.2	31.7	16.2	24.3	3.7	21.8	14.2	100.0
All manufactures (3.1-3.9)	1980	87.1	35.7	14.2	23.9	9.5	12.9	8.2	100.0
	1994	83.5	33.0	17.1	25.9	4.2	16.5	9.8	100.0

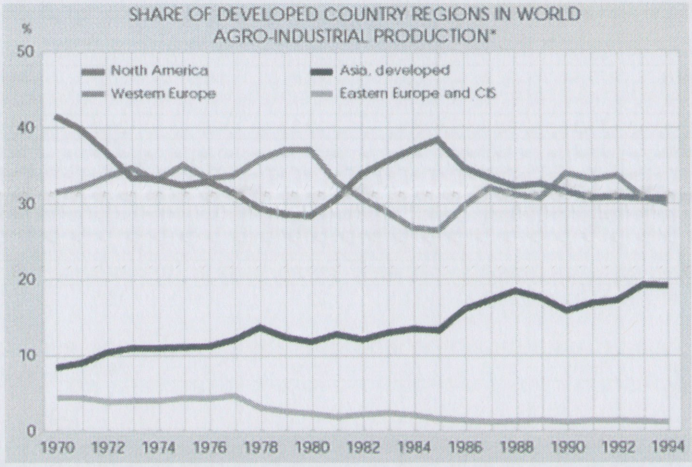
[1] Excluding China, for which data were not available. [2] At constant 1990 prices.

Table. Average annual growth of value added in agro-industries by country groups, 1980-90 and 1990-94[1]

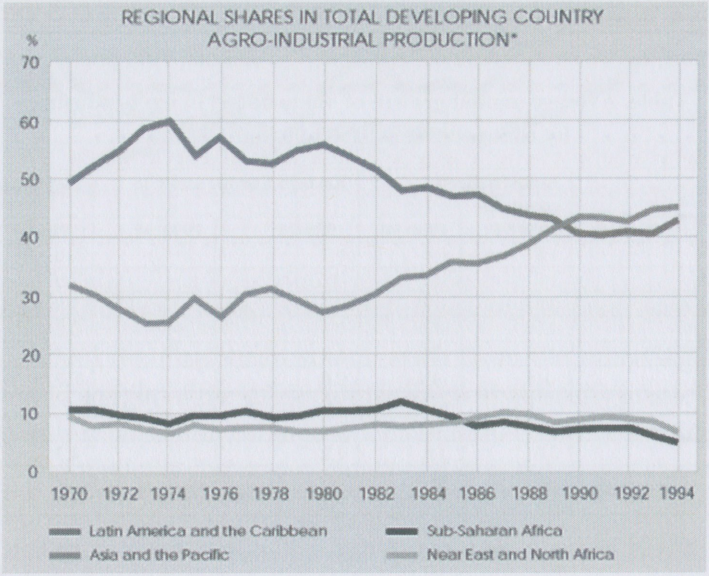
Branch (ISIC)	Industrialized countries		Eastern Europe and CIS		Developing countries	
	1980-90	1990-94	1980-90	1990-94	1980-90	1990-94
Food (3.1.1/2)	1.8	1.4	1.7	..	2.6	3.4
Beverages (3.1.3)	1.8	1.2	-1.7	..	2.6	4.9
Tobacco (3.1.4)	0.0	-1.4	0.4	..	1.8	2.1
Textiles (3.2.1)	0.2	-1.5	1.1	..	2.2	0.8
Wearing apparel (3.2.2)	-0.6	-2.3	1.7	..	2.4	-1.7
Leather (3.2.3)	-1.4	-4.1	0.0	..	0.7	-3.6
Footwear (3.2.4)	-3.1	-3.5	2.4	..	-0.4	-2.4
Wood products (3.3.1)	1.6	-0.1	2.1	..	2.1	..
Paper (3.4.1)	3.4	1.8	1.2	..	4.3	4.5
Rubber (3.5.5)	2.6	-0.3	1.4	..	4.9	3.9
Total MVA	2.8	-0.4	2.5	-10.1	4.4	3.5

[1] At constant 1990 prices.

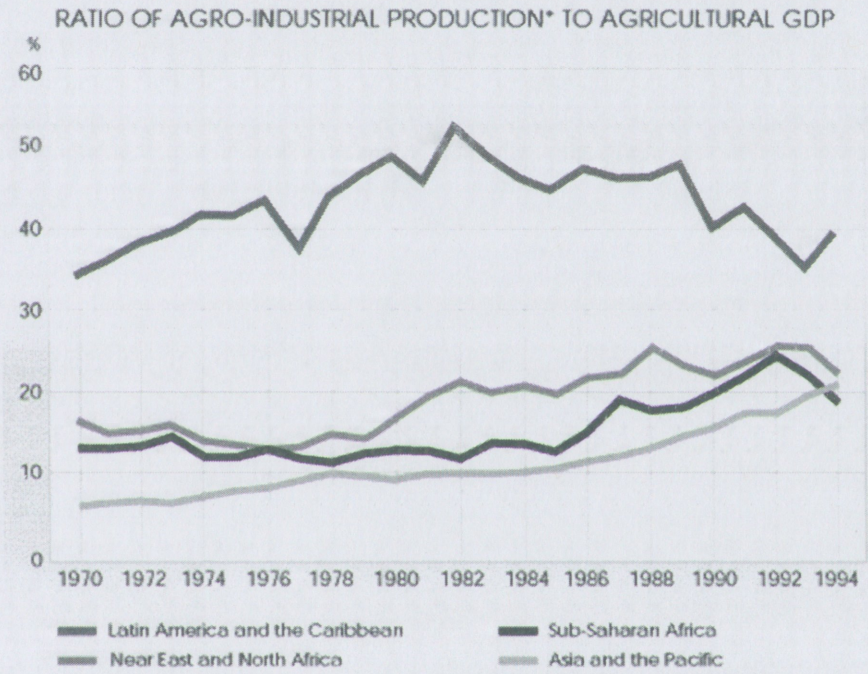
At the global level, the food, beverages and tobacco industries are dominated by the developed countries, which in 1994 accounted for about 80 percent of the world value added in the subsector, with western Europe and North America together accounting for nearly 60 percent.



In the developing countries, the lion's share of total production in the subsector is accounted for by Asia and the Pacific and Latin America and the Caribbean, each with approximately 45 percent of developing country production. Yet, while Latin America and the Caribbean, once dominant among the developing country regions, has seen its share decline significantly in the course of the 1980s from the 50 to 60 percent of the 1970s, the share of Asia and the Pacific has expanded rapidly over the same time span. The decline in the relative position of sub-Saharan Africa has been dramatic: after peaking in 1983, its share in developing country production has contracted steadily, falling below that of the Near East and North Africa.



Expressed as a ratio to agricultural GDP, value added in food, beverages and tobacco provides a broad indicator of the importance of processing relative to primary agriculture. As emerges from the figure, processing has always been an important component of overall agrifood production in Latin America and the Caribbean, indicating a relatively greater sophistication of the whole food chain in that region. However, processing has tended to lose importance *vis-à-vis* total agricultural GDP since the early 1980s in this region.



In all the other developing regions, processing has gained in importance relative to primary agricultural production, most notably so in the case of Asia and the Pacific.

DEVELOPMENTAL ROLE OF THE AGROPROCESSING INDUSTRY

Theoretical and empirical studies of the structural changes that accompany the development process have revealed a number of constant patterns. The most basic is a secular decline in the relative weight of the agricultural sector *vis-à-vis* non-agriculture as per caput income increases. This relative decline is observed as a fall in the share of agriculture in value added, employment, trade and per caput consumption. This goes together with a drop in the share of primary agricultural production in the value of the final product, and with a parallel increase in the agroprocessing industry value added.

These observations have emanated the popular prescription that development necessarily involves a transfer of resources out of agriculture and that this is largely coterminous with industrial development. More recently, however, the development debate has increasingly focused on the far more relevant issue of whether and how the

agricultural sector can be expected to make an optimum contribution to the overall process of economic growth. This question can be asked both regarding the size and functioning of the agricultural sector itself and regarding its links with the rest of the economy. More specifically, it can be argued that the development of agro-industry, for those countries with a comparative advantage in this sector, may contribute to achieving the proper balance between agriculture and industry.

A precise theoretical rationale for emphasizing the role of agro-industry during the process of development is provided by Hirschman's linkage hypothesis,[2] which postulates that the best development path lies in selecting those activities where progress will induce further progress elsewhere. Thus, an activity that shows a high degree of interdependence, as measured by the proportion of output sold to or purchased from other industries, can provide a strong stimulus to economic growth. While the issue of linkages will be discussed in some detail later, the general observation can be made here that, because of its high degree of interdependence with forward and backward activities, agro-industry can play a very important role in accelerating economic activity.

POTENTIAL FOR AGRO-INDUSTRY IN DEVELOPING COUNTRIES

The potential for agro-industrial development in the developing countries is largely linked to the relative abundance of agricultural raw materials and low-cost labour in most of them. The most suitable industries in such conditions are indeed those that make relatively intensive use of these abundant raw materials and unskilled labour and relatively less intensive use of presumably scarce capital and skilled labour.

Many of the industries using agricultural raw materials have in fact those characteristics that make them particularly suitable for the circumstances of many developing countries. Where the raw material represents a large proportion of total costs, its ready availability at a reasonable cost can often offset such disadvantages as a lack of infrastructure or skilled labour. Furthermore, for many agro-industries, a small plant may be economically efficient, which is another important factor in developing countries where the domestic market is limited by low purchasing power and sometimes by the small size of the market itself.

Table. Labour productivity and cost structure in agro-industry

Value added per employee varies widely, both among countries and among different branches of agro-industry. The Table shows value added per employee in food processing for selected countries, ranging from a high of $102 300 per worker in the United States to a low of $1 700 in India, among the countries covered. The disparities are also substantial – more than 10:1 – between NIEs (*e.g.* the Republic of Korea, Singapore and Hong Kong) and the low-income countries (*e.g.* China, Kenya and India), no doubt reflecting differences in the technologies used as well as in managerial and operative skills. The Table also shows that, as expected, wage levels rise with productivity. In food products, annual wages per employee range from a low of $600 in Indonesia to a high of $27 800 in Germany. Workers in the food industry in Singapore are paid 20 times as much on average as those in Kenya and India.

As for the cost structure, raw materials and utilities (water and power) account for well over half the total cost of production in food processing (column 3). In most countries the cost of these inputs represents between 60 and 90 percent of the gross value of production. The proportion tends to fall as productivity rises. Peak levels were found in Kenya and India, where the cost of raw materials and utilities constituted 93.1 and 87.7 percent, respectively, of the value of output in 1993. Labour costs, expressed as a percentage of the total value of output, fluctuates within a relatively narrow range, but the share tends to be higher in the industrialized than in the developing countries. Operating surplus covers the returns to capital and entrepreneurship in the form of interest payments, profits and dividends. The data do not reveal any clear-cut pattern. The level of operating surplus seems to depend more on the market conditions and degree of competition prevailing in each country than on the nature of the technology used.

Table. Selected indicators for the food industry[1] in various countries, 1991-93

Countries	Value added per employee ($'000)	Wages per employee ($'000)	Materials and utilities (%)	Percentage in output Labour (%)	Operating surplus (%)
INDUSTRIALIZED					
United States	102.3	24.0	61.8	8.9	29.3
Germany	87.3	27.8	66.2	10.8	23.0
Japan	83.3	26.7	60.7	12.6	26.7
Italy	66.1	..	79.5	12.4	8.1
France	63.8	..	69.5	15.3	11.4
United Kingdom	56.0	20.9	64.8	13.2	22.0
Russian Federation	8.4	1.9	62.9	8.3	28.8
DEVELOPING					
Korea, Rep.	50.1	10.7	60.0	8.6	31.4
Singapore	37.5	14.6	68.2	12.4	19.4
Chile	25.7	5.1	62.1	7.6	30.3
Hong Kong	23.6	11.4	66.3	16.3	17.4
Malaysia	15.2	3.6	84.5	3.7	11.8
Thailand	12.3	2.0	72.8	4.5	22.7
Ghana	6.9	1.4	65.0	7.4	27.7
Indonesia	6.1	0.6	64.8	3.7	31.5
China	3.8	3.5	71.0	3.5	12.5
Kenya	2.8	0.7	93.1	1.6	5.3
India	1.7	0.7	89.7	4.2	6.1

[1] ISIC 3.1.1/1.2.

The factors actually determining the most economic location for an agro-industry are complex. Generally transport is a main factor. Most agricultural products either lose weight and bulk in processing, meaning they can be transported more cheaply after they have been processed, or they are perishable and so can be more easily transported in processed form. The situation is also affected by labour supplies and the availability of power and other infrastructure, but industries based on these products can often be set up economically in the area where the raw material is produced. They can therefore contribute to the relief of the rural underemployment which is characteristic of developing

countries. There are, however, exceptions. For most grains, shipment of the raw material in bulk is frequently easier, while many bakery products are highly perishable and thus require production to be located close to the market. Oilseeds (except for the more perishable ones such as olives and palm fruit) are also an exception and can be transported equally easily and cheaply in raw form or as oil, cake or meal, so there is more technical freedom of choice in the location of processing. The same is true for the later stages of processing of some commodities. For example, while raw cotton loses weight in ginning, which is consequently carried out in the producing area, yarn, textiles and clothing can all be transported equally easily and cheaply.

Where there is a high degree of technical freedom in the choice of location, industries have frequently tended to be located in proximity to the markets because of the more efficient labour supply, better infrastructure and lower distribution costs in the large market centres. With production for export, this factor has often tended to favour the location of processing in the importing country. This tendency has been reinforced by other factors, including the need for additional raw materials and auxiliary materials (particularly chemicals) that may not be readily available in the raw material-producing country; the greater flexibility in deciding the type of processing according to the end use for which the product is required; and the greater regularity of supply and continuity of operations that are possible when raw materials are drawn from several different parts of the world. However, with improved infrastructure, enhanced labour efficiency and growing domestic markets in the developing countries, there is increased potential for expanding such processing in the countries where the raw materials are produced. In addition, with growing liberalization of world trade, more developing countries will be able to take advantage of lower labour costs to expand their exports of agro-industrial products.

One further aspect of importance for the location of agro-industries would appear to be the possible existence of economies of scale. Where there are considerable economies of scale (as in the production of rubber tyres and pulp and paper), large markets are of course essential. The size of market needed for economic production in such cases may be far in excess of the domestic market in individual developing countries, where it is limited not only by the low level of per caput income but also by the frequently small size of the total population. However, although in most agro-industries average costs of production can be reduced as the scale of plant is increased, the importance of economies of scale should not be exaggerated. The lower cost of production with a large-scale plant results not only from the spreading of capital and other overhead costs, but also from the frequently smaller labour requirements per unit of output in the larger plant, an aspect which is of less importance in developing countries where labour costs are low.

THE SPECIFICITY OF AGRO-INDUSTRY

Processing is only one link in a continuous chain between raw material production and final consumption. The specificity of agro-industry *vis-à-vis* other industrial

subsectors lies largely in the biological nature of the raw material. The raw materials used by agro-industry are generally characterized by the seasonal nature and the variability of their production as well as by their perishability. These aspects put particular demands both on the organization of agro-industrial activities and on the agricultural base producing the inputs, thereby adding to the need for a close integration of raw material production and processing.

Crop and livestock production cannot be controlled with great accuracy and tends to vary sharply from year to year owing to the effects of weather and pests and diseases. It is possible to some extent to reduce these fluctuations through the better use of soil and water resources and control of pests and diseases. It is generally in the interest of the processing enterprise, which requires as regular a supply of raw material as possible, to ensure or promote implementation of these measures by producers.

Furthermore, for most crops production tends to be concentrated in a particular season. It can therefore be advantageous for processing enterprises, particularly those engaged in canning and freezing, to promote the production in a particular area of a suitable range of crops and varieties maturing in different seasons in order to keep processing facilities in operation for as long as possible. The perishable nature of many crop and livestock products also requires close contact between the producer and processor as well as advance planning to keep losses to a minimum.

However, the most impelling reason for the necessity of this close contact arises from the possibility of controlling the quality of the raw materials. Their quality can be influenced by such factors as the choice of seed; the application of fertilizers; the control of weeds, pests and diseases; and sorting and cleaning. Processors are interested not only in obtaining uniformity in the quality of their raw material supplies, but in some cases their needs are quite specific. Particular varieties of some crops (for example, of tomatoes, apples and pears for canning) have long been grown for processing, but the need for such varieties is increasing as food technology develops more advanced processes. Often there are specific requirements for such factors as shape, size, texture, colour, flavour, odour, acidity, viscosity, maturity, specific gravity, soluble solids, total solids and vitamin content.

The initiative for the introduction of different varieties and practices has usually come from the processing enterprises. As a result, for some commodities, especially fruit and vegetables for canning and freezing, raw material production and processing are increasingly "vertically integrated" in the developed countries through various forms of contract farming. In the developing countries, the large-scale plantation production of such crops and sugar, coffee, tea, sisal and rubber is based on the vertical integration of raw material production and processing.

LINKAGE EFFECTS

From the point of view of development strategy, one of the most important features of any industry is the degree to which it is able to generate demand for the products of

other industries. This phenomenon is known as linkage. An industry may encourage investment both in subsequent stages of production by "forward linkage" and in earlier stages through "backward linkage".

The establishment of certain primary processing industries can lead, through forward linkage, to a number of more advanced industries. Forest industries are particularly valuable as a base on which other industries can be established in this way. Once paper and paperboard production has been started, a large number of conversion industries can emerge, such as the manufacture of paper bags, stationery, boxes and cartons, wooden containers, furniture and a wide range of timber products. There are many other examples: products such as vegetable oils and rubber are used in a wide variety of manufacturing industries; based on the preparation of hides and skins, tanning operations can be started, as can the manufacture of footwear and other leather goods.

The development of agro-industries also has many beneficial feedback effects on agriculture itself. The most direct one is, of course, the stimulus it provides for increased agricultural production through market expansion. Often, in fact, the establishment of processing facilities is itself an essential first step towards stimulating both consumer demand for the processed product and an adequate supply of the raw material. The provision of transport, power and other infra-structural facilities required for agro-industries also benefits agricultural production. The development of these and other industries provides a more favourable atmosphere for technical progress and the acceptance of new ideas in farming itself.

The capacity of agro-industry to generate demand and employment in other industries is also important because of its growing potential for activating "sideway linkages"; that is, linkages that derive from the use of by-products or waste products of the main industrial activity. For example, animal feed industries can utilize several agro-industrial by-products, such as whey, oilseed presscakes and blood, carcass and bone meal. In addition, many industries using agricultural raw materials produce waste that can be used as fuel, paper pulp or fertilizer. Recycling and biological agriculture are two activities that go together to respond to the idea of a sustainable form of exploitation of natural resources within an efficient industrial context.

An effect that is sometimes overlooked is the substantial increase in employment that may result from setting up an industry using a raw material. Even if the industrial process is itself capital-intensive, considerable employment may be generated in providing the raw material base. Finally, agro-industry gives rise to a demand for a wide variety of machinery, equipment, packaging materials and intermediate goods used in the processing itself.

THE AGROPROCESSING INDUSTRY IN THE PROCESS OF DEVELOPMENT

The role of agro-industry as a sector of the economy has multiple facets and changes in the course of development. In the early stages of growth, industrial processing of agricultural products tends to be limited to a few export crops, while the majority of

agricultural products are consumed after minimal forms of processing that are performed entirely within the agricultural sector. Upstream processing industries prevail in their more primitive form, such as rice and flour milling, oil pressing and fish canning. An example of this stage would also be the plantation economy, where agro-industry and primary agriculture appear as a vertically integrated activity, with upstream processing taking over the agricultural base through a production system that is often founded on forms of disfranchisement of labourers and small cultivators.

Other cases of apparently more diversified agro-industrial activities, based on fruits and vegetables or livestock products, may be equally primitive in their organization, the low degree of value added produced and the lack of linkages both with the chemical and mechanical industries and with marketing and financial services. Such is the case for Egypt where, in spite of the growth of vegetable and fruit production and the related transformation industry, primary agriculture still accounts for almost 90 percent of the intermediate goods purchases of the industry, while a longer chain of links has developed only for livestock-related products. Similarly, a large share of agricultural raw products in total intermediate purchases characterizes most agro-industrial production of tropical beverages and other products originating from plantation crops, as well as vegetables, fruits, tobacco and livestock in the first stage of domestic industrial development.

Even in the case of limited backward linkages outside agriculture, food processing in the early stages of development can be an important direct complement to agriculture as a source of employment for seasonal labour. It requires very little investment and provides ample opportunities for expanding value added by using underemployed resources as well as for improving incomes and nutrition. Cottage industries of various forms are found in almost all areas where agriculture is sufficiently diversified, and there is scope for extending the range and timing of production both for dietary reasons and as a hedge against uncertainty. The off-farm employment opportunities provided by food processing may thus represent the first instrument of time-smoothing in the labour market and, as such, is an important factor of capital accumulation in rural areas.

Morocco provides an example of a more advanced stage of development of agro-industry, characterized by some more sophisticated downstream industrial activities, but where off-farm employment nevertheless remains the industry's main engine of growth. In this country, the presence of a well-developed food preserve industry for tomato sauce, fruit juices and other canned fruit ensures stronger links with sectors other than agriculture, both as providers of inputs (chemicals, glass, aluminium and paper) and as dependent sectors of further processing (marketing services). The food industry in Morocco is estimated to purchase only about 70 percent of its raw materials from agriculture, while the final product sold to the consumer and exported in increasing quantities contains more than 45 percent of non-agricultural products.

A further stage of development of agro-industry as a producer of food and beverages can be observed in a number of middle-income countries, such as Turkey, Argentina

and Chile. This stage is characterized by full development of the forward linkage chain, with several marketing and other services incorporated in the final product, and product innovation prevailing over process innovation to provide a competitive advantage and sources of growth to the firms in the market. The linkage with the marketing chain tends to be well established, with both organizational and financial links between the producers and the retail outlets. The pace at which new products are introduced is extremely high, and this testifies to the importance of product innovation in this phase of the industry cycle.

Finally, for high-income areas such as the EU or the United States, the mature stage of the food industry still appears to be very dynamic. While the backward and forward links do not go much beyond what has already been achieved by third-stage firms in middle-income countries, a separate series of linkages develops through the production of specialized machinery and process innovation. Because of their size, market leadership and degree of internationalization, the food-producing companies located in the high-income countries are often instrumental in setting the base for a whole technology of processed food production. The areas involved range from the planning and quality control of agricultural products and other raw materials, to the design and manufacture of machinery, specification and monitoring of the production cycle and the provision of specialized financial and other services.

Thus, the multiplicative power of the agroprocessing industry throughout the economy through the linkage effects appears to be an important factor of growth both for developing and developed countries. An additional reason why agro-industries are especially effective in activating demand from the upstream and downstream sectors lies in the position of food in the consumption chain. Thus, even at a relatively low level of sophistication with limited backward and forward linkages, agro-industries may still be particularly effective in channelling increased global demand into increased output. This is so because, at the earlier development stages, a high share of private expenditure is directed towards cereals and other staples and, later on, as development progresses, towards fruits and vegetables and other food products whose income elasticity is relatively higher. At later stages of development, it is the growing integration of the producing sectors that mainly ensures the capacity of food production to activate the rest of the economy, although the contribution of consumption to the industry multiplier remains sustained through diversification and growth of products with higher income elasticities.

An important feature of agroprocessing industries is that they are a major source of employment and income, thus providing access to food and other necessities to large groups of population. They are, therefore, essential elements in the attainment of food security goals.

Agroprocessing industries (food, beverages and tobacco) typically employ about 10 percent of the total labour force employed in manufacturing in the developed countries and around 20 to 30 percent in the developing countries. The highest shares are found

in Africa, where they reflect at once the poor development of the other manufacturing sectors and the pioneering role of agroprocessing, and, to a lesser extent, in the Latin American countries in the sample. The share of agroprocessing wages and salaries in total wages in manufacturing. By comparing both shares, it appears that, in the developed countries, earnings in agricultural processing were on the whole lower than for other manufacturing activities. For the developing countries, patterns are less distinct, but available data indicate that agroprocessing wages compare favourably with those in most other industrial activities, except those sophisticated activities that generally require more skills and training (such as aircraft, motor vehicles, structural metal production, cement and chemicals).

A factor underscoring the importance of agroprocessing activities as sources of employment and earnings relates to the differences in productivity between, on the one hand, raw material production – where gains have been in many cases spectacular – and, on the other hand, agro-industry. Although intrasectoral comparisons may be misleading (unlike raw materials, volume gains in agro-industrial output may be relatively small per unit of input, but undergo significant quality change), faster progress in labour productivity at the farm level may suggest less ability to create, or retain, employment, than agroprocessing.

Further, the share of costs arising from primary products in total processing is in many cases so low as to be of minor significance to the food company. As economic growth and development proceed, the dynamic role of agroprocessing industries must be appraised in the framework of the increasing complexity of food systems and other agriculture-, fisheries- and forestry-based systems. This growing sophistication is accompanied by shifting relative weights of the value added and employment generated at various stages within these systems.

The growth of labour productivity, which is typically faster in agriculture than in other sectors of the economy, contributes to the release of labour force and hence its availability for other sectors, and to the decline of the value of the primary output of agriculture in the value of the final, processed goods. This is particularly noticeable in food products; the share of food in the average consumer's expenditure, in the order of 20 percent in high-income economies and 40 to 60 percent in medium- and low-income countries, compares with shares that are several times lower for the value added of agriculture in GDP. The agroprocessing sectors, as well as the trade and distribution sectors, account for most of this gap.

The ability of domestic agroprocessing to capture this economic opportunity and to contribute to progress in the agricultural sector, particularly in the quality dimension, is of great promise for the developing countries. This also underscores the continued significance of agriculture through its role as the basis for economic diversification, at the national as well as at the local level, since much of agroprocessing is taking place and can be developed at a local level, thus contributing to a decentralization of economic and social progress.

Table. Share of agroprocessing employees[1] in total employees in manufacturing, and share of agroprocessing wages in total wages in manufacturing in selected countries, 1992

Countries	Agroprocessing employees out of total employees in manufacturing	Wages to employees in agroprocessing/total wages in manufacturing
	(percentage)	
DEVELOPED		
United States	9.1	7.8
Finland	13.0	12.8
Germany	7.2	5.9
Canada	13.6	12.6
Sweden	9.8	8.8
TRANSITION		
Bulgaria	11.7	13.4
Croatia	15.3	16.7
Kyrgyzstan	12.5	10.8
Russian Federation[2]	11.2	19.6
Lithuania[3]	18.7	23.7
Hungary[3]	20.1	21.5
DEVELOPING		
Africa:		
Cameroon	35.9	38.6
Kenya	32.4	28.4
Botswana	26.1	36.9
Senegal	59.3	55.6
Zimbabwe	17.7	24.4
Asia and the Pacific:		
India	22.8	12.0
Indonesia	20.2	14.5
Korea, Rep.	7.2	6.2
Malaysia	8.4	8.6
Philippines	20.9	22.6
Sri Lanka	20.5	20.3
Latin America and the Caribbean:		
Argentina[2]	27.6	25.2
Brazil	33.0	12.5
Colombia	22.1	22.7
Ecuador	36.1	33.2
Mexico	20.9	17.6
Peru	23.5	25.5

[1] Food, beverages and tobacco. [2] Data refer to 1993. [3] Data refer to 1994.

TURNING A POLLUTANT INTO A VALUE: THE CASE OF WHEY

Whey, the liquid residual of cheese and casein manufacture, is one of the biggest reservoirs of food protein that still remains outside human consumption channels. Yet a large proportion of total whey supplies is still wasted. Traditionally, whey was considered an undesirable element, of little interest at best, and costly to get rid of at worst. The most common practice was simply to dump it in waterways, a particularly damaging

practice from the environmental viewpoint – it is estimated that a cheese factory producing 250 000 litres of whey per day can pollute as much water as does a city of 50 000 inhabitants. A less damaging practice was to feed it to calves or pigs as a supplement to their normal diet. With the development of the cheese industry, it became evident that these traditional solutions were insufficient to cope with the problem of whey disposal. Anti-pollution regulations were introduced and progressively enforced in countries where whey is more abundantly produced, thus obliging cheese manufacturers either to process their whey or to install their own sewage facilities, at a negative unit return. As the former alternative was the lesser of two evils, the industry increased its efforts to develop its existing facilities, particularly for drying, as well as trying to find new uses for whey. Whey-powder production, mainly for feed uses, emerged as the most economic solution and, indeed, this form of industry has expanded considerably over the past decades. At the same time, whey began entering food consumption as an ingredient for a wide variety of products, particularly beverages such as the (originally Swiss Rivella) fruit-flavoured beverages with a high nutritional content, and even "whey champagne" and soft drinks produced on a commercial scale in some Eastern European countries.

Although dumping whey into waterways remains a serious problem in some countries, this practice has been largely reduced, particularly in the industrialized countries, thanks to the tightening of anti-pollution measures. These measures have also contributed to intensifying research into alternative uses of whey, thereby constituting an example of how encouragement and regulation can induce the industries themselves to turn polluting wastage into profit.

THE AGROPROCESSING INDUSTRY AND THE ENVIRONMENT

Despite their important contribution to overall and agricultural development, agroprocessing industries can also give rise to undesirable environmental side-effects. Left unchecked, like any other industry, agro-industry can create environmental pollution or hazards in various ways: the discharge of organic or hazardous wastes into water supplies; the emission of dust or gases that affect air quality and produce toxic substances; and the use of dangerous machinery that can put the safety and health of workers at risk. The seriousness of the pollution problems created by agro-industrial activity greatly varies, but it appears that food transformation activities are generally less energy-intensive and release less CO_2 and metal residues than most other industrial activities. In fact, agroprocessing industries, such as sugar mills, can become not only energy self-sufficient through the energy conversion of biomass residues, but also sizeable electricity producers that feed the national grid, thus reducing CO_2 emissions. The risks of pollution are relatively smaller at the initial stages of preservation and transformation, but they may increase with the level of physical and chemical alteration, particularly in the industries using dated equipment and technology (new technologies are less polluting than old ones in terms of wastes and emissions per unit of output). The size of the

industry may be an important factor, but not determinant in itself. In fact large, centralized agro-industries can be important sources of punctual pollution, but smaller-scale industries can also generate scattered pollutants with a cumulative effect in a given geographic region. This is especially so since small industries, particularly in low-income countries, lack the financial resources to use modern and clean technologies. The damages and hazards caused by agro-industrial pollution may be all the more serious and immediately perceived since these industries tend to be concentrated in urban and peri-urban areas. Finally, the incidence of agro-industrial wastage and pollution depends to a very large extent on the efficiency of the legislative setting and regulatory action taken to protect the environment. Anti-pollution regulation can be an important contributor, not only to reducing the release of polluting residues, but also to using them in profitable ways. However, many countries still lack a policy framework that adequately addresses the environmental factor as well as the institutional, legal and monitoring structures to implement pollution control measures effectively.

CHANGING CONDITIONS FOR THE AGROPROCESSING INDUSTRY

AGRICULTURAL SUPPORT AND TRADE REGIMES AND PATTERNS OF AGRO-INDUSTRIAL PRODUCTION

National food and agricultural policies and international trade policies are a major factor determining the international division of labour and the geographical distribution of agricultural and agro-industrial production. Studies of domestic and international market prospects for food and agricultural products are essential to decisions on the set of policies that will enable producers and processors to gain competitiveness and take advantage of market opportunities.

Policies that affect the prices of inputs and outputs to producers, processors and consumers are of critical importance. Therefore, special attention should be given to policies regarding taxation, subsidies, direct price support and tariffs, both in the short and the long term.

The temptation exists for policy-makers to provide incentives or preferential treatment to the industries supplying inputs, or to producers, processors or final consumers of food. These policy interventions are provided in various forms: tax concessions to producers of inputs and products, subsidies on prices of inputs or food, support prices for producers at relatively high levels, protective tariffs or other international trade barriers. The sustainability of such policies must be given careful consideration before adoption, as history is full of examples of the disastrous consequences associated with the abrupt removal of such preferential measures.

It is important that policies applied at all levels of the food production and processing system are compatible and work towards the achievement of the same goal. Whether in

the form of a tax, subsidy, support or tariff, policy interventions must generate net benefits for society. In other words, the loss in fiscal revenue from a reduction in taxes must be more than offset by the increase in jobs and benefits associated with the industry; the cost of a subsidy must be more than offset by gains for the direct and indirect recipients of such a subsidy; relatively high prices must ensure the required increase in production and expansion of the industry concerned, with benefits in terms of employment and income; and the subsidy to final consumers must have net benefits in terms of nutrition and productivity.

An important aspect of agricultural protection policies is the phenomenon that tariffs on processed agricultural products have generally been higher than those on their primary commodities. This tariff wedge between a processed commodity and its corresponding primary commodity is often referred to as tariff escalation. Developing countries have for many years identified tariff escalation as a major issue concerning market access and an important obstacle to their efforts to establish processing industries. However, most of the empirical studies on this process are by now outdated. A recent study by FAO analyses the impact of the Uruguay Round on tariff escalation for agricultural products in the EU, Japan and the United States. The study shows that tariff escalation has been reduced as a result of the Uruguay Round, creating some opportunities for developing countries to diversify their exports into higher-value processed commodities. The study concludes, however, that high levels of escalation will still remain after the implementation of the Uruguay Round concessions.

In many developing countries, from colonial times at least until the early 1980s, agriculture tended to be directly or indirectly taxed through a combination of measures involving forced procurement at prices below market prices, taxation of inputs, subsidization of manufactures and overvalued exchange rates. However, this phenomenon presented very diversified situations. On the one hand, for tropical beverages, oils, alcohol and tobacco, often against a backdrop of underpaid or taxed agriculture, huge subsidies were paid to the processing industry, which was either organized in the form of parastatals (as in Africa), or controlled by multinationals (as in Central America and Asia), or again characterized by a tight oligopolistic structure (as in much of Latin America).

On the other hand, the rise of a modern food processing sector has often been delayed or even suppressed by the combination of agricultural taxation and consumption subsidies characteristic of traditional food policy in developing countries. Food distribution systems, in particular, have relied on forced procurement and import subsidies, thus lowering simultaneously the supply of local produce and prices of processed food products. Incentives to develop local manufactures for a variety of food products have thus been artificially depressed, especially in sectors such as dairy products, packed meat and wheat derivatives. On the other hand, in several developing countries the rise of a domestic fruit and vegetable processing industry has been indirectly encouraged by the punitive policies adopted against the production of basic food items. A policy of

"benign neglect" or, in some cases, of open subsidization in favour of irrigated crops has thus favoured the growth of an agro-industrial complex based on fruits and vegetables in such diverse countries as Morocco, Turkey, Mexico and Chile. Similarly, in the case of tropical fruits, many new industrial enterprises have been successful in producing fruit juices, preserves and products for domestic industries as a result of the relatively high profitability of these products, technological advances in the transformation processes and the need to diversify out of sugar and other plantation crops.

An interesting example of a development of the latter type is Brazil, where the production of juices from tropical fruits has increased more than twentyfold in the past ten years. These fruits, produced mostly in the northern and northeastern areas of the country, used to be consumed in processed form only in local markets, mainly because the technology did not allow the production of juices with the amount of chemicophysical stability necessary to maintain the organoleptic characteristics of the product at a commercially acceptable level. This technological barrier has been completely overcome in the course of the 1980s. As a consequence, the Brazilian industry that processes tropical fruits, together with the production of fruits themselves, has greatly expanded and acquired a large share of the export market where, for certain products (*e.g.* maracujá) it almost has a monopoly.

A special problem of change that concerns both food price policies and the processing industry is the transition to market economies of the former centrally planned economies of Eastern Europe and the CIS. Here the pricing system prior to transition was characterized by extreme subsidies to both food producers and consumers. While roughly two-thirds of agricultural land was in the hands of state or collective farms, virtually all agro-industries were state-owned monopolies. These paid little attention to quality and technological development, even for products that were high-value sources of foreign exchange (such as caviar). The transition process has changed the economic environment by removing or substantially reducing food subsidies, by privatizing agriculture and industry and by deregulating local markets. In the absence of a comprehensive liberalization programme, however, new disequilibria have been created. Higher retail prices for food are often not transmitted to farmers because the processing industry is free to use market power to appropriate monopolistic rents. At the same time local producers are faced with strong competition from imports of higher-quality, Western processed food.

The current trend towards liberalization and increased market-orientation of agricultural policies opens a series of interesting perspectives for agricultural and agro-industrial producers. In an international macroeconomic framework characterized by low inflation and low interest rates in the industrialized countries, international trade should receive a significant impulse, especially in liberalizing agricultural markets. Growth prospects appear favourable, particularly because of the increasing diversity of food consumption, the switch to high income-elasticity goods and the increasing importance of marketing and processing. These phenomena could result in a massive

reallocation of agricultural products along new lines of comparative advantage, following both the new market perspectives and the possibilities disclosed by technology and the evolution of tastes.

Moreover, in many developing countries, from the mid-1980s onwards and in the wake of the general move towards increased liberalization and market orientation, there seems to have emerged a new consciousness of the importance of agriculture and related sectors.

In many cases this new awareness has coincided with important policy changes such as the privatization of government-owned marketing and processing companies and with the end of the willingness to subsidize private oligopolies in the commodity sector. The stage appears to have been set, therefore, for an endogenous growth of the domestic food industry wherever a comparative advantage can be exploited. Nevertheless, it must be emphasized that, in many cases, discrimination against domestic agrifood industrial activities in developing countries continues, as the discriminatory policies have only attenuated rather than disappeared.

EVOLUTION OF TECHNOLOGY AND FOOD CONSUMPTION PATTERNS

Additional factors shaping the future of agro-industrial production and trade are developments occurring in technology and food consumption patterns, most noticeably in the industrialized countries. In this respect, technological development in agriculture is going through a transition phase of great interest. On the one hand, improvements in production techniques based on traditional chemical and mechanical innovations have permitted exceptional increases in yields and large improvements in quality, mainly concerning product homogeneity and lack of physical defects. On the other hand, more recent trends in agricultural research and technology point to different models, based mostly on innovations of a biological and biotechnological type as well as on modern processing technologies.

Thus, while, historically, productivity growth and price gains achieved through processing innovations have been paramount in primary agriculture, and have been easily transferred to the agro-industrial sector, product innovations are also beginning to materialize. Although the resulting improved variety and quality of final products do not necessarily go hand in hand with lower costs, the innovations promise to increase efficiency in agro-industry and, through the correspondent increase in demand for agricultural inputs by the processing industry, they can contribute to mitigating the tendency towards price declines facing primary producers.

Parallel to technological development, patterns of food consumption in industrialized countries are evolving. Between 1969-71 and 1990-92 the share of cereals, sugar and roots and tubers declined at the world level, while that of livestock products, fish and vegetable oils and fats tended to rise. There were significant variations in the patterns among country groups and regions, however. In the developing regions, for instance, the increased share of animal products was most evident in East and Southwest Asia,

followed by South Asia and Latin America and the Caribbean countries, whereas a similar increase did not occur in the Near East and Africa. The variations were equally significant between developed and developing countries. In the example of sugar, the overall reduced share reflected a marked decrease in the developed countries' share, as that of the developing countries increased.

In industrialized countries two different types of force are shaping food consumption patterns, of which the final effects on the quality, composition and geographical allocation of production are difficult to predict. One is represented by an increasing concern for health and fitness.

This was one reason for the marked decline in per caput food consumption of sugar. Also, while the consumption of livestock products has increased significantly over the past decades, the relative importance of these products is progressively decreasing, while a premium is put on products such as vegetable products and fruits which, until only recently, were considered complementary in nature and largely of lower value relative to animal products. These trends are expected to continue in future years, as shown by the example of European countries.

Fish and other marine and water products, the supply of which is enhanced and enlarged by the growth of aquaculture and other farming techniques, have also become choice foods in the diet of higher-income earners in the developed countries. Another aspect of this tendency is the revaluation of those characteristics of food products that can be traced back to an "original" or "natural" pattern of production. In addition, another biological agriculture, which appeals to environmentalistic attitudes and value judgements of intrinsic characteristics of food, is part of the tendency, as is the trend towards more nutritious products, which also possess other desirable dietary properties. These changes in the dietary patterns of middle-income brackets in developed countries mark a transformation of attitudes which is likely to have profound implications for food production patterns.

Table. Share of major food groups in total dietary energy supply (DES), 1969-71 and 1990-92

Food group	World		Developed countries		Developing countries	
	1969-71	1990-92	1969-71	1990-92	1969-71	1990-92
	(percentage)					
VEGETABLE PRODUCTS	84.4	84.3	71.7	70.9	92.3	89.7
Cereals	50.1	51.2	32.6	30.4	60.9	59.6
Sugar	9.1	8.8	13.2	12.8	6.6	7.2
Vegetable oils and fats	5.7	8.2	8.2	11.1	4.1	7.0
Roots and tubers	7.5	5.0	5.0	3.8	9.0	5.4
Vegetables and fruits	4.2	4.3	4.5	4.9	4.5	4.8
Pulses and nuts	4.8	4.0	2.3	2.3	2.3	4.7
Alcoholic beverages	2.7	2.4	5.3	4.9	5.3	1.3
Stimulants and spices	0.4	0.4	0.4	0.6	0.4	0.4
ANIMAL PRODUCTS	15.6	15.7	28.3	29.1	7.7	10.3
Meat and offal	6.4	7.4	11.1	12.8	3.5	5.2
Milk	4.8	4.3	8.9	8.6	2.2	2.6
Animal oils and fats	2.7	2.0	5.4	4.4	1.0	1.1
Eggs	0.8	0.9	1.5	1.8	0.3	0.7
Fish	0.9	1.0	1.4	1.3	0.6	0.7

Table. Growth rate in per caput consumption of selected foods, Western Europe, 1970-90 and 1988-90 to 2010

	1970-90	1988-90 to 2010
	(percentage)	
Cereals and products	0.2	-0.2
Potatoes	-0.4	-0.4
Sugar	-0.5	0.0
Pulses	1.4	0.0
Vegetables and products	1.3	0.5
Fruit and products	0.8	0.8
Vegetable oils	1.3	0.8
Milk and products	0.7	-0.3
Eggs	-0.5	-0.2
Meat and products	0.8	0.4
Population growth rate	0.2	0.1

On the other hand, modern food production technology tends to multiply the variety of products derived from original, natural products. A proliferation of goods that incorporate innovations in form, colour, organoleptic and conservation properties is flooding the supermarkets and presenting consumers with alternative choices. The return to "naturalness" and the artisanal nature of original food is thus matched, somewhat paradoxically, by an increase in the artificial nature of these new products, especially the more industrially sophisticated ones. The challenge to the food industry, in this case, is to try to reconcile the two tendencies through processing and product innovation.

An important issue is the extent to which changes in consumption patterns and the growing importance of transformed or processed food in total food consumption may affect consumer safety. In general, the contribution of agrifood industries to raising the quality, variety, nutritional value and safety of food cannot be overstated. However, risks of food infection may arise at all the stages of the food industry – production, transformation, packaging, storing and transport. Also, if inadequately controlled, the growing sophistication of the product, with the addition of preservatives, additives and other substances that may enhance its market value, may be a source of greater risk for consumers. A further factor affecting food quality and safety is the intensification of trade in food products, resulting from the general process of interdependence of agrifood systems and factors such as shifts in tastes and preferences towards well-publicized imported products, and greater demand for convenience foods. Intensified trade flows, however, raise the potential of exposing consumers in one part of the world to the food quality and safety problems of other regions. Rapid transport and increased shelf-life technology may allow for contaminated products to reach their intended destinations more quickly and remain on the market longer, thus affecting greater numbers of consumers. These problems raise the importance of adequate food standards and mechanisms for the rigorous vigilance and monitoring of the quality and safety of processed foods, of both domestic and foreign origin.

EVOLUTION OF THE AGROPROCESSING INDUSTRY AND DEVELOPING COUNTRIES

The developments in international agro-industry discussed here have implications for developing countries and the possibility of developing their agro-industrial sectors. Thus, on the one hand, the gradual process towards increased liberalization of trade and market-orientation of domestic policies in the developed countries will hopefully offer increasing opportunities for developing countries. On the other hand, the need to adapt production to the increasingly sophisticated and demanding requirements of these markets poses challenges to both agriculture and agro-industry in countries wishing to supply these markets. Indeed, the success of a number of developing countries in expanding agro-industrial production and exports has to a large extent depended on their ability to meet the requirements of the developed countries' markets.

Because developed countries practically consume only processed food, as even fresh vegetables are variously cleaned, prepared and packaged when they reach distribution outlets, the development of agro-industries is increasingly becoming one with development of industrial agriculture. Indeed, although most of the so-called new agricultural exporters, such as Chile and Thailand, have expanded their capacity to provide markets with both fresh and processed products, on closer inspection, even "fresh" fruits and vegetables are themselves processed goods undergoing sophisticated operations in collection, quality control, packaging, storage, refrigeration and transport.

Even disregarding some of the more exceptional cases, agro-industry has been an important growth component in a great number of the better performing economies of the developing world. Econometric studies show that this new and integrated form of agricultural development is invariably based on productivity growth and technological development that are as rapid and spectacular as those occurring in the manufacturing sector. Many studies report higher growth rates of total factor productivity in the agricultural sector than in other sectors. Just as important for many countries is the drive towards diversification, as this allows them to end their dependence on primary goods, which often constitute a crucial obstacle to self-sustained growth. The economy-wide drive towards diversification can be accompanied by a tendency to diversify within the sector, with recourse to an increasing number of processing technologies that expand value added and productivity for agricultural products beyond the boundaries of traditional agriculture.

One characteristic of the new agro-industrial development is the increasing importance of processing and marketing activities. That this is a key to acquiring stable shares of international markets had been realized by Israel, which represents the success story of the 1970s and was the model for similar experiences in other countries. The extraordinary export growth achieved in the 1980s and 1990s by some countries has depended on the thorough planning of all product transformation phases, from the original producers to the final consumers. For off-season fruits and vegetables, for example, which have been one major expanding export of Chile, careful time planning has been

used to ensure that they arrive on the European markets precisely in the intraseasonal intervals when local products, including off-season produce, are not available.

SUCCESS STORIES IN EXPORT-ORIENTED AGRO-INDUSTRY

Up to ten years ago, Chile had a tradition of producing high-quality fresh fruits. The development of its capacity to export against the established producers of Europe, North America and Mexico was based on careful studies of potential competitive advantage, including cost, quality and marketing characteristics such as off-seasonality and timeliness of delivery. This effort, sustained over a trial period of three to five years, brought about an expansion of exports of unprecedented magnitude, not only for Chile's fresh fruit, but also for many of its agro-industrial products such as wine and food preserves. Timeliness in harvesting, processing and transport depend on an industrial marketing structure that coordinates sales contracts, temporary storage and quality controls in all phases of the product cycle. Reliability in terms of quality, timeliness of delivery and other contractual conditions (composition, prices, packaging, etc.) have gradually contributed to earning Chilean products a reputation that ensures them a stable share of the international markets.

In addition to product choices, seasonality and careful planning of other market characteristics, a more detailed analysis of the Chilean case reveals other key factors for success. Chilean agriculture took off in the 1970s, when a series of market-friendly reforms removed earlier restrictions and ended longstanding import substitution policies. In the growth of the agricultural sector, moreover, a major role has been played by transnational agro-industrial companies, which have planned the development of fruit production in a vertically integrated mode, according to modern industrial standards and by exploiting their experience of export markets.

Chilean agriculture also constitutes a good example of the sector's importance as an engine of aggregate growth of an economy. The process of diversification and integration of the agricultural sector has coincided with analogous diversification processes of the economy which, in the early 1970s, was still heavily dependent on the exports of copper (which represented more than 70 percent of export earnings). Industrial development and a widening of the production base, accomplished in the 1980s and the 1990s, have gone hand in hand with the development of a modern agro-industrial sector, at the bottom of which industrialized agriculture has shown productivity growth comparable with that of the most advanced manufacturing activities.

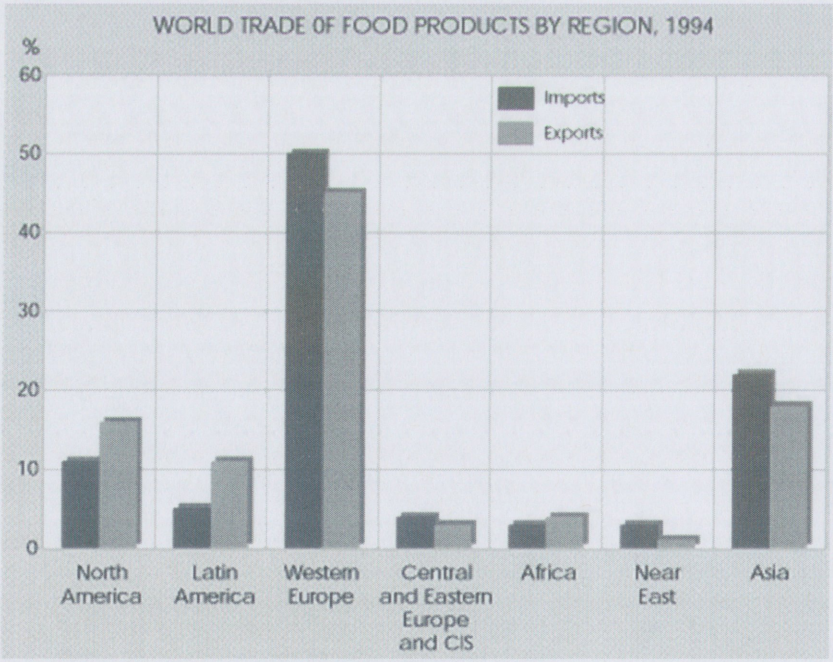
Another interesting success story is that of Thailand, which was among the world's top export performers in the 1980s when its exports expanded by an annual average of 13.2 percent in real terms, accounting for as much as 38 percent of GDP in 1990. Exports continued expanding dramatically during the first half of the 1990s, doubling in value between 1990 and 1995. Agro-industrial products, which were responsible for more than 65 percent of total exports, were developed by ensuring a market-friendly economic environment and providing adequate financial and support services. Some

elements of this success story also give an idea of the potential of agro-industry as a leading sector. Indeed, the number of manufacturing jobs in Thailand doubled between 1978 and 1991, with agro-industry accounting for 60 percent of all workers in manufacturing industries by 1990, and for 15.4 percent of GDP (up from 9.7 percent in 1960). Agro-industry grew at a rate exceeding 8 percent per year from 1980 to 1990 and, by 1990, numbered 32 000 private enterprises or 62 percent of the total number of establishments in the manufacturing industry.

THE INTERNATIONALIZATION OF AGRIFOOD SYSTEMS

AGRIFOOD TRADE AND INTERDEPENDENCE OF NATIONAL AGRIFOOD SYSTEMS

In 1994 world agrifood trade was valued at about $390 billion, about 10 percent of total world trade. A predominant role was played by Europe, which accounted for almost 50 percent of all imports and 45 percent of all exports. Asia is also an important economic area with the Japanese market playing a major role.



Latin America and the Caribbean has gained a significant market share in the past 20 years by virtue of high diversification of agricultural production and dynamic growth of primary processing industries as well as progressive trade liberalization, factors which have allowed this region to integrate remarkably well in international markets. On the other hand, Africa's presence in agrifood markets has remained modest, while the small

market share of countries in Central and Eastern Europe and the CIS bear witness to the difficult integration of these countries in world markets.

International capital activities in agro-industry have reached a very high level: out of a total of about $300 billion of foreign direct investment (FDI) in 1995, an estimated $25 billion went to the agrifood industry.

VERTICAL INTEGRATION

Despite growth and diversification in agro-industry, vertical integration and vertical coordination activities appear to be increasing in the sector. This can be seen in the progressive incorporation of large agricultural estates into food multinationals and in the rapid increase of preproduction contracts between farmers and industry. In the United States, for example, where these phenomena are more evident and tend to precede similar developments in other countries, in 1996 more than 50 percent of broiler and almost 16 percent of fruit and vegetable production were regulated through preproduction contracts.

The objective of reducing transaction costs accounts for much of the growth of vertically integrated companies, and explains some of the attempts to coordinate agricultural supply with industry needs. An integrated firm may save resources by consolidating the many contracts that pertain to sales of agricultural goods into a single line of business. Cost reductions may also derive from the consolidation of upstream contracts with labour, land and other inputs of agricultural production.

A second cause of vertical integration lies in the need for agro-industrial production to meet the quality standards required by an increasingly specific and diversified consumer demand. Because of the extra costs associated with enforcing these standards in the field, there is an incentive for individual agricultural enterprises to free-ride on quality levels already achieved. Vertical integration may also be a way of dealing with this type of problem.

Underlying the growing importance of international trade and capital flows in agro-industry has been a process of internationalization, which has increased in intensity over the past decades and has manifested itself in:

- An increasing interdependence and integration of the different national economies and agricultural systems, favoured in particular by the liberalization and external opening of domestic markets and the establishment of international zones of free exchange;
- A rapid progress and diffusion of technological innovation;
- A trend towards more homogeneous consumer products with standard characteristics at the international level – this is interrelated with the apparently contrasting process of market segmentation, whereby market segments are multiplying much faster than in the past and, rather than being limited to a single country, are extending to the international level.

FOREIGN DIRECT INVESTMENT IN AGRO-INDUSTRY

An important aspect of the economic internationalization process has been the dramatic increase in foreign direct investment (FDI), generally and in agro-industry, in the 1980s and 1990s.

According to the World Bank Debtor Reporting System, total net flows of FDI to developing countries rose from $24.5 billion in 1990 to $95.5 in 1995, while preliminary estimates for 1996 indicate a further increase to $109.5 billion in 1996. Multinational enterprises in the industrialized countries are the main source of FDI, accounting for more than 90 percent of flows in recent years.

The sectoral composition of investment flows towards developing countries is not so well documented. However, according to statistics on total flows of FDI from OECD countries to all destinations, the share going towards the food, beverages and tobacco manufacturing subsector was quite significant for a number of the major providers. Based on data for 1993 the share of FDI flows to this subsector amounted to 9.9 percent for the United States, 5.7 percent for the United Kingdom, 2.5 percent for Japan, 4.2 percent for France, 35.9 percent for the Netherlands and 13.5 percent for Switzerland, but only 0.5 percent in the case of Germany.

MULTINATIONALS IN THE INTERNATIONALIZATION PROCESS

An important aspect of the internationalization process is the increased role of multinational corporations in the agro-industrial sector of numerous countries. The creation of a multinational as an organizational entity may in many cases represent the final leap in the process of internationalizing the enterprise, a process which generally begins with the export phase.

MARKET FRAGMENTATION

The evolution of the food industry in the past 15 years may be considered as a case-study of a fragmented market that is becoming increasingly global under the effect of two powerful forces: the evolving patterns of consumption and technological progress. In the 1970s the food industry was characterized by: i) a large number of local producers, generally specialized in the production of a single good or in a set of closely related products; ii) a small number of national or international producers also specializing in a single core business; iii) an even smaller number of multinational firms, which were either extremely diversified (Unilever, Nestlé) or strictly specialized (Coca Cola).

The fragmented nature of the market was the result of both natural and policy-induced constraints. Natural constraints mainly comprised, for local products, tastes, local equipment, brand loyalty and consumer information. Policy-induced constraints resulted mainly from non-tariff barriers associated with health and hygiene regulations and from discriminatory policies of local traders and retail shops. Because their products could not be replicated in a standard form by the larger producers, local manufacturers enjoyed the double advantage of higher prices and lower transport costs. Their traditional

equipment and the local brands also proved to be a very effective means of discouraging national producers from trying to penetrate local markets, except with products that did not compete directly with local ones.

Starting in the mid-1980s, however, the larger producers in Europe and the United States gradually took over local markets by developing a high-growth strategy based on three tenets: i) covering the market to achieve dominance of a few standard products; ii) increasing the degree of differentiation by acquiring or by directly challenging the local leaders; and iii) introducing new products that could embody some of the characteristics of local products without trying to replicate them. This strategy not only required rapid growth, but also an expansionary policy of horizontal acquisitions and aggressive control of marketing activities, such as advertising, retailing and investment in research and development for product innovation. The present trends, which constitute a continuation of the expansion at the national level, are mostly characterized by national producers' attempts to upgrade their traditional leadership to an international level.

In the current environment of increasing competition in international markets the main strategies adopted by the agrifood enterprises have been those of obtaining, through acquisitions of other enterprises operating on foreign markets, a level of competitiveness which would otherwise have been more costly or risky to achieve. Indeed, the food industry has been affected since the early 1980s by major acquisitions, mergers and agreements, the main product of which has been a strong market concentration in numerous sectors. According to data from UNCTAD, over the period 1990-95, cross-border mergers and acquisitions in the food, beverages and tobacco manufacturing subsectors amounted to an annual average of $12.2 billion, representing 7.7 percent of total cross-border mergers and acquisitions over the period.

BENEFITS OF FOREIGN DIRECT INVESTMENT

In its 1996 annual report, WTO discusses several aspects of FDI. The report contains a review and discussion of some of the benefits and costs of FDI to the host country, a question which has been the object of strong debate between supporters and critics of this type of investment. Although the discussion relates to all forms of FDI, it is of obvious relevance to the debates on the role of FDI in the agro-industrial sector and on the agrifood multinationals. Following are some of the main points that emerge from the WTO report.

According to the proponents of FDI, in general terms the benefits accruing to the host country are represented by an increase in national output and income exceeding the gain to the investor. These benefits can accrue either to domestic labour (in the form of expanded real wages), domestic consumers (through lower prices and/or improved product quality) or government (as increased revenues).

Much criticism has, however, been voiced against FDI and the role of multinational corporations. Critics point to potential negative balance-of-payments effects in the medium term, as the multinational corporations increase imports of intermediate goods

and start repatriation of profits. Other points of criticism or concern are the potential market power of multinational corporations on the domestic market of the host country, which would allow them to engage in various restrictive practices that reduce competition, and the possible vulnerability of the host country governments to political pressures. In general, WTO does not believe that these concerns can constitute a sufficient case against FDI as such. As for the potential negative balance-of-payments effect, it is pointed out that FDI in countries with high levels of import protection tends to be less export-oriented than in countries with low protection levels and also that any balance-of-payments effect will depend on the exchange rate regime of the country. In any case, it does not appear that the potential costs associated with FDI outweigh the benefits deriving from it. Also, it is the belief of WTO that some of the problems and concerns associated with FDI could be adequately dealt with in the framework of a multilateral agreement on FDI.

Table. The top 20 multinationals of the agrifood industry, 1994

Group	Country	Main sector of activity	Agrifood business volume *(million $)*
Philip Morris	United States	Multiproduct	53 288
Cargill	United States	Cereal transformation	50 000
Nestlé	Switzerland	Multiproduct	40 247
Pepsico	United States	Beverages and soft drinks	28 472
Unilever	Netherlands	Multiproduct	26 150
Coca Cola	United States	Beverages and soft drinks	23 828
Conagra	United States	Multiproduct	23 512
RJB Nabisco	United States	Multiproduct	15 366
Danone (BSN)	France	Multiproduct	12 843
Anheuser Bush	United States	Beer	11 364
Grand Metropolitan	United Kingdom	Multiproduct	11 300
Snow Brand Milk Products	Japan	Dairy products	10 600
Archer Daniels Midland	United States	Oils and vegetable fats	10 344
Bunge y Born	Argentina	Cereal transformation	9 500
Maruha (Taiyo Fishery)	Japan	Fish	9 221
Eridania/Beghin-Say	Italy	Oils and vegetable fats	9 157
Kirin Brewery	Japan	Beer	9 020
George Weston Ltd	Canada	Food distribution	8 939
General Mills	United States	Multiproduct	8 517
Allied Domecq Plc	United Kingdom	Wines and liquors	8 375

Table. Division by zone of origin of the top 100 agrifood multinationals

Countries	Number	
	1974	1994
United States	50	28
Western Europe	37	43
Japan	7	20
Others	6	9

On the positive side, FDI has considerable importance as a vehicle for technology transfer. This transfer can of course take place directly to the firms affected, but there

may also be important effects of indirect diffusion of technology in the host country. Such diffusion may be deliberate, for example through the upgrading of technologies in other domestic firms doing business with the foreign affiliate, or in the form of spillover effects, such as when technology is copied by other firms. Other important positive effects in the host country could be the pressure on domestic producers to upgrade and improve efficiency. According to WTO, the empirical evidence tends to support the view that FDI is the most potent vehicle for technology transfer and that FDI leads to higher productivity in locally owned firms.

FDI also has important effects on employment The view that multinational corporations may have little impact on the development of local skills is rejected by the empirical evidence; rather, evidence tends to support the view that multinational corporations can fill critical management gaps, facilitate employment of local labour and transfer skills to local managers and entrepreneurs.

Within the framework of the increasing market concentration, the multinationals have played a role of primary importance, strengthening their position in the majority of the world agrifood sectors and basing their competitive strength on high degrees of diversification.

The majority of the top 100 agrifood multinationals are located in Europe. Over the past 20 years the multinationals of European and Japanese origin have increased their share of the top ranking as compared with the Americans who, in 1974, occupied 50 positions out of 100. Out of a total business volume of $599 billion in 1990, the top ten multinational groups operating in the agrifood sector accounted for 32 percent, and the market is becoming even more concentrated in the hands of a few multinationals.

The geographical distribution of the industry is subject to rapid change. The United States, which was the leading producer at the beginning of the 1980s, lost ground in the course of the 1980s and the early 1990s, to the point where the EU is now the main world producer, with a turnover of more than $600 billion, corresponding to more than 35 percent of the value of total production. The reduction in the United States' supremacy, however, is less accentuated in terms of the largest holdings, with Cargill, Kraft, Pepsico and Coca Cola still at the top of the industry, respectively in first, third, fifth and sixth place in the worldwide ranking by turnover, while the Swiss Nestlé and the Dutch-English Unilever occupy second and fourth position.

UNILEVER

Perhaps no other company may be taken to represent the worldwide food business as Unilever. Founded in the early nineteenth century through the merger of two successful "colonial" companies, respectively the property of the English and the Dutch crown, Unilever has grown to become perhaps the single largest producer of processed food in the world. With 1 700 subsidiaries in all countries of the world, Unilever's profits place it twenty-first in *Fortune*'s 500 top-ranking companies. Fully 50 percent of its business is from food, with a portfolio of a balanced mix of local, regional and international

brands which take into account the differences as well as the similarities in consumer demand.

Unilever describes itself as "international", not "global", because it does not attempt to enter all markets with the same product. Rather, it takes the view that successful food business must be based on local tastes. As a multinational conglomerate, however, Unilever can hardly be said to be local, except for its intense involvement with the food business of a great many countries, with special attention for developing ones. Recent business expansions, for example, concern Malaysia, Thailand, Pakistan, Bangladesh, the United Republic of Tanzania and Mozambique. Older, better established and rather successful ventures can be counted in Mexico, Brazil, India and several other middle-income countries.

According to the official company account: "Generating growth in emerging markets is a key business priority for Unilever. These markets are set to overtake the advanced industrial countries in their share of world output by the year 2000. Unilever already has a strong presence in emerging markets."

Rationalizing its strategy as one of diversification and market winning, the company statement goes on by describing its product innovation philosophy: "A 'broad product base' is more than an expression of size. It conveys strategic flexibility. Unilever can enter a market through the product category which is most relevant: it may be laundry soap (Brazil), margarine (Hungary), tea (Arabia) or detergents (Thailand). It can then gradually build its business by introducing other categories."

The need to control the supply of raw materials and the increasing concentration of the industry has resulted in a process of expansion based on foreign subsidiaries. On average, the first 100 companies control 15 subsidiaries A policy environment for agro-industrial development.

IMPORTANCE OF ECONOMY-WIDE POLICIES

To a very large extent promoting agro-industrial development and ensuring that agro-industry provides the optimal contribution to economic development depend on appropriate economic and other policies throughout the economy, more than on sector-specific policies and interventions. Worldwide experience has shown that competitive markets are the best way yet found for efficiently organizing the production and distribution of goods and services. Domestic and external competition provides the incentives that unleash entrepreneurship and technological progress. However, markets cannot operate in a vacuum – they require a legal and regulatory framework that only governments can provide. Also, there are many other tasks in which markets sometimes prove inadequate or fail altogether. That is why governments must, for example, invest in infrastructure and provide essential services for the poor. It is not a question of state or market: each has a large and irreplaceable role.

The consensus that has been gradually forming emphasizes the role of government in creating an enabling environment conducive to private sector investment, principally

by providing a stable macroeconomic foundation and removing market distortions and rigidities through policy reforms. Without going into the components of such an economy-wide enabling environment, the most general aspect would be the need to establish a stable macroeconomic framework through sound monetary and fiscal policies that control inflation, limit budgetary deficits and public sector borrowing requirements and maintain realistic exchange rates. Other important elements would be open trade policies, an efficient financial system and liberal financial markets, together with free international capital movements. A favourable business environment also depends on the absence of legal and regulatory constraints to enterprise, such as price controls, investment licensing, etc. as well as the existence of modern business legislation, a reliable judicial system and liberal labour codes and landownership laws. Further elements in a favourable general economic environment would be efficient and non-distorting systems of taxation and the reduction of the public sector's role in productive activities, among other things, to avoid the diversion of allocations from important support services (such as infrastructure and education) required by the private sector.

Taking for granted the fundamental importance of an appropriate economy-wide enabling environment briefly identifies some of the key policy issues that are of particular importance for development of agro-industrial potential in developing countries. The discussion does not claim to introduce elements of originality, but can be said largely to reflect lessons of experience as well as the current consensus.

PROMOTING DOMESTIC AGRICULTURE

The specificity of agro-industry *vis-à-vis* other industrial sectors lies in the agricultural origin of a large part of its inputs. In most cases, for developing countries it is domestic agriculture which is, or would be, the main supplier of raw materials to agro-industry, just as the potential for agro-industrial development in developing countries is largely linked to the actual or potential availability of such agricultural inputs to the processing industries. For this reason, increasing the efficiency of domestic agriculture is an important aspect of promoting agro-industrial development. At the same time agro-industrial processing activities can themselves have a positive impact on efficiency in primary agriculture by promoting technological innovation and stimulating competition within the sector.

INVESTMENT AND TECHNOLOGY POLICIES

Governments have often sought to promote agro-industry by investing directly in state-owned enterprises, but have lacked sufficient familiarity with technical and market requirements to prepare adequate feasibility studies and make appropriate technological choices. Public investment projects designed by foreign consultants and funded by aid have too often turned out to be white elephants because the sponsors have lacked personal stakes in, or a long-term commitment to, the commercial viability of the project. Technical and managerial resources to run state-owned enterprises efficiently are

generally scarce and, in any case, budgetary constraints are requiring governments to look increasingly to the private sector as the main source of investment in agro-industry.

Ways of raising technology levels in national agro-industry in the absence of direct government involvement in the sector include the tapping of the research and development capacities of multinational corporations by encouraging direct investment, promoting joint ventures and licensing and franchising arrangements and encouraging the secondment of their staff. Foreign manufacturers of agro-industrial machinery and equipment can be encouraged to establish plants or partnerships in developing countries to develop technology that is better adapted than much imported technology to the available raw materials, scales of production, worker skills and consumer requirements of the domestic markets in those countries. Also, freedom of entry should be granted to foreign and domestic suppliers of services to agro-industry, including accountants, technical consultants, suppliers of raw materials, intermediate inputs and equipment.

FDI can provide an important contribution to economic development in general, and to agro-industrial development in particular. The benefits of direct investment lie not only in attracting additional capital and skills but also in expediting the transfer and assimilation of technology and managerial expertise as well as in a readier access to international markets. An essential condition for attracting such investment is the existence of a generally favourable business environment, as discussed above. But other more specific measures aimed at encouraging direct investments would be the lifting of restrictions on entry by foreign firms as well as on their access to foreign exchange and on dividend and profit remittances, on foreign ownership of land and financial assets; and on the employment of expatriates.

PROTECTING THE ENVIRONMENT

In order to minimize the impact of agro-industrial residues on the environment, administrative tools to limit such releases must be developed. The most direct is enforced legislation prohibiting the discharge of residues into the environment. This can be coupled with incentives such as soft loans to invest in control measures. Legislation can also be accompanied by economic disincentives that penalize polluting industries. Other measures, applicable according to the circumstances, may be pollution entitlement shares and permissible limits (including trade permits); taxes on inputs or resource use (*e.g.* on water) rather than on the level of pollutants; subsidies to invest in environmentally friendly technologies; fees to cover the costs of removing pollutants, etc. It is important in any case that standards and regulations be realistic, enforceable and consistent with the overall policy environment.

In many cases, prohibiting the release of residuals results in a more profitable use of raw materials. The case of whey, discussed above, is an example. Others are the recovery of blood from slaughter operations and mill stream offals from cereals which can be converted into feeds, and the recovery of fish processing waste for food and feed products. Residues from the sugar and starch processing industries can be easily converted into

fuel alcohol through fermentation. This would provide the double advantage of utilizing a processing residue and at the same time producing an energy source that is less polluting than conventional fossil fuels.

Although technological means of improving the environmental performance of many industrial activities already exist, their mere existence does not guarantee that they will be adopted, especially by small firms. One effective way to influence small firms is through extension and advisory services for industries. For example, the Pollution Control Cell of the National Productivity Council in India's Ministry of Labour works to devise solutions that both reduce pollution and improve profits.

Generally, building pollution prevention into new agrifood investments is cheaper than adding it on later. Hence the importance of undertaking environmental impact assessments for proposed new large-scale investments. Developing countries with open markets will be able to gain from importing clean technologies already in use in industrial countries.

PROTECTING THE CONSUMER

For agro-industrial development to go ahead, it is important for countries to introduce and update national food legislation. Without up-to-date food laws, modern approaches to food control cannot be implemented, thus often preventing the efficient use of precious resources and impeding the government's authority and ability to regulate the food industry. With a properly administered modern food law, consumers and traders are provided the necessary assurances that build the type of confidence required for food products to be accepted as being of suitable quality and safety for both domestic consumption and trading in international markets. There is little doubt that trade at all levels has played a significant role in improving social, political and economic conditions worldwide. Countries that increase their trade prospects by assuring safe and high-quality food products for international markets will benefit at the expense of those who do not.

FAO/WHO guidelines for developing food control systems lay down basic principles based on national practice and experience. They suggest that food law be kept simple with detailed specification about food processing, food standards, hygienic practices, packaging and labelling and food additives to be incorporated in a body of food regulations, rather than the food law. Prompt revisions of regulations may become necessary because of new scientific knowledge, changes in food processing technology or emergencies requiring quick action to protect public health. Such revisions can be made more expeditiously by executive agencies than by legislative bodies. Regulations must be written in clear, concise language and a regulation should be promulgated only when there is a recognized need for it. When a regulation is developed as a result of a recognized need, it is more likely to be practicable and acceptable to the regulated sector. Regulations that are prepared by the government with the participation of the affected industries, consumers and other interested parties hold the best chance of acceptability because the stakeholders

have had a part in their development and recognized their need. The national food control system should include appropriately organized, multidisciplinary and multipurpose functional units that collectively contribute to the overall official food control effort. This can be achieved through specialized government agencies in public health, agriculture or trade, or, in some cases, through a single food control agency with multidisciplinary subdivisions. A national food control system should include inspectional, investigational, analytical and compliance (regulatory or voluntary) functions; provide technical, advisory and educational services; and be oriented towards public service in terms of industry, media and the public. Decisions made by food control officials should be based on up-to-date scientific information, carried out in a transparent manner and represent a fair balance of the sometimes competing interests of consumer protection, industry and trade development.

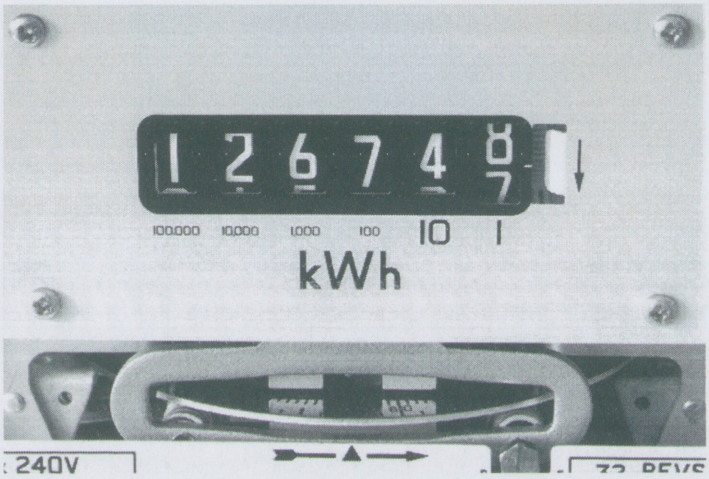
The production and handling of food throughout the chain (from farm to table) must be carried out under appropriate conditions in compliance with established principles that are consistent, transparent and scientifically supported. Such principles should be an integral part of any national set of food standards and regulations, established under the authority of an up-to-date food law to protect public health and facilitate trade in food. Many of these principles already exist and were established by the Codex Alimentarius Commission (CAC) in a harmonized manner using hazard analysis and risk assessment methods. They include more than 40 different commodity-related codes of practice; the General Principles of Food Hygiene; a system of food safety based on the Guidelines on the Application of Hazard Analysis and Critical Control Point (HACCP); and Good Manufacturing Practices.

In addition, 237 standards for foods considered to be most important to international trade have been promulgated by CAC for adoption by the Member Governments of FAO and WHO. CAC has also evaluated the use of 185 different pesticides; set safe residue levels for 3 274 pesticides; established guidelines for the maximum levels of 25 environmental and industrial food contaminants; established acceptable daily intake levels of over 780 chemical additives to foods; and evaluated the use of 54 different veterinary drugs used in animal husbandry. These guidelines and standards should serve as a benchmark for national governments in the regulation of their food industry. National governments which meet the requirements of Codex standards are also presumed to meet the international requirements expressed in WTO's Agreement on the Application of Sanitary and Phytosanitary Measures for food safety in international trade, providing a competitive advantage and assurance of acceptability for traders worldwide. Compliance with these standards is essential for the protection of public health and for successful trade in both international and domestic markets.

OHMIC HEATING IN THE FOOD INDUSTRY

For food processing applications, ohmic heating may be defined as a process where an electric current is passed through the food with the main purpose of heating it.

Under these circumstances, heat is internally generated due to the food's electrical resistance and this simple fact is responsible for the particular characteristics of this technology.



Ohmic heating is often placed among the so-called 'novel food processing technologies'. This is correct if we consider that only in the last 10 to 15 years have the scientific and technical developments achieved finally allowed its safe application at the industrial scale. However, the bases of the technology were set in the late 19th century and the 'Electropure Process' was developed in the 1930's. By 1938 it was used in approximately 50 milk pasteurisers in five US states and served approximately 50,000 consumers.

The ohmic heating's main control parameters, its main distinctive features, advantages and disadvantages and examples of existing and potential industrial applications.

The amount of energy generated as heat per second (the heating rate) depends on the voltage gradient and on the electrical conductivity of the product (σ). The most critical property affecting ohmic heating rate is σ which is in turn affected by a large number of parameters such as temperature, ionic strength, material microstructure, presence of a second phase and its concentration, presence and concentration of non-electrolytes, etc.

Ohmic heating has been shown, for example, to influence mass transfer properties. The electrical conductivity affects the diffusion from a food sample and at a steady-state temperature, differences in sample ó between conventional and ohmic conditions account for the difference in the extent of

Several other studies have demonstrated the effect of frequency and wave shape of alternating current on the ohmic heating of foods.

It is possible to have the same heating rate in solid and liquid phases, so overheating of particulates can easily be avoided.

Modern process systems engineering offers a number of tools (namely computer-aided simulation, optimisation and control), which can be used to design new processes

or to improve existing ones. These process engineering tools are based on mathematical models and offer a powerful, rational and systematic way of designing and operating food processes. A good example of the benefits of process optimisation can be found in thermal processing (sterilisation, pasteurisation), where it has been shown that new operating policies, computed by suitable optimal control methods, present significant advantages with respect to classical constant-temperature operation.

Thus, it can be expected that a similar approach for the case of ohmic heating might also bring a number of improvements and in fact, a number of researchers have investigated the mathematical modelling of ohmic heating, which is certainly a non-trivial task. Different fundamental methodologies for the ohmic process modelling have been followed and reviewed.

The main innovation brought by ohmic heating is the way through which it allows the heating of foods (internal heat generation).

This makes all the difference from other commercially available heat processing technologies where heat is either transmitted by conduction or convection (as happens with most types of heat exchanging equipment). Also when compared to microwave heating, for example, ohmic heating presents advantages. In the former, heating is achieved only in a certain depth of the product while the latter heats the entire volume, no matter its size.

Its ability to heat materials rapidly and uniformly is its principal advantage: the over processing of the foods is therefore prevented and so is the further destruction of nutrients and flavour compounds, leading to a higher quality product, both from the nutritional and the organoleptic points of view. Other advantages include:

- The involvement of no hot surfaces: therefore leading to fewer chances of fouling
- Better controllability: once the rate of heating is governed only by the power supply available (in turn, dependent on the product's electrical conductivity and, in continuous processes, on the flow rate used)
- Less damages caused to shear-sensitive food components: once shear rates are comparable to those existing in conventional pipe work with little additional disturbance to the flow; this leads to low pressure drops in the system
- High efficiency: once virtually all of the electrical power supplied to the system is dissipated as heat in the product (typical efficiencies of ohmic heaters are above 95 per cent)
- Possibility of handling slurries with high solid contents (products with up to 80 per cent particulates can be processed)

Despite these advantages, there are potential problems with ohmic heating; the main being products with low electrical conductivity values (*e.g.* those with high fat contents). In this case, ohmic heating might just not be applicable due to the high power input required to process such products. Other limitations include:

- The energy costs of electrical heating systems (these will be depend on the region where it is implemented)

- The limitation imposed by the minimum and maximum values of the electrical conductivity allowed for a given throughput, which in turn will limit the type of products that can be processed by ohmic heating
- The limitation imposed by the maximum power available from the local electrical supply
- The requirement for non-conductive materials to be used in linings/housing in order to isolate electrical components

Ohmic heating can be considered a High Temperature Short Time (HTST) aseptic process, therefore the microbiological safety of the products is not affected (and may even be improved). In fact, the principal mechanisms of microbial inactivation are based on thermal inactivation. It is generally believed that destruction of microorganisms by ohmic heating is due to the thermal effect and electricity plays no role on inactivation. However, the thermal requirement for inactivation is reduced when sub-lethal electrical treatment is applied and recent results clearly show that there is a non-thermal (electrical) effect of the application of ohmic heating on microbial growth3.

Similar conclusions are being collected with respect to the non-thermal effects of ohmic heating on food enzymes or vitamins for example, just to quote a few works.

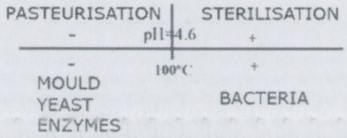
The potential applications of this technique in the food industry are very wide and include blanching, evaporation, dehydration, fermentation, pasteurisation and sterilisation. The advantages discussed above make ohmic heating especially useful for very sticky (viscous) materials or fluids containing solid particles; it may also be used wherever non-uniform heating must be avoided or where mechanical agitation to improve heat transfer is not recommended. A few examples follow.

The thermal processing of fruit purees and jams is traditionally difficult, essentially due to their rheological properties. The problem is aggravated when fruit particles are present in the slurry, as in the case of fruit purees to be incorporated in yoghurts, for example. In fact, in order to process them fully to meet food safety requirements, an over-processing of the liquid phase is necessary. This is mainly due to the heat exchange mechanism used (conduction) and leads to important losses both in nutritional and organoleptic terms. The use of conventional heat exchangers is not possible and scraped surface devices are normally used instead. The contact of the slurry with a hot surface is promoted and mixing is achieved by means of rotating blades. These are responsible for mechanical damage to the fruit particles affecting the final quality of the product and diminishing its acceptability to the consumer. The maintenance of such scraped surface heat exchangers is also more expensive than that of the most usual plate-and-frame or shell-and-tube options. This is one of the cases where ohmic heating can be used with clear advantages over the conventional processes.

The same thermal over-processing problems leading to nutritional and flavour losses are present in the production process of canned soups for instance, which normally integrate food solid particles (*e.g.* peas, carrot cubes), or even during pet food production, where reported nutritional and flavour losses due to thermal over-processing of the

product are considerable. Despite all the efforts made so far, the application of ohmic heating to food processing is still not fully characterised and not all of its potentialities have been exploited due to the complexity of both the food materials and the phenomena occurring during ohmic heating processing.

THERMAL TREATMENT IN FOOD INDUSTRY



The thermal treatment of food is necessary in order to:

- Reduce the microbiological flora present in the food
- Avoid alterations produced in the food by non-pathogenic micro-organisms
- Apply the appropriate amount of heating/cooling to each of the foods in question

The four principal objectives of the application of thermal treatment are:

- Destroy micro-organisms which could affect the health of the consumer
- Destroy micro-organisms which could alter the properties of the food
- Deactivate any enzyme action
- Optimise the retention of quality factors at minimum cost

The thermal treatment depends on:

- The thermal resistance of the micro-organisms and enzymes present in the food
- The initial microbial content contained in the food prior to treatment
- The pH of the food
- The physical state of the food

Thermal Treatment encompasses a range of procedures, but the principle ones are pasteurisation and sterilisation, which are designed to destroy microbes, rather than scalding or cooking, which also achieve a reduction in microbial content, but whose principal objective is a variation in the structure of the food.

Pasteurisation implies the destruction, by the application of heat, of all of those organisms in a vegetative state which would produce illness, or the destruction or reduction in the number of those organisms which would produce alterations in certain foods, such as high acid foods (with a pH less than 4.6). In these foods, the only micro-organisms which develop are those which alter the food but which are not pathogenic to man. Sterilisation signifies the destruction of all viable organisms and their spores which could be cultivated using appropriate techniques by means of the application of temperatures in excess of 100°C.

For example, a low acid food (pH>4.6) requires heating above 100°C, generally between 116°C and 130°C for a time which is sufficient to reduce the number of *Clostridium botulinium* spores by the value of 1012. However, high acid foods (fruit juices) do not need such intensive treatment as bacteriological development does not take place at these pH values.

Nevertheless, normal practice inclines towards the application of the higher temperatures with a consequent reduction in processing times, which enables the product to retain the nutritional and organic properties to a maximum. HTST pasteurisation has a high degree of acceptance in the food industry given the operational efficiency which it brings. Properly operated these units allow high production volumes with minimum space. The principle of this system lies in establishing an appropriate relationship between the process variables of time-temperature-pressure.

OTHER CONSIDERATIONS

Although the principal objective may be the destruction of the micro-organisms it must not be forgotten that other processes take place, some of which may be desirable (enzyme destruction, softening of the tissues) but must still be controlled, and other less desirable effects (destruction of nutrients, loss of organic qualities). Any thermal treatment has the potential to affect other components such as enzymes, proteins, vitamins etc, which can in turn affect the physical properties: colour, form, consistency etc.

Given the complexity of the potential effects of thermal treatments on foods it is necessary to optimise the way in which we achieve the results required in each case. Any thermal treatment must be adjusted to maximise the desirable results and minimise the undesirables which inevitably leads to choosing conditions which compromise between one and the other but which give an overall result which is acceptable.

BASIC DRYING THEORY

THREE STATES OF WATER

Pure water can exist in three states, solid, liquid and vapour. The state in which it is at any time depends on the temperature and pressure conditions and it is possible to illustrate this on a phase diagram.

If we choose any condition of temperature and pressure and find the corresponding point on the diagram, this point will lie, in general, in one of the three labelled regions, solid, liquid, or gas. This will give the state of the water under the chosen conditions.

Under certain conditions, two states may exist side by side, and such conditions are found only along the lines of the diagram. Under one condition, all three states may exist together; this condition arises at what is called the triple point, indicated by point O on the diagram. For water it occurs at 0.0098°C and 0.64 kPa (4.8 mm of mercury) pressure.

If heat is applied to water in any state at constant pressure, the temperature rises and the condition moves horizontally across the diagram, and as it crosses the boundaries a change of state will occur. For example, starting from condition A on the diagram adding heat warms the ice, then melts it, then warms the water and finally evaporates the water to condition A'. Starting from condition B, situated below the triple point, when heat is added, the ice warms and then sublimes without passing through any liquid state.

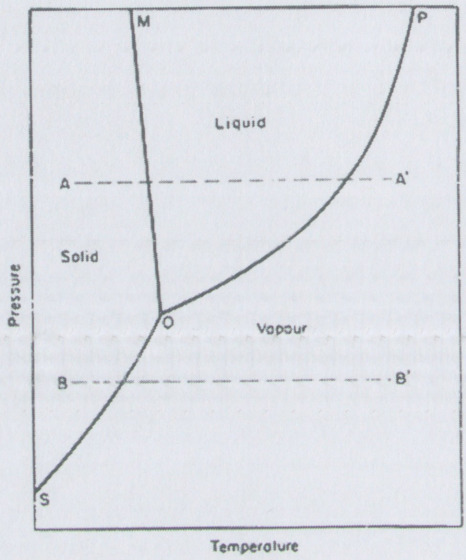


Fig. Phase diagram for water

Liquid and vapour coexist in equilibrium only under the conditions along the line OP. This line is called the vapour pressure/temperature line. The vapour pressure is the measure of the tendency of molecules to escape as a gas from the liquid. The vapour pressure/temperature curve for water, which is just an enlargement for water of the curve OP.

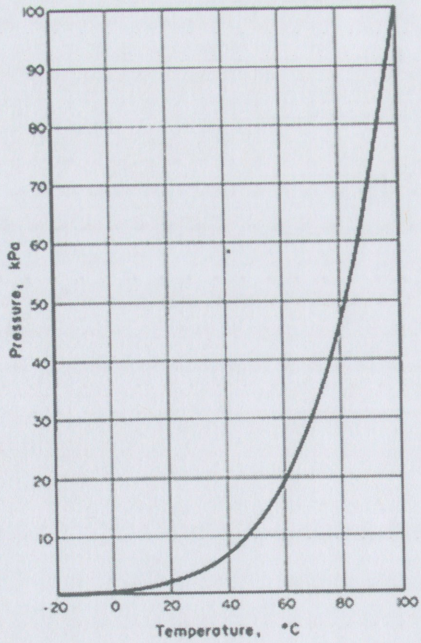


Fig. Vapour pressure/temperature curve for water

Boiling occurs when the vapour pressure of the water is equal to the total pressure on the water surface. The boiling point at atmospheric pressure is of course 100°C. At pressures above or below atmospheric, water boils at the corresponding temperatures above or below 100°C for temperatures below 100°C.

HEAT REQUIREMENTS FOR VAPORIZATION

The energy, which must be supplied to vaporize the water at any temperature, depends upon this temperature. The quantity of energy required per kg of water is called the latent heat of vaporization, if it is from a liquid, or latent heat of sublimation if it is from a solid.

The heat energy required to vaporize water under any given set of conditions can be calculated from the latent heats given in the steam, as steam and water vapour are the same thing.

Heat Energy in Air Drying

A food containing 80% water is to be dried at 100°C down to moisture content of 10%. If the initial temperature of the food is 21°C, calculate the quantity of heat energy required per unit weight of the original material, for drying under atmospheric pressure. The latent heat of vaporization of water at 100°C and at standard atmospheric pressure is 2257 kJ kg^{-1}.

The specific heat capacity of the food is 3.8 kJ kg^{-1} $°C^{-1}$ and of water is 4.186 kJ $kg^{-1}°C^{-1}$. Find also the energy requirement/kg water removed.

Calculating for 1 kg food

Initial moisture = 80%

800 g moisture are associated with 200 g dry matter.

Final moisture = 10 %,

100 g moisture are associated with 900 g dry matter,

Therefore (100 x 200)/900 g = 22.2 g moisture are associated with 200 g dry matter.

1kg of original matter must lose (800 - 22) g moisture = 778 g = 0.778 kg moisture.

Heat energy required for 1kg original material

= heat energy to raise temperature to 100°C + latent heat to remove water

= (100 - 21) x 3.8 + 0.778 x 2257

= 300.2 + 1755.9

= 2056 kJ.

Energy/kg water removed, as 2056 kJ are required to remove 0.778 kg of water,

= 2056/0.778

= 2643 kJ.

Steam is often used to supply heat to air or to surfaces used for drying. In condensing, steam gives up its latent heat of vaporization; in drying, the substance being dried must take up latent heat of vaporization to convert its liquid into vapour, so it might be reasoned that 1 kg of steam condensing will produce 1 kg vapour. This is not exactly

true, as the steam and the food will in general be under different pressures with the food at the lower pressure. Latent heats of vaporization are slightly higher at lower pressures. In practice, there are also heat losses and sensible heat changes which may require to be considered.

Table. Latent heat and saturation temperature of water

Absolute pressure (kPa)	Latent heat of vaporization ($kJ\ kg^{-1}$)	Saturation temperature (°C)
1	2485	7
2	2460	18
5	2424	33
10	2393	46
20	2358	60
50	2305	81
100	2258	99.6
101.35 (1 atm)	2257	100
110	2251	102
120	2244	105
200	2202	120
500	2109	152

Heat Energy in Vacuum Drying

Using the same material as in Example 7.1, if vacuum drying is to be carried out at 60°C under the corresponding saturation pressure of 20 kPa abs. (or a vacuum of 81.4 kPa), calculate the heat energy required to remove the moisture per unit weight of raw material.

Heat energy required per kg raw material

= heat energy to raise temperature to 60°C + latent heat of vaporization at 20 kPa abs.

$= (60 - 21) \times 3.8 + 0.778 \times 2358$

$= 148.2 + 1834.5$

$= 1983$ kJ.

In freeze drying the latent heat of sublimation must be supplied. Pressure has little effect on the latent heat of sublimation, which can be taken as 2838 $kJ\ kg^{-1}$.

Heat Energy in Freeze Drying

If the foodstuff in the two previous examples were to be freeze dried at 0°C, how much energy would be required per kg of raw material, starting from frozen food at 0°C?

Heat energy required per kilogram of raw material= latent heat of sublimation

$= 0.778 \times 2838$

$= 2208$ kJ.

HEAT TRANSFER IN DRYING

We have been discussing the heat energy requirements for the drying process. The rates of drying are generally determined by the rates at which heat energy can be transferred to the water or to the ice in order to provide the latent heats, though under some circumstances the rate of mass transfer (removal of the water) can be limiting. All three of the mechanisms by which heat is transferred - conduction, radiation and convection - may enter into drying.

The relative importance of the mechanisms varies from one drying process to another and very often one mode of heat transfer predominates to such an extent that it governs the overall process.

As an example, in air drying the rate of heat transfer is given by:

$$q = h_s A(T_a - T_s)$$

where q is the heat transfer rate in J s^{-1}, h_s is the surface heat-transfer coefficient J m^{-2} s^{-1} $°C^{-1}$, A is the area through which heat flow is taking place, m^2, T_a is the air temperature and T_s is the temperature of the surface which is drying, °C.

To take another example, in a roller dryer where moist material is spread over the surface of a heated drum, heat transfer occurs by conduction from the drum to the foodstuff, so that the equation is,

$$q = UA(T_i - T_s)$$

where U is the overall heat-transfer coefficient, T_i is the drum temperature (usually very close to that of the steam), T_s is the surface temperature of the food (boiling point of water or slightly above) and A is the area of drying surface on the drum.

The value of U can be estimated from the conductivity of the drum material and of the layer of foodstuff. Values of U have been quoted as high as 1800 J m^{-2} s^{-1} $°C^{-1}$ under very good conditions and down to about 60 J m^{-2} s^{-1} $°C^{-1}$ under poor conditions.

In cases where substantial quantities of heat are transferred by radiation, it should be remembered that the surface temperature of the food may be higher than the air temperature. Estimates of surface temperature can be made using the relationships developed for radiant heat transfer although the actual effect of combined radiation and evaporative cooling is complex. Convection coefficients also can be estimated using the standard equations.

For freeze drying, energy must be transferred to the surface at which sublimation occurs. However, it must be supplied at such a rate as not to increase the temperature at the drying surface above the freezing point. In many applications of freeze drying, the heat transfer occurs mainly by conduction.

As drying proceeds, the character of the heat transfer situation changes. Dry material begins to occupy the surface layers and conduction must take place through these dry surface layers which are poor heat conductors so that heat is transferred to the drying region progressively more slowly.

DRYER EFFICIENCIES

Energy efficiency in drying is of obvious importance as energy consumption is such a large component of drying costs. Basically it is a simple ratio of the minimum energy needed to the energy actually consumed. But because of the complex relationships of the food, the water, and the drying medium which is often air, a number of efficiency measures can be worked out, each appropriate to circumstances and therefore selectable to bring out special features important in the particular process. Efficiency calculations are useful when assessing the performance of a dryer, looking for improvements, and in making comparisons between the various classes of dryers which may be alternatives for a particular drying operation.

Heat has to be supplied to separate the water from the food. The minimum quantity of heat that will remove the required water is that needed to supply the latent heat of evaporation, so one measure of efficiency is the ratio of that minimum to the energy actually provided for the process. Sensible heat can also be added to the minimum, as this added heat in the food often cannot be economically recovered.

Yet another useful measure for air drying such as in spray dryers, is to look at a heat balance over the air, treating the dryer as adiabatic with no exchange of heat with the surroundings. Then the useful heat transferred to the food for its drying corresponds to the drop in temperature in the drying air, and the heat which has to be supplied corresponds to the rise of temperature of the air in the air heater. So this adiabatic air-drying efficiency, η, can be defined by:

$$\eta = (T_1 - T_2)/(T_1 - T_a)$$

where T_1 is the inlet (high) air temperature into the dryer, T_2 is the outlet air temperature from the dryer, and T_a is the ambient air temperature. The numerator, the gap between T_1 and T_2, is a major factor in the efficiency.

Efficiency of a Potato Dryer

A dryer reduces the moisture content of 100 kg of a potato product from 80% to 10% moisture. 250 kg of steam at 70 kPa gauge is used to heat 49,800 m^3 of air to 80°C, and the air is cooled to 71°C in passing through the dryer. Calculate the efficiency of the dryer. The specific heat of potato is 3.43 kJ kg^{-1} $°C^{-1}$. Assume potato enters at 24°C, which is also the ambient air temperature, and leaves at the same temperature as the exit air.

In 100 kg of raw material there is 80% moisture, that is 80 kg water and 20 kg dry material,

total weight of dry product = 20 x (10/9)
= 22.2 kg
weight of water = (22.2 - 20)
= 2.2 kg.
water removed = (80 - 2.2)
= 77.8 kg.

Heat supplied to potato product

= sensible heat to raise potato product temperature from 24°C to 71°C + latent heat of vaporization.

Now, the latent heat of vaporization corresponding to a saturation temperature of 71°C is 2331 kJ kg^{-1}

Heat (minimum) supplied/100 kg potato

= 100 x (71 - 24) x 3.43 + 77.8 x 2331

= 16 x 10^3 + 181 x 10^3

= 1.97 x 10^5 kJ.

Heat to evaporate water only = 77.8 x 2331

= 1.81 x 10^5 kJ

The specific heat of air is 1.0 J kg^{-1} $°C^{-1}$ and the density of air is 1.06 kg m^{-3}

Heat given up by air/100 kg potato

= 1.0 x (80 - 71) x 49,800 x 1.06

= 4.75 x 10^5 kJ.

The latent heat of steam at 70 kPa gauge is 2283 kJ kg^{-1}

Heat in steam = 250 x 2283

= 5.71 x 10^5 kJ.

Therefore (a) efficiency based on latent heat of vaporisation only:

= (1.81 x 10^5)/ (5.71 x 10^5)

= 32%

(b) efficiency assuming sensible heat remaining in food after drying is unavailable

= (1.97 x 10^5)/ (5.71 x 10^5)

= 36%

(c) efficiency based heat input and output, in drying air

= (80 – 71)/ (80 – 24)

= 16%

Whichever of these is chosen depends on the objective for considering efficiency. For example in a spray dryer, the efficiency calculated on the air temperatures shows clearly and emphatically the advantages gained by operating at the highest feasible air inlet temperature and the lowest air outlet temperatures that can be employed in the dryer.

Examples of overall thermal efficiencies are:

drum dryers 35-80%

spray dryers 20-50%

radiant dryers 30-40%

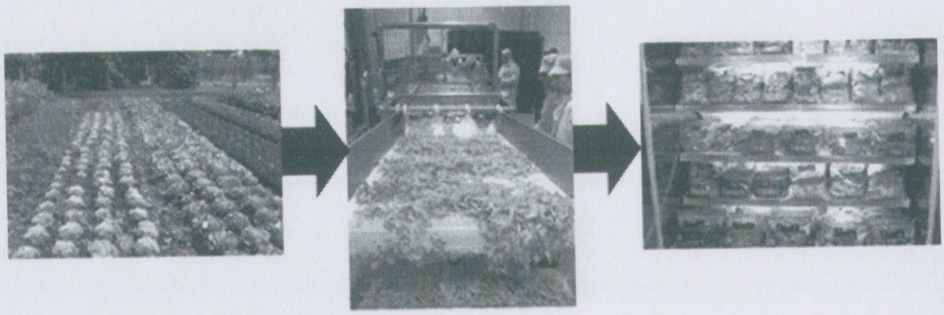
After sufficient energy has been provided to vaporize or to sublime moisture from the food, some way must be found to remove this moisture. In freeze-drying and vacuum systems it is normally convenient to condense the water to a liquid or a solid and then the vacuum pumps have to handle only the non-condensible gases. In atmospheric drying a current of air is normally used.

"MINIMAL PROCESSED FOODS"



Among others, visual properties of fresh-cut fruit and vegetable commodities are one of the most important parameter to evaluate the total quality of the product by consumers. Looking at the package, it will be possible to evaluate absence or presence of discolouration (enzymatic browning of cut surfaces, yellowing of green vegetables and pale colour of bright vegetables), mechanical damage (foiled lettuce leaves, absence of cutting damage), as well as decay

Minimally processing can provide fresh and quality products through a hurdle approach. Minimally processing renders produce highly perishable, requiring chilled storage to ensure reasonable shelf life. No heat is applied to maintain fresh like characters.



PRESERVATION TECHNIQUES

Peeling, Cutting and Grating

During processing many cells are broken and intracellular products, such as oxidizing enzymes, are released accelerating the decay of the product. Additionally, the cut surfaces of any processed vegetable support better microbial growth. In fact, each step in the processing affects quality and microflora of fresh-cut fruit and vegetables. For these reasons, the cutting and shredding must be performed with knives or blades as sharp as

possible made from stainless steel. However, many different solutions have been tested to avoid the acceleration of decay due to peeling, cutting or slicing. The newest tendency is called the immersion therapy.. Cutting a fruit while it is submerged in water will control turgor pressure, due to the formation of a water barrier that prevents movement of fruit fluids while the product is being cut. Additionally, the watery environment also helps to flush potentially damaging enzymes away from plant tissues.

On the other hand, UV-C light has been also used while cutting fruit to cause a hypersensitive defence response to take place within its tissues, reducing browning and injury of in fresh-cut products. Another alternative could be the use of water-jet cutting, a non-contact cutting method which utilizes a concentrated stream of high-pressure water to cut through a wide range of foodstuffs (Ingersoll Rand Ltd).

However, the main steps throughout the processing chain of minimal processing fruits and vegetables are washing and disinfection. For this reason, guidelines for packing fresh or minimally processed fruits and vegetables generally specify a washing or sanitizing step to remove dirt, pesticide residues, and microorganisms responsible for quality loss and decay.

The current published data suggests that any of the available washing and sanitizing methods, including some of the newest sanitizing agents such as chlorine dioxide, ozone, and peroxyacetic acid, were not capable of reducing microbial population by more than 90 or 99%. Additionally, different washing and disinfection treatments may negatively affect the nutritional and sensory quality of the product. However, little is known about nutritive value content of minimally processed produce. Therefore, washing and disinfection of the produce before preparation or consumption is recommended but does not guarantee that fresh produce is pathogen free.

On the other hand, the potential of MAP to extend shelf-life for many foods is well documented. It is known that beneficial modified atmospheres within fresh-cut produce packages are attained by correctly choosing packaging materials that will provide the appropriate levels of oxygen and carbon dioxide within a fresh-cut produce package. In fact, there are a wide variety of polymers and gas mixtures available for packaging fresh-cut produce that should be optimize for each commodity. However, there is still a major concern about the product safety associated with the use of MAP mainly due to the desired suppression of spoilage microorganisms which extends the shelf-life if compared to food products stored in a normal air environment, and this may create opportunities for slower growing pathogenic bacteria.

It would be expected that combinations of sanitizers and/or other intervention methods, would have additive, synergistic or antagonistic interactions. According to this, the hurdle technology looks after the combination of different preservation techniques as preservation strategy. The intelligent selection of hurdles in terms of the number required, the intensity of each and the sequence of applications to achieve a specified outcome are expected to have significant potential for the future of minimally processed fruit and vegetables.



Table. Psychrotrophics in minimally processed carrots and green peppers, packed under air, vacuum and modified atmosphere (MA) stored under refrigeration at 1°C±1°C

	Psychrotrophics (CFU g-1) Storage (days)			
Treatment	**1**	**7**	**14**	**21**
		Carrots		
Air	1.1×10^2	1.5×10^2	1.8×10^4	1.5×10^3
Vacum	1.9×10^2	5.8×10^2	1.2×10^5	2.8×10^2
MA	3.5×10^2	6.0×10^2	9.0×10^3	7.0×10^2
		Green peppers		
Air	8.3×10^2	4.9×10^3	1.0×10^6	6.9×10^5
Vacuum	3.5×10^3	6.4×10^3	4.0×10^5	5.9×10^5
MA	3.1×10^3	4.1×10^4	2.2×10^5	1.8×10^6

USE OF COMBINED PRESERVATION METHODS

Photochemical processes

Recently, many studies have demonstrated the effectiveness of surface decontamination techniques to reduce the microbial risk involved with the consumption of fresh fruits and vegetables.

Non-ionizing, artificial ultraviolet-C (UV-C) radiation is extensively used in a broad range of antimicrobial applications including disinfection of water, air, food preparation surfaces, food containers and surface disinfection of vegetable commodities. The ultraviolet light acts as an antimicrobial agent directly due to DNA damage and indirectly due to the induction of resistance mechanisms in different fruit and vegetables against pathogens. Exposure to UV-C also induces the synthesis of health-promoting compounds such as anthocyanins and stilbenoids. However, high UV doses, can cause damage to the treated tissue. Therefore, the possibility of decreasing the treatment intensity by

combining two or more treatments to preserve the fruit and vegetable quality without decreasing the inactivation properties appears very promising. Additionally, UV-C light has already been recommended as best used in combination with other preservation techniques, since the accumulative damage due to microbial DNA appears effective in decreasing the overall number of bacteria cells, but does not result in complete sterilization. Further, these postharvest treatments can be easily added to other techniques such as chilling, disinfection and MAP to preserve quality of minimally processed fruits and vegetables.

Many researchers have already tested the synergistic effects of combining UV-C light with chemical disinfection and/or MAP on vegetable produce. The beneficial effects of combining chlorinated water to disinfect freshcut fruit and vegetables with UV-C light treatments and storage in MAP has already been tested. Most of the studies showed the effectiveness of microbial reductions in fresh-cut fruits and vegetables by using chemical disinfection, low UV-C light doses (from 1 to 4 kJ mK2) and storage under conventional MAP, without any detrimental effect on the organoleptical quality of the product.

UV-C light has also been combined with other postharvest treatments such as mild thermal treatments. Light pulses have been used successfully as a new technique for the inactivation of bacteria and fungi on the surface of food products when the major composition of the emitted spectrum is UV light. Additionally, combination of pulsed light with mild heat treatments in strawberries and cherries has also been reported.

Low-dose gamma irradiation is very effective reducing bacterial, parasitic, and protozoan pathogens in raw foods. Irradiation was approved by the FDA for use on fruits and vegetables at a maximum level of 1.0 kGy. It has already been tested in minimally processed fruit and vegetables observing that dose of 2.0 kGy strongly inhibited the growth of aerobic mesophilic and lactic microflora in shredded carrots. Additionally, it has been combined with Conventional disinfection methods such as chlorinated water or preservation technologies by using MAP. Treating fresh-cut lettuce with low-dose irradiation of about 0.20–0.35 kGy combined with a chlorine (80–100 ppm NaOCl) wash and MAP, increases the microbiological shelf-life without adversely affecting the visual quality or flavour of the product. Additionally, when inoculated cilantro was treated with a combination of irradiation (1.05 kGy) and chlorination (200 ppm), Escherichia coli O157:H7 was reduced more than 7 log cycles without adversely affecting the sensory quality of the product. This combined treatment was more efficient than irradiation or chlorination alone.

Non- Photochemical Processes

Many combinations of physical and chemical treatments have been tested in recent years to enhance the antimicrobial action of different disinfectant agents. Among them, the use of acidic electrolyzed water (AcEW) produced by the electrolysis of an aqueous sodium chlorite solution as a disinfectant for minimally processed vegetable products

has been successfully applied. Chlorine dioxide (ClO_2) has been recognized as a strong oxidizing agent with a broad biocidal effectiveness due to the high oxidation capacity of about 2.5 times greater than chlorine. Many studies have demonstrated its antimicrobial activity since its use was allowed in washing fruits and vegetables by the FDA (1998).

Power ultrasound, as used for cleaning in the electronics industry, has a potential application to fresh produce decontamination. Ultrasonic fields consist of waves at high amplitude, which form cavitation bubbles, which generate the mechanical energy which has a 'cleaning action on surfaces.

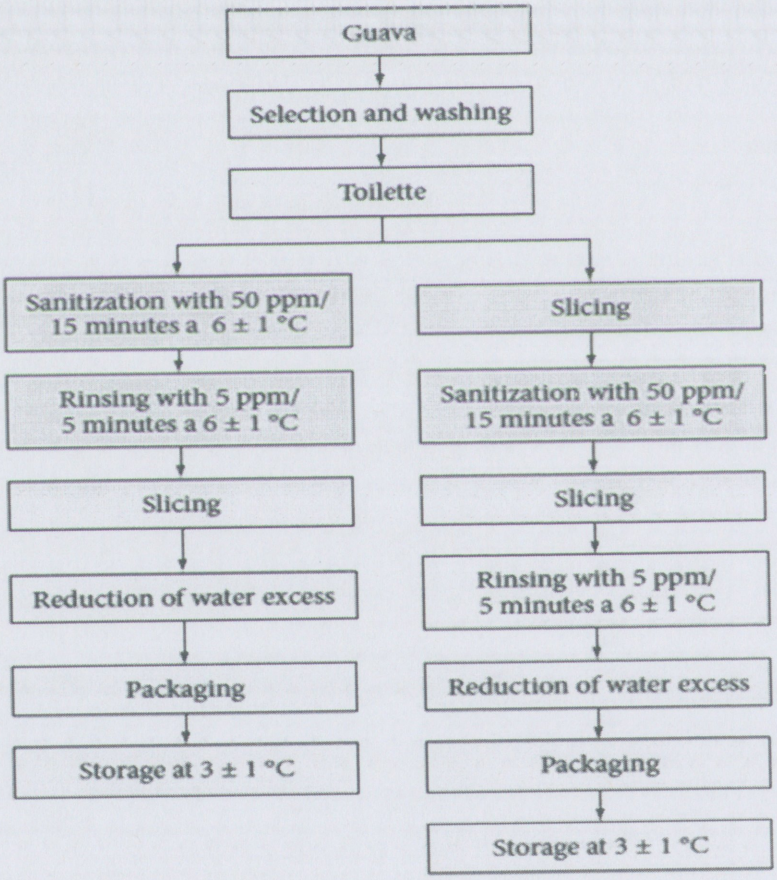


Fig. Flowchart describing the minimally processed guava procedures

A newer tendency has been reported by combining the efficacy of chemical disinfectant with the antimicrobial effect of bacteriocins produced by lactic acid bacteria. They investigated the efficacy of nisin and pediocin treatments in combination with EDTA, citric acid, sodium lactate, potassium sorbate and phytic acid in reducing Listeria monocytogenes on fresh-cut produce. Pediocin and nisin applications in combination with organic acids caused a significant reduction of native microflora and inoculated

populations on fresh produce. Finally, the combined use of several disinfectant agents has been widely report in the last few years. Combinations of lactic acid, chlorinated water, thyme essential oil solution, sodium lactate, citric acid, hydrogen peroxide, ozone and peroxyacetic acid were already tested. In general, combinations of chemical disinfectants maintain better both, sensory and microbial quality of the product.

FACTORS AFFECTING QUALITY

Main factors affecting quality of minimally processed produce are

- Harvesting operations,
- Raw material,
- Preparation procedures
- Trimming,
- Cutting,
- Peeling,
- Shredding, and
- Processing conditions
- Good Manufacturing Practices,
- Packaging and storage.

5

Food Processing and Preservation

Food processing and preparation activities cover three main fields: (1) the preservation of foods by (a) modern methods such as refrigeration, canning and irradiation, and (b) traditional methods such as drying, salting, smoking and fermentation; (2) the development of protein - rich foods; (3) food additives.

FOOD PRESERVATION

It was noted that several Divisions, including those of Fisheries, Animal Production and Health, Plant Production and Protection, were engaged in food technology activities in their respective fields of interest. The Nutrition Division's interest was mainly, in their nutritional implications, in particular in reducing wastage of food, in preventing losses in nutritive value and in conserving or enhancing palatability. In certain fields, there was co - operation with other Divisions in FAO, with UNICEF and WHO, and with certain governmental and non-governmental organizations.

The Conference noted that countries were showing increasing interest in applying modern food technology to their food and nutrition problems. Advice and assistance from FAO had taken a number of forms, being concerned with surveys and food technology, developments in individual countries, the establishment of work programmes for food technology institutes, cereal technology, dehydration and canning.

The Conference also noted that because of current interest in radiation sterilization, the Nutrition Division was keeping abreast of developments in this field. In co - operation with the Atomic Energy Branch, a regional meeting on this subject had been held in Harwell, England, in 1958; other smaller meetings were under consideration for 1960

- 61. The Conference welcomed the attention given to community processing, which was developing in a number of countries, and noted that a European meeting on community, processing might be held in 1960.

The Ninth Session of the Conference had requested the Director - General to collect and disseminate information on indigenous methods of food processing applied on the village or household scale. Because of lack of resources, insufficient attention had been given to this matter in 1958 - 59. The Conference re - emphasized the importance of collecting information on indigenous methods, especially those used for the production of protein - rich foods, so that investigations might be undertaken to improve and extend such methods. Simple and cheap equipment is needed for this purpose. The Conference adopted the following resolution:

Resolution No. 35/59

Methods of Food Processing and Preservation

THE CONFERENCE

Having noted *the request of the 1957 Session of the Conference concerning traditional methods of food processing and preservation,* and

Having considered *that such methods can he improved and their use extended, thereby preventing wastage of food and losses in nutritive value,*

Requests *Member Governments to assist the Organization in collecting information in this field, so that studies may be undertaken for the improvement and extension of such methods;*

Urges *Member Governments to collaborate with the Organization by including such studies in the programmes of food and nutrition institutes;*

Draws *the attention of Member Governments to the need for the dissemination through extension services of information about improved methods; and*

Requests *the, Director - General to consider expanding the Organization's work in this field to the extent that resources permit.*

Food technology training in highly developed countries is often not adapted to the needs of developing countries. The Conference considered that FAO should pay greater attention to the training of food technologists in already existing institutes, and emphasized the importance of adapting training programmes to the needs of developing countries, due consideration being given to the application of improved traditional methods.

DEVELOPMENT OF PROTEIN - RICH FOODS

The Conference noted that progress had been made in developing processes for the manufacture of protein - rich foods from cheap protein - rich materials such as defatted oilseed flours (*e.g.*, soy, cottonseed, peanut, sesame and combinations of these'), fish flour, and coconut and leaf protein; that activities in this field were being carried out in

co - operation with UNICEF and WHO; and that apart from research problems, many others would have to be solved, *e.g.*, those of marketing and consumer acceptance. The Conference considered that FAO should intensify its activities in this field, which would become of greater and more immediate importance because of the reduction of surplus skim milk supplies in 1959 and early 1960 for supplementary feeding programmes.

FOOD ADDITIVES

The Conference was of the opinion that work on food additives, a joint FAO/WHO enterprise, had progressed along sound lines. Apart from the interest in the subject in developed countries, there was also in many developing countries a growing concern about the increasing number of food additives present in imported foods. The Joint FAO/WHO Expert Committee on Food Additives had held its third session in 1958 and its report on specifications for identity and purity of selected antimicrobials and antioxidants had been published. These specifications were being scrutinized by a number of industries, institutes and experts, and would be published in due course by WHO and FAO in book form, comparable to the *International Pharmacopoeia.* The joint Committee, at its next session in December 1959, would consider food colours in the same, way.

The periodical *Current Food Additives Legislation,* issued ten times a year in cooperation with the Rural Legislation Branch, now also contained information on legislation on food enrichment and pesticide residues. In accordance with a recommendation of the FAO 'WHO Conference on Food Additives (1955) a beginning had been made with a *Food Additives Control* series, each issue of which would deal with the relevant legislation of one country, together with comments. The first number, *Food Additive Control in Canada,* had been published recently; others were in preparation.

FAO and WHO would continue the preparation of data sheets on food additives (antimicrobials and antioxidants) similar to those on food colours issued by WHO in 1957, FAO being responsible for the physical and chemical aspects. More attention would be given in the future by both organizations to the pharmacological aspects of food additives.

NUTRITION SERVICES

340. Activities under this heading included the organization of national nutrition services, the promotion of supplementary, feeding programmes, the development of education in nutrition, and the training of personnel.

The Conference emphasized the importance of national nutrition services in promoting necessary, research and in developing applied nutrition programmes. It also stressed the importance of co - ordination at the national level which might be effectively achieved through national food and nutrition committees, and the need for close and permanent contacts between countries and international organizations.

The Conference considered it desirable for each country to have an appropriate agency to carry out programmes in applied nutrition. It might also be advantageous to group in one regional Institute the responsibilities for research and training services for several countries with a common geographic, economic or ethnological background. Assistance to such institutes should be provided by FAO and other international organizations, within the framework of existing programmes and available resources.

SUPPLEMENTARY FEEDING

The Organization had further developed its activities in the field of supplementary feeding during 1958 and 1959, particularly through schools and to a lesser extent through community development programmes. During that period two regional school - feeding seminars had been convened and direct assistance provided to a number of countries. Support from UNICEF was making it possible to assist an increasing number of countries in developing programmes, particularly in rural areas, to improve family and child nutrition, emphasis being given to education in better habits of diet and the local production and use of nutritious foods, so that dependence on imported supplies would gradually decrease. The Conference recommended that 1 such joint activities should be further extended.

The Conference noted that FAO would be co - operating with the United Nations Bureau of Social Affairs and UNICEF in improving the diets in children's institutions, such as kindergartens, crèches and orphanages.

The collective feeding of workers is becoming increasingly important in view 1 of modern living conditions, and has given rise to new nutritional, social and economic problems. The organization and functioning of workers' restaurants and canteens could be greatly improved if better trained personnel were available. The Conference suggested that FAO should give greater attention to the various aspects of collective feeding, including the opportunities it offered for consumer education. The offer of Poland to serve as a pilot area was noted with interest.

EDUCATION IN NUTRITION

The Conference noted that programmes of education in nutrition had been organized in many countries with FAO assistance. It was emphasized that, while improvement in diet might result from increased purchasing power, faster and better results could be obtained if at the same time consumers were taught better habits of diet.

The Conference noted the work done on methods of teaching nutrition and in developing books on nutrition and school gardens, and audio - visual and other teaching aids.

The studies proposed for 1960 and 1961 on the methodology of teaching and on criteria for evaluating educational programmes in the nutritional field should be a valuable contribution. Collaboration with UNESCO with respect to teaching methods should be continued.

The Conference emphasized the need not only to promote education in nutrition through schools, maternal and child welfare centers, community development and extension programmes, but also to develop comprehensive national and regional campaigns to promote appropriate levels of consumption of locally available foods of high nutritive value (*e.g.*, fish, eggs, grain, legumes) as well as new protein - rich food products such as fish flour and defatted oilseed flours.

THE TRAINING OF PERSONNEL

The Conference agreed that the availability of well trained national personnel is the key to the satisfactory, development of all programmes aimed at raising levels of nutrition. The training of personnel in nutrition should therefore remain one of FAO's basic activities in the field of nutrition. FAO had organized both regional and national courses for training personnel. The Conference considered that such activities should be intensified at the regional level, particularly those concerned with training of top level workers in nutrition or in certain specialized related fields. These workers must be the pillars of any national nutrition services and the leaders of applied nutrition programmes.

FAO should increase direct assistance to countries to promote the training in nutrition both of professional personnel at the university level and of personnel in different disciplines who could contribute to practical programmes. This should include the organization of national seminars for both classes of personnel. Full use should be made of all trained personnel. Implementation of this and the preceding recommendation was contingent upon the availability of funds, and in many cases upon governments including appropriate requests in their ETAP and Special Fund proposals.

HOME ECONOMICS

The Conference considered the home economics programme within the broad context of national and international developments in this field and of other FAO activities directly related to family welfare. It noted with satisfaction the progress made in the various aspects of the home economics work and approved the approaches used in developing them. It welcomed the attention that had been given to furthering home economics education through schools and to reaching out to school youth and adults by means of extension and community development programmes. The Conference stressed the important contribution which home economics can make to family welfare and to programmes to improve maternal and child nutrition, like those carried out in collaboration with UNICEF, and considered that such work should be extended.

It was considered important to develop home economics in universities and other institutions of higher learning where the technical aspects of home economics could be associated with, and strengthened by, the social, biological and physical sciences. The Conference endorsed the importance attached to this by the Subcommittee on Extension in Agriculture, Home Economics and Rural Youth of the European Commission on Agriculture and supported FAO's efforts to promote home economics education at higher

levels. Increased collaboration with international governmental and non-governmental bodies had been a feature of the FAO Programme of Work for 1958 - 59. FAO had participated in a number of conferences organized by such bodies, at which an examination was made of the nature of home economics and its contribution to family and community welfare, especially in countries undergoing rapid social and economic change. The Conference emphasized the importance of such collaboration, which has as its objective the study and support of family life. FAO has assisted governments in examining and assessing their current home economics programmes in relation to family needs, and a number of national seminars had been held. which demonstrated the relation of home economics to agricultural extension and other FAO services had been strengthened. The Conference laid emphasis on the need to expand home economics extension services and, in particular, on the. need to study, and develop such services in Africa; it considered that such a study, was essential as a basis for future work in that region and should be undertaken without delay. A consultant might be employed to make it. The development of home economics in Africa would, however, require the services of a full - time regional hcme economics officer.

The decrease in the number of ETAP requests from governments in the home economics field was noted. Concern was expressed that the nature of FAO's home economics programme had to date received insufficient attention in the FAO publications programme.

The Conference recommended that more attention should be given in future to the interpretation of home economics and the contribution of home economics to the improvement of nutrition and family and community welfare. The many aspects of consumer education of concern to the home maker call for special consideration. Interpretation of the subject matter included in home economics is also needed, as well as of the methods used in developing home economics work in schools, and extension and community development programmes. Home economics programmes generally are handicapped by the dearth of research or special studies which specifically and comprehensively describe living conditions, particularly of rural populations. This is true not only with respect to nutrition but also to clothing, housing, health and hygiene, education, work and working conditions, and other factors. The Conference endorsed the emphasis given by the Home Economics Advisory Committee to the need for more research as a basis for sound educational and extension programmes, and especially on evaluation research. Assistance to Member Governments in evaluating their home economics programmes had, however, been handicapped by inadequately developed research methods. Special note was taken of the study on Methodology in Home Economics Extension now being undertaken, and of the plan to hold a European seminar on this subject in 1960.

The relation of the home economist to the social worker in helping to raise levels of family living is an important question, especially in countries where specialists in various family services cannot as yet be provided. The Conference noted the plans made for an

FAO/UN study of this relation - ship, and for a joint seminar in 1961 which would consider the "Role of Social Workers and Home Economists in Meeting Family Needs.

The dry skim milk situation. The Conference considered at length the situation created by the interruption in October 1959 of donations of dry skim milk from the United States and in particular the effect of the prospective reduction in supplies on the distribution of dry skim milk through UNICEF, UNRWA and various voluntary agencies for the supplementary feeding of mothers and children. It noted that in 1958 some 282 million kilograms of dry skim milk had been distributed through these and other channels, benefiting many millions of people, and expressed gratitude to the donor countries, in particular the United States, which had generously provided the great bulk of supplies for making this widespread distribution possible.

UNICEF hoped to be able to meet the most urgent of its presently planned feeding programmes through June 1960. The originally planned rate of feeding in the assisted countries for the 12 - month period ending June 1960 was to use about 60 million kilograms of dry skim milk, over half of which would go to mothers and children in the maternal and child health centers. The position after 1 July 1960 was subject to future milk availabilities and to policies to be determined by, the UNICEF Executive Board.

It was emphasized that, while efforts would be made to continue programmes, the distribution through UNICEF, UNRWA and the voluntary agencies would be more limited, at least for a temporary period, and school - feeding programmes seriously curtailed. The halting of free milk supplies even for a short period would have serious repercussions on programmes depending on such supplies, as it impeded planning and disrupted arrangements for national supplementary feeding. The majority of countries now receiving free milk for supplementary feeding would not be in a position to supply milk or to purchase it from exporting countries, at least not in quantities needed to maintain programmes by these means at anything like their current level. Plans for future programmes depending on free milk should be made on the basis of firm supply commitments.

The Conference regarded the outlook as most serious from the standpoint of nutrition, in view of the extent of malnutrition and the deficiency of protein - rich foods in many countries. It was informed that in certain countries the interruption of supplies might mean an increase in malnutrition and have social, economic and even political implications. It recommended the following action on the part of FAO:

1. A study should be undertaken immediately to indicate the programmed needs and current position in individual countries with respect to stocks of dry skim milk on hand and in transit, the extent to which foods other than milk were being used in supplementary feeding, and to determine the possibilities of expanding local production and conservation of milk. Attention should also be given to the extent to which milk now utilized for other purposes could be used for human feeding.
2. Priorities should be established for distribution of available supplies of dry,

skim milk among population groups within assisted countries. This could be done in collaboration with WHO and UNICEF, taking into account recommendations previously made by expert nutrition committees and recommendations contained in the Report on UNICEF - Assisted Programmes of Dry Skim Milk Distribution.

3. Advice should be provided to governments, upon request, regarding the reorientation of school - feeding programmes, so that available dry skim milk supplies might be supplemented to the greatest possible extent by other foods, particularly local foods. Special attention should also be given to the possibilities of continuing such programmes, largely, on the basis of local foods.
4. Further efforts should be made to encourage the local production and to achieve the fullest local utilization of such foods as milk, fish and pulses, that are important sources of protein and other nutrients and are thus of great dietary value, especially in the feeding of mothers and children. In this connection it would be necessary to intensify the development of jointly - assisted projects under Expanded Aid to Maternal and Child Nutrition; these projects include efforts to develop the local production and consumption of an assortment of foods that can provide nutritionally adequate diets, and education in nutrition. The FAO UNICEF - assisted programme of milk conservation should also be intensified.
5. Intensified efforts should be made to promote the development and use of processed protein - rich foods other than milk. Among the important foods of this type are groundnut, sesame, cottonseed and soybean preparations and fish flour, several of which have already been investigated by, FAO, WHO and UNICEF with respect to their nutritive value, methods of processing, consumer acceptability and availability. Increased attention should be given to the feasibility of using such products to supplement or replace dry skim milk in the different countries concerned. The importance of providing for calcium and other nutrients, of which milk is a rich source, required careful consideration.
6. Governments should be urged to expand the local production of milk where domestic shortages existed, FAO providing increasing assistance for this purpose through its various technical services, including those services rendered in connection with UNICEF supported milk plants.
7. FAO, UNICEF and other international organizations should assist governments to draw up long - term plans for supplementary feeding, which would make it possible for such programmes to be developed on a permanent basis, independent of donations.

FUTURE DEVELOPMENT OF PROGRAMME

One important feature of the nutrition programme noted by the Conference was the relatively small proportion of ETAP funds devoted to projects in nutrition and associated

fields. This meant intensifying the provision of advice and assistance to countries directly through the regular staff and through consultants. In 1960 - 61, assistance through consultants should be increased to the extent that resources allow, thereby making it possible for the regular staff to concentrate on basic activities, on providing leadership, and on ensuring satisfactory liaison with governments. Increasing emphasis should be placed on the training of personnel at all levels.

THE CONFERENCE

Having examined *the programmes of FAO in the fields of nutrition, food technology and home economics,*

Having considered *the important contribution which these are making to economic and social progress in developing countries,*

Emphasizes *that lack of suitably trained personnel is a serious handicap in most countries to the development of satisfactory work in these fields;*

Draws attention *to the lack of facilities for providing training adapted to the needs of each particular country;*

Urges *Member Governments to give increasing attention to the establishment of suitable training facilities and to make* full *use of the available trained personnel;*

Requests *the Director - General to intensify assistance to Member Governments in the development of training programmes in the broad fields of nutrition, food technology and home economics through regional and national training courses and the establishment of permanent higher training facilities, within available resources.*

With regard to the future programme, the Conference expressed approval of the plans for 1960 - 61 contained in the Programme of Work and Budget. Various points at which the work in food consumption and planning, food processing and preparation, nutrition services and home economics could profitably be expanded have been indicated in the preceding sections.

With respect to the more remote future, the Conference was in general agreement with the expansions assigned to work in food and nutrition, home economics and associated fields in the Forward Appraisal, with due regard to budgets approved by future sessions of the Conference. The further development of activities carried out jointly with UNICEF and WHO, relating to the improvement of the nutrition of mothers and children and concerning many aspects of the Nutrition Division's programme, should be a prominent objective in future years.

PLANT PRODUCTION AND PROTECTION

The Conference approved the work of the Plant Production and Protection Division carried out during the biennium 1958 - 59 and studied its programme of work for 1960 - 61. It noted with satisfaction the balance achieved between long - term work on certain fundamental aspects of plant science and work on practical aspects of great and immediate importance in crop production, improvement and protection.

CROP PRODUCTION AND IMPROVEMENT

The Conference stressed the work on improvement in rice, wheat, barley and maize, and recommended that this should be extended to other crops of tropical and subtropical regions, which contribute to better balance in human nutrition, and to diversification of farming, maintenance of soil fertility, and better feeding of livestock. This need was greatest in grain legumes, sorghums and millets, root, oil and fibre crops, and pasture and fodder crops, all of which could be grown in crop rotations.

The catalogues of genetic stocks of rice, wheat and barley and the tabulated list of varieties of grain legumes are of value to breeders in general, particularly in locating useful breeding material. Doubt was expressed as to the need to publish supplements so frequently; longer intervals were suggested. The Director - General was requested to investigate whether this type of catalogue was the best way of distributing information on genetic stocks. With regard to the registration of varietal names of crops, the Conference agreed that information should be collected and collated, and that a report should be made to its Eleventh Session; it could then be decided whether FAO could be responsible for acting as a registering authority.

The Conference recognized the value to the Near Eastern countries of the regional wheat and barley project, with its emphasis on the provision of the services of breeding experts, the training of technicians through fellowships and national training centers, and the convening of biennial technical meetings. These activities had facilitated exchange of information on seed stocks, the adoption of improved cultural practices, and the introduction of adapted disease - resistant varieties. The Conference approved the preparation of a long - term project on wheat and barley for the Near East region.

Plant exploration and introduction was recognized as an appropriate field for international collaboration. There was great need and scope for the provision to plant breeders of new genetic material, particularly, of wild species and primitive forms. It was agreed that many existing crops had too narrow a genetical basis, that the genetic resources in the main areas of origin and maximum variability, had not by any means been fully tapped and, most urgent of all, that the natural vegetation and primitive cultivated forms were being rapidly eliminated through overgrazing, burning, Cutting for fuel, clearance for new cultivated land, and the introduction of superior varieties. It would be highly desirable that countries in regions containing important centers of origin of crop plants should collaborate, under the Organization's ecological programme, by establishing protected areas in critical regions, to ensure the preservation *in situ* of important native material for future use.

The Conference agreed that the Organization should continue to act as a clearinghouse of information on plant exploration and introduction, commended the *Plant Introduction Newsletter,* and requested the Director - General to do everything possible to provide further assistance to Member Governments, especially in co - ordinating plans for plant exploration, in order that collections should be efficiently organized and serviced, and the proceeds shared equitably among interested parties. The Conference recommended

that the Organization assist towards international co - operation and co - ordination by convening an international meeting of specialists in plant exploration and introduction to meet as soon as possible. The Conference learned with approval that plans had been made to commence, early in 1960, an Inter - Agency Project on Agroclimatology, involving collaboration between FAO, WMO and UNESCO. Basic projects of this nature are of the greatest importance for all aspects of the work in plant production but particularly for general ecology, land use planning, plant exploration and introduction, seed exchange, and the activities of regional officers and working parties.

The Conference approved the programme on tropical crops in general. Recognizing the severe limitations of agricultural systems based on one or a limited number of crops, for both subsistence and export, the Conference emphasized the need for increased attention to crop diversification and the integration of crop and animal husbandry in balanced systems of land utilization. This would contribute greatly to an improvement of human diets, higher total production, and distribution of economic risks, at the same time providing a balance in local agricultural systems as between food and cash crops.

The Conference acknowledged the significance for the cacao - producing areas of the first FAO technical meeting on cacao, and stressed the need for the early implementation of its recommendations.

THE CONFERENCE

Considering *the steadily increasing importance of cacao for the improvement of living standards of a large number of smallholders in many areas of the tropics,*

Convinced *that many technical problems concerned with the production and processing of cacao can best be solved through international co - operation,*

Having examined the resolutions contained in the Report of the First FAO Technical Meeting on Cacao (Doc. FAO/59/4/2269) held in Accra, Ghana, in February 1959,

Supports *the request made to the Director General of FAO by that meeting for the establishment of an FAO Technical Working Party on Cacao Production; and*

Recommends *that, within this Working Party, a Technical Advisory Committee, com posed of highly qualified cacao workers, be set up to assist the Director - General in the implementation of its programme on cacao production and processing.*

As regards industrial crops such as rubber and cotton, which represent important sources of income in a number of tropical and subtropical areas, and which are facing strong competition from synthetic products, the Conference indicated the necessity for more work on varietal improvement and the development of better cultural practices, with the objectives of improving the quality of crops and the resulting products, as well as reducing production costs.

THE CONFERENCE

Considering *the great importance of the coconut as a cash and subsistence crop, primarily in Southeast Asia and the Pacific Islands,*

Noting *the increased interest shown by several Member Governments in the solution of technical problems of production, protection and processing through co - ordinated joint action,*

Supports *the establishment of an FAO Technical Working Party on Coconut Production, Protection and Processing.*

It was noted that the First FAO Technical Meeting on Coffee Production would be held in 1960 and that a long - term programme for the improvement of this crop would be prepared. Similar work was considered highly desirable with regard to maize, millets and sorghums in the tropics, particularly in Africa South of the Sahara.

The Conference recognized the excellent progress with the work on rice production, improvement and protection in Southeast Asia, requested that this work should be intensified and, if possible, extended to other regions, particularly Africa South of the Sahara, for which purpose it is recommended that the International Rice Commission's Working Party on Rice Production and Protection should intensify its activity in Africa, particularly by holding periodic meetings in that region. It was noted with approval that a long - term project for rice production, improvement and protection was under preparation.

The Conference reaffirmed the importance of fruit and vegetable crops, both for human nutrition and in the diversification of farming systems, particularly in tropical areas. High priority should be given to the convening of technical meetings on fruit and vegetable production in the Latin American and Far East regions in 1960 - 61, and possibly later in Africa, in addition to the banana meeting planned for Africa in 1960. Approval was also given to the publication of a World *List of Living Collections of Fruit Species* and an Agricultural Study, *Date Palm Growing,* as well as for the preparation for subsequent publication of further studies on *Vegetable Growling in the Tropics* and *The Ecological Requirements of Fruit Species.* The Conference emphasized the need to assist member countries in the Near East region in vegetable seed production, through the work of the regional horticulturist and the organization of national training centers.

The Conference noted with approval that the joint project of the Plant Production and Protection Division and the Nutrition Division on grain legumes in agriculture and human nutrition had made good progress, particularly through the convening of the joint FAO/CCTA Technical Meeting in Bukavu, Belgian Congo, in November 1958. The plans to hold similar meetings in other regions, and first in Latin America, and to publish a joint review on grain legumes in agriculture and human nutrition in Africa were approved.

The continuation of the Working Parties on Pasture and Fodder Development in the Mediterranean area, the Near East and Central America was approved, provided Member Governments in these regions gave greater support and agreed to take part in long - term programmes of research and development. The Conference welcomed the extension of the regional approach in this field, particularly the plans to convene a meeting of a

new Working Party, for Grassland and Fodder Development in Tropical America in 1960, as a counterpart to the FAO Inter American Livestock Meetings. The Conference requested that account should be taken of the resolution of the FAO/CCTA Technical Meeting on Legumes in Agriculture and Human Nutrition in Africa, and recommended that a Working Party on Grassland and Fodder Development in Africa South of the Sahara should be formed and should hold its first meeting as soon as possible. The Conference commended the cooperation between plant, forestry, animal and dairy specialists in the development of joint approaches to the over - all problem of providing grazing and fodder in optimal quantities and qualities for livestock throughout the year.

COMMON METHODS OF PROCESSING AND PRESERVING FOOD

Food processing is a way or technique implemented to convert raw food stuff into well-cooked and well preserved eatables for both the humans and the animals. All these methods are used by food processing industry to give out processed or preserved foods for our daily consumption. Best quality harvested, slaughtered and butchered and clean constituents are used by food processing industry to manufacture very nutritious and easy to cook food products. Following are some techniques and methods used to convert food into processed or preserved food.

- *Preservation process:* This includes heating or boiling to destroy micro-organisms, oxidation, toxic inhibition, dehydration or drying, osmotic inhibition, freezing, a sort of cold pasteurization which destroys pathogens and various combinations of all these methods.
- *Drying:* This is probably the most ancient method used by humans to preserve or process their food. Drying reduces the water content in the product and lack of water delays the bacterial growth very much. Drying is the most common technique to preserve or process cereal grains like wheat, maize, oats, rice, barley, grams and rye etc.
- *Smoking:* Many foods such as meat, fish and others are processed, preserved and flavoured by the use of smoke mostly in big smoke houses. This process is very simple as the combination of smoke to preserved food without actually cooking it and the aroma of hydro-carbons generated from the smoke processes the food and makes it even tastier to eat.
- *Freezing:* Probably, it is the most common technique used in modern world to preserve or process the food both on commercial and domestic basis. This freezing is conducted in big cold storages which can stockpile huge amount of food stuffs which can be further used in some natural emergencies. A very big range of products can be frozen to preserve and process which includes some which do not need freezing when are in their natural condition. For example potato chips and potato wafers requires freezing whereas a potato does not.

- *Vacuum packs:* In this method, food is packed in airtight bags and bottles in a vacuum area. This method is used in processing the food as the air-tight environment doesnâ€™t provide oxygen needed by germs especially bacteria to survive. This then, prevents food from getting rotted. This method is very commonly used for preserving processed nuts.
- *Salting:* The method of salting is used in food processing as it sucks out the moisture from the food. This is done through the process of osmosis. Meat is the best example of the food processed by salting as nitrates are used very frequently to treat meat.
- *Sugaring:* The method of using sugar to preserve or process food is very frequent where it comes to preserve fruits. In this method fruits such as apples, peaches and plums are cooked with sugar until they are crystallized and then it is stored dry. Now days, sugar is also used in combination of alcohol to make some branded alcohol and spirits.
- *Pickling:* In this method of preserving or processing food, food is cooked in chemicals and materials which destroy micro-organisms. This is very strictly kept in mind that these chemicals or materials are fit to eat for humans. Normally, these include brine, vinegar, ethanol, vegetable oil and many other types of oils. Pickling is very commonly seen in vegetables such as cabbage and peppers. Corned beef and eggs are the non- vegetarian eatables that are pickled.

These are some very common methods of preserving or processing food. These all will work only when processing and preserving is done under very strict rules and regulation set by the governments.

FOOD PROCESSING STRATEGIES FOR QUALITY

Food processing is the set of methods and techniques used to transform raw ingredients into food or to transform food into other forms for consumption by humans or animals either in the home or by the food processing industry. Food processing typically takes clean, harvested crops or butchered animal products and uses these to produce attractive, marketable and often long shelf-life food products. Similar processes are used to produce animal feed.

Food processing encompasses all the steps that food goes through from the time it is harvested to the time it arrives on consumer's plate. According to Food and Agriculture Organization (FAO), processed foods can be classified into three types (1) Primary (2) Secondary and (3) Tertiary. The primary processing includes basic cleaning, grading and packaging as in case of fruits and vegetables. Secondary processing includes alteration of the basic product to a stage just before the final preparation as in case of milling of paddy to rice. Tertiary processing leads to a high value-added ready-to eat

food like bakery products, instant foods, health drinks, etc. Traditional food processing had two functions: to make food more digestible and to preserve food during times of scarcity. Most crops are seasonal. There are times of the year when either glut can result in high levels of wastage or shortages can arise if adequate measures are not taken to preserve and store the foods. This is particularly important in areas that have a dry season or winter period when crops cannot be grown and animals are slaughtered because of a lack of fodder. In these situations stored dry grains or root crops provide energy; dried, salted or smoked meats, or cheeses provide a source of protein, vitamins and minerals; and processed fruits and vegetables such as pickles, chutneys or dried fruits or leaves provide vitamins and minerals. A few crops, including cassava and some types of beans also contain poisons or anti-nutritional components, which must be removed by processing to make the food safe to eat. Hence, Food processing enables to maintain the health of the human beings throughout the year by increasing its food security.

By processing food, it can be customized to suit the nutritional requirements of groups such as the elderly, pregnant women, infants, young children and athletes. Such foods are characterized by a balanced composition of energy suppliers in the form of fats, carbohydrates and proteins, and by a cocktail of vitamins and minerals composed according to the current state of scientific knowledge. Food processing is a route to creating sustainable livelihoods and economic development for rural communities.

Sophisticated technologies define modern food production. They include many areas. Agricultural machinery, led by the tractor, has reduced the human labour in many areas of production. Biotechnology is driving much change, in areas as diverse as agrochemicals, plant breeding and food processing. Many other areas of technology are also involved, to the point where it is hard to find an area that does not have a direct impact on the food industry. Computer technology is also a central force, with computer networks and specialized software providing the support infrastructure to allow global movement of the myriad components involved.

Modern food processing has three major aims:

1. To make food safe (microbiologically, chemically)
2. To provide products of the highest quality (flavour, colour, texture)
3. To make food into forms that is convenient (ease of use)

The following table summarizes the item to be controlled in food processing and comments on the major approaches involved in this control.

- Heat
- Cold
- Chemicals
- Active water
- Mechanical
- Micro-organisms
- Prevents growth

- Reduces growth rate
- Preservatives retard growth
- Do not grow below Aw of 0.6
- Reduces numbers
- Enzymes
- Destroyed by heat activity
- Decrease reaction rate
- Modify activity
- Alters rate of enzyme activity
- increase ES complex formation
- Chemical Reactions
- Increases chemical rate, browning, oxidation
- Reduces reaction rate
- May inhibit or activate
- Can alter rate of reaction, like oxidation
- Not applicable
- Physical Structure
- Increases effects
- Decreases effects
- May modify structure
- High. Aw may cause caking
- Can destroy structures
- The significant benefits for different stakeholders involved in food processing are:
- Farmer - higher yield, better farm realization, lower risk
- Consumer - greater variety, lower prices, new products
- Companies - new business opportunities, demand growth
- Economy/Government - Employment generation, reduced rural migration
- The emerging opportunities in food processing are interesting and challenging as well.

NEED FOR FOOD PROCESSING

Once food is harvested, it begins to deteriorate immediately due to the following factors:

- Micro-organisms (yeast, mould, bacteria);
- Intrinsic enzymes;
- Temperature;
- Moisture; and
- Insects and vermin

Because of the risk of spoilage, much of our food is processed in some way to increase its availability. A food is considered preserved once it is stabilized with respect to safety and quality.

Nearly every food preparation process reduces the amount of nutrients in food. In particular, processes that expose foods to high levels of heat, light, and/or oxygen cause the greatest nutrient loss. Nutrients can also be "washed out" of foods by fluids that are introduced during a cooking process. For example, boiling a potato can cause much of the potato's B and C vitamins to migrate to the boiling water. We can still benefit from these nutrients if we consume the liquid (*i.e.* if the potato and water are being turned into potato soup), but not if we throw away the liquid. Similar losses also occur when we broil, roast, or fry in oil, and then drain off the drippings. It's important to note that no type of food processing can transform poor quality raw materials into good ones. It can only increase the product's shelf life. To ensure that product meets high standards:

- Use the highest quality raw ingredients;
- Establish good processing techniques-and follow them; and
- Maintain an appropriate product environment after processing.

Not all processing methods are applied to foods to achieve preservation. Some are also used to change or stabilize food texturally.

Microorganisms require water, nutrient, oxygen and a suitable temperature for optimal growth and reproduction.

Microorganism can only survive in condition with optimum pH and solute concentration as these will not destroy them. Food can be preserved by destroying the microorganism present in the food or by stopping the activities of these microorganisms

FOOD PROCESSING METHODS USED FOR FOOD PRESERVATION

Methods of processing food can be divided into two main categories-chemical and physical.

Chemical Processing Methods

The following techniques use the chemical approach in processing food.

Intermediate Moisture Foods (IMF)

Binding the water that is present preserves intermediate moisture foods-for example, cookies, cake and bread. This reduces the availability of the water for deteriorative reactions.

Water is immobilized by adding permissible humectant additives such as glycerol, glycols, sorbitol, sugars and salts.

Generally, IMFs possess water activities that range from 0.6 to 0.85. This enables the food to be stable at room temperature, because the growth of most micro-organisms is inhibited at these levels.

Water Activity (aw)

Water is the most important factor in controlling the rate of deterioration of a food. However, knowledge of the moisture content of a food is not sufficient to predict its

stability. It is the availability of water for microbial, enzymatic, or chemical activity that determines the shelf life of foods. This water availability is measured as water activity (aw).

Water activity is measured on a scale of 0 to 1, where 0 indicates no water and 1 indicates all water. Food spoilage micro-organisms, in general, are inhibited in food where the water activity is below 0.6. However, if the pH of the food is less than 4.6, micro-organisms are inhibited when the water activity is below 0.85.

Addition of Chemicals

The addition of some chemicals inhibits microbial growth in foods. These chemicals include not only those classified as preservatives. Salt, sugars, wood smoke and some spices also inhibit the growth of micro-organisms.

PH Control

Almost every food, with the exception of egg whites and soda crackers, has a pH value of less than 7. Foods can be broadly categorized on the basis of their pH as high acid, acid, medium acid or low acid.

Examples of each category include:

- High acid (3.7): apples, lemons, raspberries
- Acid (3.7 to 4.6): oranges, olives, tomatoes (some)
- Medium acid (4.6 to 5.3): bread, cheese, carrots
- Low acid (over 5.3): meat, fish, most vegetables

Most micro-organisms grow best in the pH range of 6.5 to 7.5. Yeasts and moulds are capable of growing over a much broader pH range than bacteria. Few pathogens will grow below pH 4.0. This information is important, because it will help us in determining food stability with respect to microbial spoilage.

PHYSICAL PROCESSING METHODS

A number of physical methods are available to you for processing foods.

STERILIZATION (RETORTING)

A pathogen is any microorganism that causes illness. Food pathogens cause food-borne illnesses such as food poisoning or food intoxication.

Sterilization destroys all pathogenic and spoilage micro-organisms in foods and inactivates enzymes by heating. All canned foods are sterilized in a retort (a large pressure cooker). This process enables food to have a shelf life of more than two years.

Foods that have a pH of more than 4.6, such as meat and most vegetables must undergo severe heating conditions to destroy all pathogens. These foods are heated under pressure to 121°C for varying times.

Severe conditions are applied to ensure that Clostridium botulinum spores are destroyed during processing. These spores produce the deadly botulinum toxin under

anaerobic conditions (that is, where there's no oxygen). The spores are destroyed by heat or are inhibited at pH values of less than 4.6. Therefore, a food with a pH of less than 4.6 that is packaged anaerobically, such as spaghetti sauce, doesn't need to undergo such a severe heat treatment.

PASTEURIZATION

Pasteurization is the process of heating a food-usually a liquid-to or below its boiling point for a defined period of time. The purpose is to destroy all pathogens, reduce the number of bacteria, inactivate enzymes and extend the shelf life of a food product.

Foods with a pH of less than 4.6, such as milk and spaghetti sauce, can be pasteurized.

Permanent stability-that is, shelf life of about two years-is obtained with foods that can withstand prolonged heating, such as bottled juices.

There is a greater loss of flavour from foods that are exposed to a longer time-temperature relationship. Therefore, temporary stability (that is, limited shelf life) is only obtained with some foods where prolonged heating would destroy its quality. These foods, such as milk, usually require subsequent refrigeration.

"High temperature short time" (HTST) and "ultra high temperature" (UHT) processes have been developed to retain a food's texture and flavour quality parameters.

BLANCHING

Blanching is a slight heat treatment, using hot water or steam that is applied mostly to vegetables before canning or freezing. Blanching is used before freezing to inactivate enzymes present that cause deteriorative reactions to foods during frozen storage. These reactions include colour and texture changes, off-flavours and a decrease in nutritional value. Blanching is used before canning for different reasons, because enzymes will inevitably be destroyed during canning. Blanching induces a vacuum in canned goods, and it's also used to control the fill into containers (for example, spinach).

MICROWAVING

Microwave ovens are rarely used for processing large quantities of food. They are mainly of interest if you cater to the convenience food market. Microwave ovens use electromagnetic radiation to excite water molecules in food. The actual waves penetrate only about 10 inches from the source of the radiation. Within the food, the waves only penetrate 3.4 to 1 inch on all sides. As a result, the actual ovens must be limited in size. Heat is produced within the food by the friction of water molecules, which spreads to the centre of the food by conduction. Small portions are cooked rapidly in microwave ovens. As the quantity of food increases, however, the efficiency is lost.

FRYING

Frying differs from other methods of heat processing in that the cooking medium is hot oil. Because of the big difference between the temperature of the oil and the food,

as well as the small size of the food pieces, cooking is completed in a relatively short time-anywhere from 20 seconds to six minutes.

Fried foods are known for their characteristic crispy outer surface as well as their high fat content. The fat that is absorbed by the food product varies from 10 percent to 40 percent, depending on the time the food is immersed in the oil. Continuous fryers are often used in the food industry.

REFRIGERATION

Refrigerators should be set to below 4°C to control the growth of micro-organisms in foods.

This lowered temperature also reduces the respiration rate of fruits and vegetables, which retards reactions that promote spoilage.

Refrigeration is generally used to:

- Reduce spoilage during distribution of perishable foods;
- Increase the holding period between harvesting and processing

Extend the storage life of commercially processed foods.

Not all foods benefit from cold temperatures. For example, bananas turn black and bread goes stale when refrigerated.

FREEZING

While many home freezers are held at -10°C, commercial freezers are under -18°C. At this temperature, the growth of micro-organisms is almost stopped. Deteriorative microbial reactions will still occur, but over a much longer time.

In addition, deteriorative enzymatic reactions will still take place during frozen storage. Uncooked fruits and vegetables must be blanched before freezing to prevent these reactions.

During freezing, the water in food forms ice crystals. The rate of this phenomenon has a big impact on the quality of frozen foods:

Slow freezing (*e.g.* home freezer)

- Large ice crystals formed, which puncture cell walls
- Cellular fluid released
- Results in shrunken appearance of thawed food

Rapid freezing (*e.g.* blast freezer)

- Small, numerous ice crystals formed
- No change to cell structure

The shelf life of frozen foods is largely dependent on storage conditions. Under ideal conditions, frozen foods can have a shelf life of one year.

However, if foods are continuously exposed to warmer temperatures, such as the opening and closing of freezer doors, then heat shock occurs. Heat shock is when ice melts and re-forms into larger ice crystals. The best example is ice cream, which has a gritty texture if large ice crystals have developed.

IRRADIATION

Irradiation is the controversial process of applying low doses of gamma radiation to food products. Research have shown that the process exhibits no safety hazard. As a result, irradiation is permitted in some countries to:

- Prevent sprouting in potatoes and onions
- Control insect infestation of wheat flour; and
- Reduce the microbial load of ground spices

If irradiation becomes more widespread among various other food products, it is expected to replace fumigation, ensure hygienic quality and reduce the dependence on refrigeration.

BATCH VS. CONTINUOUS PROCESSING

Food is processed in either discrete batches or a continuous system. Although there are advantages and disadvantages to each method, choice in the matter is restricted only to those replacing or setting up a new processing line. Generally, batch systems are used to produce small quantities of food, whereas larger volumes are required for continuous systems.

ADVANTAGES OF BATCH PROCESSING

ADVANTAGES OF CONTINUOUS PROCESSING

- Greater flexibility to change product
- Formulation and rates
- Lower operation and labour costs
- Lower equipment costs
- Less floor space required
- Easier operation and control
- Greater product uniformity

EVAPORATION

Evaporation is the partial removal of water from liquid foods by boiling. When the operation is done under vacuum, boiling is avoided and the food's flavour qualities are retained.

Some of the foods that have undergone evaporation are evaporated milk, tomato paste and juice concentrates.

This process is carried out for three main reasons:

- To reduce the weight and, therefore, reduce storage and transport costs
- To preserve foods by decreasing the water activity and increasing the solids content
- To provide consumers with convenient foods

DEHYDRATION

Dehydration-or drying-is the nearly complete removal of water from solid foods. One of the oldest methods of food preservation, it was traditionally carried out by the sun. This application is used for the same reasons that liquid foods undergo evaporation-preservation, convenience and cost savings. Dried soup mixes, dried fruit, powdered milk and spices are just a few examples of dehydrated foods. Spray drying and freeze drying are two drying methods used widely today. Spray drying is when a liquid food is atomized into a fine, dry powder. Examples include natural and artificial flavours and milk powders. Freeze drying involves first freezing the food and then driving off the ice, leaving a high quality, porous dried food such as instant coffee.

EMULSIONS

An emulsion is a system containing two liquid phases that don't mix, where one phase (dispersed phase) is distributed throughout the other phase (continuous phase) in the form of very small droplets. Generally there are two types of emulsions:

- Oil in water (O/W)
- Water in oil (W/O)

An example of an O/W emulsion is salad dressing, and an example of a W/O emulsion is butter.

HOMOGENIZATION

Homogenization is used to stabilize an emulsion. More specifically, it is the reduction in size and the increase in number of droplets of the dispersed phase by the application of intense shearing forces.

Generally, homogenization is applied to change the functional properties or improve the texture of emulsions. For example, most fluid milk sold at the retail level is homogenized to improve its stability, and most caramel fillings are homogenized to increase their smoothness.

EXTRUSION

Extrusion is the process in which a food is compressed and worked to form a semi-solid mass. This mass is then forced through a restricted opening, or die, to create a desired texture or shape. The purpose of this application is simply to provide a greater variety of textured foods to consumers.

Food may also be cooked while extruded. This is referred to as extrusion cooking, or hot extrusion.

Some extruded food products are licorice, puffed wheat and cornflakes.

HURDLE OR COMBINATION PROCESSING

Hurdle technology is a concept that was developed to address the consumer demand for more natural, fresh-like foods. It is a way for food processors to employ only mild

preservation techniques to their food products. The idea is to use deliberate low-level combinations of existing and novel preservation techniques ("hurdles") to eliminate the growth of micro-organisms. Lower-intensity individual methods can be used because of the collective effect of the combined methods. Some of the more common hurdles include:

- Pasteurization
- Water activity (aw)
- Salt
- Blanching
- Freezing; modified atmosphere packaging (MAP)
- pH
- Preservatives
- Refrigeration
- Irradiation

Some micro-organisms present will be able to survive the individual treatments applied. However, no microorganism will be able to overcome all of the combined hurdles. Thus the food is stable and safe.

The only way to ensure that the correct combination of hurdle technologies is used is to make sure that a qualified resource conducts quality and safety shelf-life studies.

Examples of hurdle processing can be found in traditional and recently developed foods, such as yogurt and pre-packaged fresh salads. The hurdles employed in yogurt manufacture include low temperatures, high acid and competitive microbial flora. Those used to prepare pre-packaged fresh salads include low temperatures and modified atmospheres.

GLOBAL FOOD PROCESSING INDUSTRY

The global processed food industry is estimated to be valued around EUR 2.5 trillion and accounts for three-fourth of the global food sales. The global food industry is ever changing and evolving. However, health, convenience and value continue to be the key value propositions in this industry.

Despite the large size of the industry, only 6 percent of processed foods are traded across borders compared to 16 percent of major bulk agricultural commodities. The United States and European Union together account for over 60 percent of total retail processed food sales in the world.

Trade liberalization policies through multi-lateral and regional trade agreements have led to a rapid growth in food processing. In the Asian region, Japan is the largest food processing market, but India and China are likely to grow at a faster rate in the next decade. The processed food industry is strong in Japan and South Korea, as they are the leading meat importing countries in the world and consumption of meat is high in these countries. The Australian processed food industry is one of the most technically

advanced in the world and it produces products of international standards at comparatively lower prices for the world market. The U.S. continues to live up to its reputation as the "breadbasket to the world". Countries in the Sub-Sahara African region, Latin America and parts of Asia continue to be on the lower-end of technology prowess in food items and are inclined to their staple diets, whereas, those in Europe, North America, and Japan are on the higher-end of technology, with a sharper shift towards convenience and diet foods.

Apart from the current large size of the processed foods, the growth trends reported are very encouraging. According to a study done by AC Nielsen, "What's Hot around the globe in F&B in 2006", the growth in the global Food and Beverages (F&B) was estimated at 4 %. The most interesting aspect of the study is the growth in emerging markets like India, where the estimated growth is over 13% year over year. Further, the study reports that the world's major food processors are looking for low cost sourcing options with proven quality standards, strong backward and forward linkages to ensure uninterrupted, traceable and quality products to the discerning world customers.

FRUITS AND VEGETABLES

The installed capacity of fruits and vegetables processing industry has doubled from 1.1 mn tonnes in January 1993 to 2.1 mn tonnes in 2006. The major processed items in this segment are fruit pulps and juices, fruit based ready-to-serve beverages, canned fruits and vegetables, jams, squashes, pickles, chutneys and dehydrated vegetables. The new arrivals in this segment are vegetable curries in retortable pouches, canned mushroom and mushroom products, dried fruits and vegetables and fruit juice concentrates.

The fruits and vegetable processing industry is rather fragmented. A large number of units are in household and small-scale sector, having low capacities of up to 250 tonnes per annum. From the year 2000 onwards the industry has seen a significant growth in ready-to-serve beverages, pulps and fruit juices, dehydrated and frozen fruits and vegetable products, pickles, processed mushrooms and curried vegetables, and units engaged in these segments are export oriented.

MEAT AND POULTRY

Since 1995, production of meat and its products has been significantly growing at a rate of 4% per annum. Presently the processing level of buffalo meat is estimated at 21%, poultry is estimated at 6% while marine products are estimated at 8%. But only about 1% of the total meat is converted into value added products like sausages, ham, bacon, kababs, meatballs, etc. Processing of meat is licensed under the Meat Food Products Order, 1973. Presently the country has 3,600 slaughterhouses, 9 modern abattoirs and 171 meat-processing units licensed under the meat products order.

Poultry industry is also among the faster growing sectors rising at a rate of 8% per year. It is observed that the vertical integration of poultry production and marketing has

lowered costs of production, consumer prices of poultry meat and marketing margins. There are eight integrated poultry processing units in the country, which of course hold a significant share in the industry.

Meat export is largely driven by poultry, buffalo, sheep and goat meat, which is growing at close to 30% per annum in terms of quantity. It is considered that the growing number of fast food outlets in the country has and will have a notable impact on the meat processing industry. Exports of Meat and Meat Products (Quantity in MT, Value in Rs Mn)

PACKAGED/ CONVENIENCE FOODS

Consumer food industry mainly consists of ready-to-eat and ready-to-cook products, salted snacks, chips, pasta products, cocoa based products, bakery products, biscuits, soft drinks, etc.

There are around 60,000 bakeries, several pasta food units and 20,000 traditional food units and in India. The bakery industry is among the few processed food segments whose production has been increasing consistently in the country in the last few years. Products of bakery include bread, biscuits, pastries, cakes, buns, rusk etc.

This activity is mostly concentrated in the unorganized sector. Bread and biscuits constitute the largest segment of consumer foods with an annual production of around 4.00 million tonnes.

Bread manufacturing is reserved for the small-scale sector. Out of the total production of bread, 40% is produced in the organized sector and remaining 60% in the unorganised sector, in the production of biscuits the share of unorganized sector is about 80%.

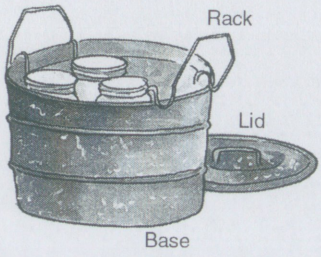
FOOD PRESERVATION METHODS: CANNING, FREEZING, AND DRYING

Canning is the process of applying heat to food that's sealed in a jar in order to destroy any microorganisms that can cause food spoilage. Proper canning techniques stop this spoilage by heating the food for a specific period of time and killing these unwanted microorganisms. During the canning process, air is driven from the jar and a vacuum is formed as the jar cools and seals.

Although you may hear of many canning methods, only *two* are approved by the United States Department of Agriculture (USDA). These are water-bath canning and pressure canning:

- Water-bath canning: This method, sometimes referred to as *hot water canning*, uses a large kettle of boiling water. Filled jars are submerged in the water and heated to an internal temperature of 212 degrees for a specific period of time. Use this method for processing high-acid foods, such as fruit, items made from fruit, pickles, pickled food, and tomatoes.

Water-bath canning kettle



- Pressure canning: Pressure canning uses a large kettle that produces steam in a locked compartment. The filled jars in the kettle reach an internal temperature of 240 degrees under a specific pressure (stated in pounds) that's measured with a dial gauge or weighted gauge on the pressure-canner cover. Use a pressure canner for processing vegetables and other low-acid foods, such as meat, poultry, and fish.

ABOUT FREEZING FOOD

Freezing foods is the art of preparing, packaging, and freezing foods at their peak of freshness. You can freeze most fresh vegetables and fruits, meats and fish, breads and cakes, and clear soups and casseroles. The keys to freezing food are to make sure it's absolutely fresh, that you freeze it as quickly as possible, and that you keep it at a proper frozen temperature (0 degrees).

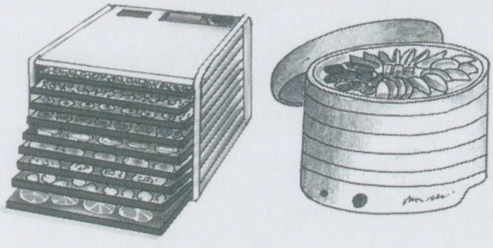
Here are three things to help you avoid freezer burn:

- Reduce exposure to air: Wrap food tightly.
- Avoid fluctuating temperatures: Keep the freezer closed as much as possible. Know what you want to remove before opening the door.
- Don't overfill your freezer: An overly full freezer reduces air circulation and speeds freezer damage.

DRYING FOOD

Drying is the oldest method known for preserving food. When you dry food, you expose the food to a temperature that's high enough to remove the moisture but low enough that it doesn't cook. Good air circulation assists in evenly drying the food.

Two Electric Dehydrators



An electric dehydrator is the best and most efficient unit for drying, or dehydrating, food. Today's units include a thermostat and fan to help regulate temperatures much better. You can also dry food in your oven or by using the heat of the sun, but the process will take longer and produce inferior results to food dried in a dehydrator.

CANNING AND PRESERVING FOR DUMMIES CHEAT SHEET

Preserve food by water-bath canning, pressure canning, freezing, or drying — all are time-honoured and safe techniques. Canning and preserving are great ways to save foods at their peak freshness and flavour and to stock your pantry with nutritious and delicious fare. These checklists provide quick instructions for each food-preservation method; information on how to adjust recipes for high-altitude processing; advice to ensure canning success; and details on must-have canning and preserving equipment.

PRESERVE FOOD BY CANNING, FREEZING, AND DRYING

This at-a-glance guide shows how to preserve foods by canning, freezing, and drying. People have been preserving food for eons. Newer, safer food preservation techniques and equipment enable you to stock your pantry or freezer with delicious, healthy foods. Pick your preferred method — water-bath canning, pressure canning, freezing, or drying — and follow these basic instructions.

Water-Bath Canning	Pressure Canning	Drying	Freezing
1. Gather supplies and equipment; keep jars hot. 2. Prepare food. 3. Fill your jars, leaving proper headspace and releasing air bubbles. Put on lids and hand-tighten screw bands. . 4. Place jars in water-bath canner. 5. Bring water to boil and allow to boil for amount of time specified in recipe. 6. At end of processing time, remove jars and allow to cool completely. 7. Test seals. 8. Store!	1. Gather supplies and equipment; keep jars hot. 2. Prepare food. 3. Fill your jars, leaving proper headspace and releasing air bubbles. Put on lids and hand-tighten screw bands. 4. Place jars in pressure canner. 5. Close and lock the canner. 6. Process jars as outlined in the recipe. 7. At end of processing time, allow pressure to return to 0. 8. Remove jars from canner and allow to cool completely. 9. Test seals. 10. Store!	1. Gather supplies. 2. Prepare food. 3. Arrange food on dehydrator trays. 4. Dry at specified temperature, occasionally turning food and rotating trays. 5. Check for doneness, using guidelines in recipe for what properly dried food looks and feels like. 6. Place in airtight storage container and store in cool, dry place out of direct sunlight.	1. Gather supplies. 2. Prepare food. 3. Place food in freezer containers, leaving specified headspace (if using rigid containers) or pressing out all excess air (if using freezer storage bags). 4. Slightly chill food or, if it was blanched, allow to come to room temperature. 5. Loosely pack food in freezer. 6. When completely frozen, repack more tightly in freezer.

ADJUSTMENTS FOR HIGH-ALTITUDE CANNING

Home cooks who live at high altitudes may be used to adjusting recipes; high-altitude adjustments apply to home canning, as well. Canning food safely requires your filled

jars to be processed at a specified temperature or pressure level for a specified amount of time. If you live at altitudes higher than 1,000 or 2,000 feet above sea level, adjust your canning recipes for food safety.

- Water-bath canning: Generally, recipes are written for water bath canning at altitudes less than 1000 feet. If you live higher than 1,000 feet above sea level, follow these guidelines:

For processing times of less than 20 minutes: Add 1 additional minute for each additional 1000 feet of altitude.

For processing times of more than 20 minutes: Add 2 additional minutes for each 1000 feet of altitude.

- Pressure Canning: Pressure canning recipes are generally written for altitudes of less than 2000 feet. If you live higher than 2000 feet above sea level, make this adjustment: Increase pounds of pressure by 1/2 pound for each additional 1,000 feet.

TIPS FOR SUCCESSFUL AND SAFE CANNING

Keep safety in mind whether you're water-bath canning or pressure canning. By canning foods safely, you can prevent kitchen accidents and food spoilage. Increase your chances for successful canning and maximum safety by following these guidelines:

- Used recipes made for modern-day canning (about 2000 or newer) and follow them exactly. Don't increase or decrease your ingredients, processing time, or pressure level (for pressure canning).
- Don't double recipes. If you want more than one recipe, prepare the recipe more than once.
- Use the proper ingredients: only unblemished and not overly ripe fruit or vegetables, and when a recipe calls for salt, use only canning or pickling salt.
- Use jars and two-piece lids approved for canning, and never reuse lids.
- Always label and date your finished product and use within one year of the date of processing.
- Periodically check your jars for any signs of spoilage and, if in doubt about the quality or safety of a preserved product, dispose of it without tasting.

TOOLS AND EQUIPMENT FOR CANNING AND PRESERVING

If you plan to can, freeze, or dry your food, you'll need some special tools. The equipment involved with canning or preserving food is designed for efficiency and safety, so be sure you to use them. If you have these pieces already, great! If not, add them to your shopping list:

- Tongs: Have tongs ready for lifting hot foods out of boiling or simmering water. Any variety that you prefer will work, but a locking mechanism keeps them out of the way when not in use.
- Candy thermometer: Find a good quality thermometer, with a clip for attaching

it to the side of a pot. This item is so useful; it is a good idea to have a backup in case one breaks while you are using it.

- Jar lifter: This tool is a specialized set of tongs. Its rubberized ends fit securely around any size canning jar, to lift them in and out of your canner.
- Canning funnel: Used for canning foods, this wide mouth tool keeps the rims of jars clean. It can also be used to fill ziplock bags neatly.
- Canning jars: Canning jars are made from tempered glass to withstand the high heat and pressure of your canner. Both narrow- and wide-mouth jars are available, with wide-mouth being easiest to remove the food from once it is canned.
- Water-bath and/or pressure canner. If you're going to can, you must use the appropriate canner. For canning high-acid foods (fruits, jellies, relishes, and pickles), get a water-bath canner. For low-acid foods (vegetables and meats), get a pressure canner.

CANNING AND PRESERVING FOR DUMMIES ALL-IN-ONE CHEAT SHEET

Canning and preserving foods is an easy way to accumulate a healthy variety of foods for your pantry. You can store everything from herbs to fruits, vegetables to meats, in ways that preserve the flavour and make the foods convenient to use.

REAP THE BENEFITS OF CANNING AND PRESERVING FOOD

Canning and preserving are ways to protect food from spoilage so that you can use the food at a later time. There's no doubt that being able to offer fresh-tasting, home-canned, or -preserved foods to your family and friends throughout the year is definitely one of life's luxuries.

Whatever preservation method you choose, your efforts will benefit you in many ways:

- A pantry full of fresh, homegrown foods: Having a stocked pantry offers a cushion against the fluctuating cost of healthy foods.
- Convenience: You can build a pantry of convenience foods that fit into your busy lifestyle and that your family will enjoy.
- Protection against rising food costs: The whole idea of canning and preserving is to take advantage of fresh food when it's abundant. And abundant food generally means lower cost.
- A sense of relaxation and accomplishment: For many people, working in the kitchen and handling food provides a sense of relaxation, and watching family and friends enjoy the products of your efforts gives you a great sense of accomplishment.
- Confidence in the ingredients that go into your food: If you love fresh ingredients

and like to know what goes into your food, doing your own canning and preserving is the answer.

- A good time: Producing canned and preserved food in your kitchen is fun and easy — and who doesn't like fun?

BASIC TECHNIQUES FOR CANNING AND PRESERVING FOOD

You'll have no doubts about preparing safe home-canned and preserved food after you discover what each method does, which method is best for different foods, the rules for the technique you choose, and safe food-handling techniques.

Canning food is the most popular preserving method used today and is the process of applying heat to food that's sealed in a jar in order to destroy any microorganisms that can cause food spoilage. All foods contain these microorganisms. Proper canning techniques stop this spoilage by heating the food for a specific period of time and killing these unwanted microorganisms. Also, during the canning process, air is driven from the jar, and a vacuum is formed as the jar cools and seals. This vacuum prevents microorganisms from entering and recontaminating the food.

Although you may hear of many canning methods, only two are approved by the United States Department of Agriculture (USDA):

- *Water-bath canning:* This method, sometimes referred to as hot water canning, uses a large kettle of boiling water. Filled jars are submerged in the water and heated to an internal temperature of 212 degrees for a specific period of time. Use this method for processing high-acid foods, such as tomatoes, fruit and items made from it, pickles, and pickled food.
- *Pressure canning:* Pressure canning uses a large kettle that produces steam in a locked compartment. The filled jars in the kettle reach an internal temperature of 240 degrees under a specific pressure (stated in pounds) that's measured with a dial gauge or weighted gauge on the pressure-canner cover. Use a pressure canner for processing vegetables and other low-acid foods, such as meat, poultry, and fish.

Other methods for preserving food include

- *Freezing food:* Freezing food is the art of preparing and packaging foods at their peak of freshness and plopping them into the freezer to preserve all that seasonal goodness. Freezing is a great way to preserve foods that can't withstand the high temperatures and long cooking of conventional canning methods. The keys to freezing food are to make sure that the food you're freezing is absolutely fresh, that you freeze it as quickly as possible, and that you keep it at a proper frozen temperature (0 degrees).
- *Drying food:* When you dry food, you expose the food to a temperature that's high enough to remove the moisture but low enough that it doesn't cook. Good air circulation assists in evenly drying the food. An electric dehydrator is the best and most efficient unit for drying, or dehydrating, food.

- *Smoking, salting, and curing food:* Smoking foods, especially meats, adds a new dimension of flavour to your diet. Smoking is a simple process that infuses smoky flavours into ordinary cuts of meat. Applying rubs and curing in brine, in addition to smoking, increases the number of ways that your ho-hum meats can become spectacular.
- *Fermenting:* Fermenting is the process of introducing good bacteria into foods, in a safe way. Much more than beer-making, fermenting is the technique behind the sour tang of sauerkraut, vinegar, and yogurts. Fermenting is also the perfect beginner's preserving technique because it takes very little time and requires a short list of ingredients.
- *Juicing:* Juicing is a wonderful way to introduce healthy eating in a playful (and delicious) way to anyone who eyes a salad with suspicion. Juicing includes fruits, greens, and vegetables in combinations that may surprise you. Full-bodied and filling, juicing is a great way to bring tasty foods that might otherwise be overlooked to the table.

FOLLOW CANNING AND PRESERVING RULES

When you can and preserve foods, it's important to follow all the steps for each method. You compromise the quality and safety of your food if you make your own rules. An example is when you shorten your processing period to try to cut corners and substitute important parts of recipes. It's always best to start following directions to the letter, until you become fluent in the process.

Here are some general rules for handling, preparing, and processing your food:

- Start with the freshest, best products available. Preserving doesn't improve food quality.
- Know the rules and techniques for your canning or preserving method before you start your work. Don't try to learn a technique after you've started your processing.
- Work in short sessions to prevent fatigue and potential mistakes. Process no more than two items in one day and work with only one canning method at a time.
- Stay up-to-date on new or revised guidelines for your preserving method.
- When canning, use the correct processing method and processing time to destroy microorganisms. The recipe will tell you what method to use, but it helps if you understand the difference between high- and low-acid foods and how the canning methods for each differ.
- Know the elevation you're working at. Adjust your processing time or pressure when you're at an altitude over 1,000 feet above sea level.
- Put together a plan before you start your preserving session. Read your recipe (more than once). Have the proper equipment and correct ingredients on hand to prevent last-minute shortages and inconvenient breaks.

- Test your equipment. If you're using an electric dehydrator or pressure canner, test out the equipment to ensure that everything's working properly. And always check the seals on your jars.
- Use recipes from reliable sources or ones that you've already made successfully. Follow your recipe to the letter. Don't substitute ingredients, adjust quantities, or make up your own food combinations. Improvisation and safe food preservation aren't compatible. This approach also means you can't double your recipe. If you require more than what the recipe yields, make another batch.

HOW TO DETECT SPOILED FOODS

No one can promise you that your home-canned foods will always be free from spoilage, but you can rest assured that your chances for spoiled food are greatly reduced when you follow the precise guidelines for each preserving method.

FOOD PRESERVATION

Food preservation is to prevent the growth of microorganisms (such as yeasts), or other microorganisms (although some methods work by introducing benign bacteria or fungi to the food), as well as slowing the oxidation of fats that cause rancidity. Food preservation may also include processes that inhibit visual deterioration, such as the enzymatic browningreaction in apples after they are cut during food preparation.

Many processes designed to preserve food involve more than one food preservation method. Preserving fruit by turning it into jam, for example, involves boiling (to reduce the fruit's moisture content and to kill bacteria, etc.), sugaring (to prevent their re-growth) and sealing within an airtight jar (to prevent recontamination). Some traditional methods of preserving food have been shown to have a lower energy input and carbon footprint, when compared to modern methods.

Some methods of food preservation are known to create carcinogens. In 2015, the International Agency for Research on Cancer of the World Health Organization classified processed meat, *i.e.* meat that has undergone salting, curing, fermenting, and smoking, as "carcinogenic to humans".

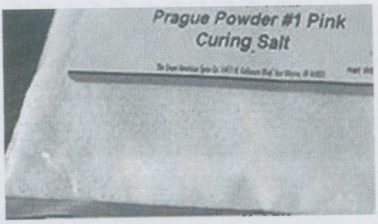
Maintaining or creating nutritional value, texture and flavour is an important aspect of food preservation.

TRADITIONAL TECHNIQUES

New techniques of food preservation became available to the home chef from the dawn of agriculture until the Industrial Revolution.

Curing

Bag of Prague powder #1, also known as "curing salt" or "pink salt". It is typically a combination of salt and sodium nitrite, with the pink colour added to distinguish it from ordinary salt.



The earliest form of curing was dehydration or drying, used as early as 12,000 BC. Smoking and salting techniques improve on the drying process and add antimicrobial agents that aid in preservation. Smoke deposits a number of pyrolysis products onto the food, including the phenols syringol, guaiacol and catechol. Salt accelerates the drying process using osmosis and also inhibits the growth of several common strains of bacteria. More recently nitrites have been used to cure meat, contributing a characteristic pink colour.

Cooling

Cooling preserves food by slowing down the growth and reproduction of microorganisms and the action of enzymes that causes the food to rot. The introduction of commercial and domestic refrigerators drastically improved the diets of many in the Western world by allowing food such as fresh fruit, salads and dairy products to be stored safely for longer periods, particularly during warm weather. Before the era of mechanical refrigeration, cooling for food storage occurred in the forms of root cellars and iceboxes. Rural people often did their own ice cutting, whereas town and city dwellers often relied on the ice trade. Today, root cellaring remains popular among people who value various goals, including local food, heirloom crops, traditional home cooking techniques, family farming, frugality, self-sufficiency, organic farming, and others.

Freezing

Freezing is also one of the most commonly used processes, both commercially and domestically, for preserving a very wide range of foods, including prepared foods that would not have required freezing in their unprepared state. For example, potato waffles are stored in the freezer, but potatoes themselves require only a cool dark place to ensure many months' storage. Cold stores provide large-volume, long-term storage for strategic food stocks held in case of national emergency in many countries.

Boiling

Boiling liquid food items can kill any existing microbes. Milk and water are often boiled to kill any harmful microbes that may be present in them.

Heating

Heating to temperatures which are sufficient to kill microorganisms inside the food is a method used with perpetual stews. Milk is also boiled before storing to kill many microorganisms.

Sugaring

The earliest cultures have used sugar as a preservative, and it was commonplace to store fruit in honey. Similar to pickled foods, sugar cane was brought to Europe through the trade routes. In northern climates without sufficient sun to dry foods, preserves are made by heating the fruit with sugar. "Sugar tends to draw water from the microbes (plasmolysis). This process leaves the microbial cells dehydrated, thus killing them. In this way, the food will remain safe from microbial spoilage." Sugar is used to preserve fruits, either in an antimicrobial syrup with fruit such as apples, pears, peaches, apricots, and plums, or in crystallized form where the preserved material is cooked in sugar to the point of crystallization and the resultant product is then stored dry. This method is used for the skins of citrus fruit (candied peel), angelica, and ginger. Also, sugaring can be used in the production of jam and jelly.

Pickling

Pickling is a method of preserving food in an edible, antimicrobial liquid. Pickling can be broadly classified into two categories: chemical pickling and fermentation pickling. In chemical pickling, the food is placed in an edible liquid that inhibits or kills bacteria and other microorganisms. Typical pickling agents include brine (high in salt), vinegar, alcohol, and vegetable oil. Many chemical pickling processes also involve heating or boiling so that the food being preserved becomes saturated with the pickling agent. Common chemically pickled foods include cucumbers, peppers, corned beef, herring, and eggs, as well as mixed vegetables such as piccalilli. In fermentation pickling, bacteria in the liquid produce organic acids as preservation agents, typically by a process that produces lactic acid through the presence of lactobacillales. Fermented pickles include sauerkraut, nukazuke, kimchi, and surströmming.

Lye

Sodium hydroxide (lye) makes food too alkaline for bacterial growth. Lye will saponify fats in the food, which will change its flavour and texture. Lutefisk uses lye in its preparation, as do some olive recipes. Modern recipes for century eggs also call for lye.

Canning

Canning involves cooking food, sealing it in sterilized cans or jars, and boiling the containers to kill or weaken any remaining bacteria as a form of sterilization. It was invented by the French confectioner Nicolas Appert. By 1806, this process was used by the French Navy to preserve meat, fruit, vegetables, and even milk. Although Appert had discovered a new way of preservation, it wasn't understood until 1864 when Louis Pasteur found the relationship between microorganisms, food spoilage, and illness.

Foods have varying degrees of natural protection against spoilage and may require that the final step occur in a pressure cooker. High-acid fruits like strawberries require

no preservatives to can and only a short boiling cycle, whereas marginal vegetables such as carrots require longer boiling and addition of other acidic elements. Low-acid foods, such as vegetables and meats, require pressure canning. Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened.



Fig. Preserved food

Lack of quality control in the canning process may allow ingress of water or microorganisms. Most such failures are rapidly detected as decomposition within the can causes gas production and the can will swell or burst. However, there have been examples of poor manufacture (underprocessing) and poor hygiene allowing contamination of canned food by the obligate anaerobe *Clostridium botulinum*, which produces an acute toxin within the food, leading to severe illness or death. This organism produces no gas or obvious taste and remains undetected by taste or smell. Its toxin is denatured by cooking, however. Cooked mushrooms, handled poorly and then canned, can support the growth of Staphylococcus aureus, which produces a toxin that is not destroyed by canning or subsequent reheating.

Jellying

Food may be preserved by cooking in a material that solidifies to form a gel. Such materials include gelatin, agar, maize flour, and arrowroot flour. Some foods naturally

form a protein gel when cooked, such as eels and elvers, and sipunculid worms, which are a delicacy in Xiamen, in the Fujian province of the People's Republic of China. Jellied eels are a delicacy in the East End of London, where they are eaten with mashed potatoes. Potted meats in aspic (a gel made from gelatin and clarified meat broth) were a common way of serving meat off-cuts in the UK until the 1950s. Many jugged meats are also jellied.

A traditional British way of preserving meat (particularly shrimp) is by setting it in a pot and sealing it with a layer of fat. Also common is potted chicken liver; jellying is one of the steps in producing traditional pâtés.

Jugging

Meat can be preserved by jugging. Jugging is the process of stewing the meat (commonly game or fish) in a covered earthenware jug or casserole. The animal to be jugged is usually cut into pieces, placed into a tightly-sealed jug with brine or gravy, and stewed. Red wine and/or the animal's own blood is sometimes added to the cooking liquid. Jugging was a popular method of preserving meat up until the middle of the 20th century.

Burial

Burial of food can preserve it due to a variety of factors: lack of light, lack of oxygen, cool temperatures, pH level, or desiccants in the soil. Burial may be combined with other methods such as salting or fermentation. Most foods can be preserved in soil that is very dry and salty (thus a desiccant) such as sand, or soil that is frozen.

Many root vegetables are very resistant to spoilage and require no other preservation than storage in cool dark conditions, for example by burial in the ground, such as in a storage clamp. Century eggs are traditionally created by placing eggs in alkaline mud (or other alkaline substance), resulting in their "inorganic" fermentation through raised pH instead of spoiling. The fermentation preserves them and breaks down some of the complex, less flavourful proteins and fats into simpler, more flavourful ones. Cabbage was traditionally buried during Autumn in northern US farms for preservation. Some methods keep it crispy while other methods produce sauerkraut. A similar process is used in the traditional production of kimchi. Sometimes meat is buried under conditions that cause preservation. If buried on hot coals or ashes, the heat can kill pathogens, the dry ash can desiccate, and the earth can block oxygen and further contamination. If buried where the earth is very cold, the earth acts like a refrigerator. Before burial, meat (pig/boar) can be fatted. The tallow of the animal is heated and poured over meat in a barrel. Once the fat hardens the barrel is sealed and buried in a cold cellar or ground.

Fermentation

Some foods, such as many cheeses, wines, and beers, use specific micro-organisms that combat spoilage from other less-benign organisms. These micro-organisms keep

pathogens in check by creating an environment toxic for themselves and other micro-organisms by producing acid or alcohol. Methods of fermentation include, but are not limited to, starter micro-organisms, salt, hops, controlled (usually cool) temperatures and controlled (usually low) levels of oxygen. These methods are used to create the specific controlled conditions that will support the desirable organisms that produce food fit for human consumption.

Fermentation is the microbial conversion of starch and sugars into alcohol. Not only can fermentation produce alcohol, but it can also be a valuable preservation technique. Fermentation can also make foods more nutritious and palatable. For example, drinking water in the Middle Ages was dangerous because it often contained pathogens that could spread disease. When the water is made into beer, the boiling during the brewing process kills any bacteria in the water that could make people sick. Additionally, the water now has the nutrients from the barley and other ingredients, and the microorganisms can also produce vitamins as they ferment.

MODERN INDUSTRIAL TECHNIQUES

Techniques of food preservation were developed in research laboratories for commercial applications.

PASTEURIZATION

Pasteurization is a process for preservation of liquid food. It was originally applied to combat the souring of young local wines. Today, the process is mainly applied to dairy products. In this method, milk is heated at about 70 °C (158 °F) for 15–30 seconds to kill the bacteria present in it and cooling it quickly to 10 °C (50 °F) to prevent the remaining bacteria from growing. The milk is then stored in sterilized bottles or pouches in cold places. This method was invented by Louis Pasteur, a French chemist, in 1862.

VACUUM PACKING

Vacuum-packing stores food in a vacuum environment, usually in an air-tight bag or bottle. The vacuum environment strips bacteria of oxygen needed for survival. Vacuum-packing is commonly used for storing nuts to reduce loss of flavour from oxidization. A major drawback to vacuum packaging, at the consumer level, is that vacuum sealing can deform contents and rob certain foods, such as cheese, of its flavour.

ARTIFICIAL FOOD ADDITIVES

Preservative food additives can be *antimicrobial*—which inhibit the growth of bacteria or fungi, including mold—or *antioxidant*, such as oxygen absorbers, which inhibit the oxidationof food constituents. Common antimicrobial preservatives include calcium propionate, sodium nitrate, sodium nitrite, sulfites (sulfur dioxide, sodium bisulfite, potassium hydrogen sulfite, etc.), and EDTA. Antioxidants include butylated

hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). Other preservatives include formaldehyde (usually in solution), glutaraldehyde (insecticide), ethanol, and methylchloroisothiazolinone.

IRRADIATION

Irradiation of food is the exposure of food to ionizing radiation. The two types of ionizing radiation used are beta particles (high-energy electrons) and gamma rays (emitted from radioactive sources such as cobalt-60 or cesium-137). Treatment effects include killing bacteria, molds, and insect pests, reducing the ripening and spoiling of fruits, and at higher doses inducing sterility. The technology may be compared to pasteurization; it is sometimes called "cold pasteurization", as the product is not heated.

The irradiation process is not directly related to nuclear energy, but does use radioactive isotopes produced in nuclear reactors. Cobalt-60, for example does not occur naturally and can only be produced through neutron bombardment of cobalt-59. Ionizing radiation at high energy levels is hazardous to life (hence its usefulness in sterilisation); for this reason, irradiation facilities have a heavily shielded irradiation room where the process takes place. Radiation safety procedures are used to ensure that neither the workers in such facilities nor the environment receives any radiation dose above administrative limits. Irradiated food does not and cannot become radioactive, and national and international expert bodies have declared food irradiation as wholesome. However, the wholesomeness of consuming such food is disputed by opponents and consumer organizations. National and international expert bodies have declared food irradiation as "wholesome"; organizations of the United Nations, such as the World Health Organization and Food and Agriculture Organization, endorse food irradiation. International legislation on whether food may be irradiated or not varies worldwide from no regulation to full banning. Irradiation may allow lower-quality or contaminated foods to be rendered marketable.

Approximately 500,000 tons of food items are irradiated per year worldwide in over 40 countries. These are mainly spices and condiments with an increasing segment of fresh fruit irradiated for fruit fly quarantine.

PULSED ELECTRIC FIELD ELECTROPORATION

Pulsed electric field (PEF) electroporation is a method for processing cells by means of brief pulses of a strong electric field. PEF holds potential as a type of low-temperature alternative pasteurization process for sterilizing food products. In PEF processing, a substance is placed between two electrodes, then the pulsed electric field is applied. The electric field enlarges the pores of the cell membranes, which kills the cells and releases their contents. PEF for food processing is a developing technology still being researched. There have been limited industrial applications of PEF processing for the pasteurization of fruit juices. To date, several PEF treated juices are available on the market in Europe. Furthermore, for several years a juice pasteurization application in

the US has used PEF. For cell disintegration purposes especially potato processors show great interest in PEF technology as an efficient alternative for their preheaters. Potato applications are already operational in the US and Canada. There are also commercial PEF potato applications in various countries in Europe, as well as in Australia, India, and China.

MODIFIED ATMOSPHERE

Modifying atmosphere is a way to preserve food by operating on the atmosphere around it. Salad crops that are notoriously difficult to preserve are now being packaged in sealed bags with an atmosphere modified to reduce the oxygen (O_2) concentration and increase the carbon dioxide (CO_2) concentration. There is concern that, although salad vegetables retain their appearance and texture in such conditions, this method of preservation may not retain nutrients, especially vitamins. There are two methods for preserving grains with carbon dioxide. One method is placing a block of dry ice in the bottom and filling the can with the grain. Another method is purging the container from the bottom by gaseous carbon dioxide from a cylinder or bulk supply vessel.

Carbon dioxide prevents insects and, depending on concentration, mold and oxidation from damaging the grain. Grain stored in this way can remain edible for approximately five years.

Nitrogen gas (N_2) at concentrations of 98% or higher is also used effectively to kill insects in the grain through hypoxia. However, carbon dioxide has an advantage in this respect, as it kills organisms through hypercarbia and hypoxia (depending on concentration), but it requires concentrations of above 35%, or so. This makes carbon dioxide preferable for fumigation in situations where a hermetic seal cannot be maintained.

Controlled Atmospheric Storage (CA): "CA storage is a non-chemical process. Oxygen levels in the sealed rooms are reduced, usually by the infusion of nitrogen gas, from the approximate 21 percent in the air we breathe to 1 percent or 2 percent. Temperatures are kept at a constant 0–2 °C (32–36 °F). Humidity is maintained at 95 percent and carbon dioxide levels are also controlled. Exact conditions in the rooms are set according to the apple variety. Researchers develop specific regimens for each variety to achieve the best quality. Computers help keep conditions constant." "Eastern Washington, where most of Washington's apples are grown, has enough warehouse storage for 181 million boxes of fruit, according to a report done in 1997 by managers for the Washington State Department of Agriculture Plant Services Division. The storage capacity study shows that 67 percent of that space—enough for 121,008,000 boxes of apples—is CA storage."

Air-tight storage of grains (sometimes called hermetic storage) relies on the respiration of grain, insects, and fungi that can modify the enclosed atmosphere sufficiently to control insect pests. This is a method of great antiquity, as well as having modern equivalents. The success of the method relies on having the correct mix of sealing,

grain moisture, and temperature. A patented process uses fuel cells to exhaust and automatically maintain the exhaustion of oxygen in a shipping container, containing, for example, fresh fish.

NON-THERMAL PLASMA

This process subjects the surface of food to a "flame" of ionized gas molecules, such as helium or nitrogen. This causes micro-organisms to die off on the surface.

HIGH-PRESSURE FOOD PRESERVATION

High-pressure food preservation or pascalization refers to the use of a food preservation technique that makes use of high pressure. "Pressed inside a vessel exerting 70,000 pounds per square inch (480 MPa) or more, food can be processed so that it retains its fresh appearance, flavour, texture and nutrients while disabling harmful microorganisms and slowing spoilage."

By 2005, the process was being used for products ranging from orange juice to guacamole to deli meats and widely sold.

BIOPRESERVATION

Biopreservation is the use of natural or controlled microbiota or antimicrobials as a way of preserving food and extending its shelf life. Beneficial bacteria or the fermentation products produced by these bacteria are used in biopreservation to control spoilage and render pathogens inactive in food. It is a benign ecological approach which is gaining increasing attention.

Of special interest are lactic acid bacteria (LAB). Lactic acid bacteria have antagonistic properties that make them particularly useful as biopreservatives. When LABs compete for nutrients, their metabolites often include active antimicrobials such as lactic acid, acetic acid, hydrogen peroxide, and peptide bacteriocins. Some LABs produce the antimicrobial nisin, which is a particularly effective preservative.

These days, LAB bacteriocins are used as an integral part of hurdle technology. Using them in combination with other preservative techniques can effectively control spoilage bacteria and other pathogens, and can inhibit the activities of a wide spectrum of organisms, including inherently resistant Gram-negative bacteria.

METHODS OF FOOD PRESERVATION

Food, by nature, is perishable. Without intervention, food falls victim to the forces of nature, namely bacteria, yeast, and fungus, and begin to degrade. The effects of food spoilage are not only unappetizing, but the agents of spoilage can also cause foodborne illnesses or even death.

For thousands of years, humans have been using various methods to prolong the freshness and safety of their food in order to stabilize their food supply.



While some of these methods are relatively new, many of them date back to ancient times. We may have refined the processes and come to better understand the mechanisms, but the basic concepts remain the same today. Here are a few of the most common ways to preserve food:

- Chilling and Freezing - Bacteria and yeast grow best at specific temperatures, usually between 40-140°F. By lowering the temperature below 40°F their metabolic and reproductive action is significantly slowed. While this may not actually kill the bacteria and yeast, it does slow the spoilage process. Although freezing food has been used in colder climates for hundreds of years, the expansion of electricity and home appliances in the early and mid-20th century greatly expanded the use of freezing as a food preservation method.
- Canning - Canning preserves food by removing the oxygen needed for most microorganisms to grow. Because some organisms are able to flourish in the absence of oxygen, canning is usually combined with a second factor that inhibits microbial growth, like acid or salt (usually in the form of a brine). Canning became a popular method of food preservation with the industrial revolution and is still quite popular today.
- Dehydrating - Most microorganisms also require moisture to grow, so removing the moisture from food is a very effective method of preservation. The key to dehydration is to complete the process faster than the spoilage occurs. Evaporation is usually quickened with the addition of moderate heat, sometimes provided by natural sunlight. The added bonus of sunlight are ultra violate rays, which also serve to kill microbes. Modern methods of dehydration use circulating air that is heated just enough to promote dehydration without "cooking" the food. Dehydration is the method of food preservation used for meat jerky, dried fruit or fruit leathers, and herbs.
- Fermenting - Fermenting is another ancient technique of food preservation that

has remained popular to this day. The popularity is most likely attributed to the unique flavour that is accrued through fermentation. Fermentation itself is a form of food spoilage, but when the microorganisms are tightly controlled, it can produce desirable effects and provide safeguards against harmful organisms. The bacteria or yeast used in the fermentation process produce acid as a byproduct, which acts to prevents other, potentially harmful bacteria from thriving. As an added bonus, many of the organisms used to ferment foods are also healthy additions to the natural flora of the human gastrointestinal tract. Both sauerkraut and kimchi are examples of the use of fermentation to preserve cabbage.

- Salting - Salting preserves food by removing the moisture and creating an environment unsuitable for microbial growth. Very few bacteria grow in high salt solutions, so simply adding a very high amount of salt can be an effective method of preservation. Salting is one of the oldest known methods of food preservation. Natural sea salts abundant in the Mediterranean region were readily available in ancient times and were used to preserve meat, fish, vegetables, and even some fruit. The amount of salt alone needed to preserve food is extremely high and therefore can be unpalatable. Therefore, salt is often used in combination with another method, like dehydration or an acidic solution, to preserve food. Examples of salt-preserved foods include: hard salamis, bacon, salt pork, smoked fish, anchovies, olives, pickles, and preserved lemons.

NEW AND EMERGING NON-THERMAL TECHNOLOGIES IN FOOD PRESERVATION

Consumer demands for high quality foods that are fresh tasting and nutritious have created considerable interest in the development of new food-processing techniques. Interest in the development of new food processing technologies has increased dramatically over the past decade primarily due to consumer demand for food with fresh-like taste, crisp texture and natural colour. Consumers are also increasingly becoming aware of food-borne disease hazards and are concerned about the safety of their food supply. Developments in non-thermal technologies have been advanced by both industry and academia in an attempt to meet the challenge of producing safe processed food of a high quality. There is no doubt that high quality food can be produced through the use of non-thermal processing technologies. The safety and microbiological quality of food processed using these technologies, however, needs to be affirmed. Emphasis is given to high pressure processing (HPP), and processing with the use of pulsed electric fields (PEF).

With the advent of new technologies, methods and techniques-to ensure that food is kept in pristine, nutritionally sound, and cost effective condition-the opportunities for impacting this dynamic and innovative market are increasing.

NEW AND EMERGING TECHNOLOGIES

These health issues have thus led to the following list of health related necessaries for a food process must create to deliver the foods of the future that may.

A 2020 Vision for Food Preservation Technologies have staying power.

- Decreased calories
- Decreased saturated fat
- No trans fatty acids
- Poly and mono unsaturated fats in place of other fats
- Reduced cholesterol
- Reduced salt
- Reduced sugar
- Increased dietary fibre
- Increased probiotics
- Increased natural anti-oxidants and anti-carcinogens
- No artificial colours, MSG or preservative additives
- No pesticides
- No pathogens
- No growth hormones
- No genetically modified foods
- Long shelf life with no loss of nutritional value

Alternatives to heat treatment

Cold techniques

Electro heating technologies

- Hydrostatic High Pressure

(HHP or HPLT) technology

- Micro Filtration
- Ultrasonication
- Irradiation (ionizing radiation)
- Pulsed electric fields
- Ohmic heating
- Microwave heating
- Radio frequency heating

HIGH PRESSURE PROCESSING (HPP)

What is High Pressure Processing?

High Pressure Processing (HPP) is a way to process foods without using heat. It has the potential to produce high-quality, fresh, nutritious, safe-to-eat foods without using chemical preservatives.

HPP involves subjecting food to 300 to 700 MPa of pressure. For comparison, atmospheric pressure is normally around 0.1 MPa and the pressure at deepest point in

the ocean is around 110 MPa. The high pressure used in HPP kills most micro-organisms, by damaging cell components such as cell membranes.

CURRENT ACTIVITIES

The Food Futures Flagship is:

- Developing applications of HPP for chilled foods
- Determining how HPP affects the quality characteristics, functional properties and nutritional value of:
- Dairy foods
- Muscle foods (seafood and meat)
- Horticultural products
- Studying the combined effects of high pressure and heat to develop high quality shelf stable foods
- Determining the packaging requirements for processing foods with HPP.

OUTCOMES

Unlike thermal treatment, HPP does not significantly affect the flavour and nutritional value of foods. Therefore, with HPP it is possible to produce safe fresh foods with enhanced organoleptic (smell, taste etc), nutritional and functional properties with an extended shelf life. The successful development of HPP in Australia would make it possible to commercialise high quality foods such as meats, seafood, and horticultural and dairy products, which will contribute to greater financial returns to the Australian agrifood industry.

Modes of Operation

A simplified mode of operation used in a high-pressure processing system. In a high-pressure process, the pressure vessel is filled with a food product and pressurized for a desired time, following which it is depressurized.

The time required to pressurize the vessel is influenced by the compressibility of the pressure medium and the nature of the food material. If water is used as the pressure-transmitting medium for most food materials, compressibility is similar to that of the pressure medium. Typically, the pressurization time for foods is independent of the quantity of food placed in the pressure vessel. The presence of air in the food increases the pressurization time, since air is considerably more compressible than water. After pressurization, the food is kept under high pressure for the required process time, which may be for several minutes. Upon completion of the pressure exposure, depressurization can be done quite rapidly.

The critical process factors in HPP include pressure, time at pressure, time to achieve treatment pressure, decompression time, treatment temperature (including adiabatic heating), product initial temperature, vessel temperature distribution at pressure, product pH, product composition, product water activity, packaging material integrity and

concurrent processing aids. Other processing factors present in the process line before or after the pressure treatment were not included.

ADVANTAGES OF HHP

The benefits are as follows:

- Taste and texture are retained in products *e.g.* orange juice and guacamole
- Food poisoning organisms can be destroyed leading to safer products
- Shelf life is increased
- Novel foods can be produced and properties of existing foods changed

APPLICATION OF HHP IN FOOD INDUSTRY

HHP technology has been applied to shellfish, sliced meats, vegetables, cheese, meat, fish, juices and smoothies, ready-to-eat meals, sauces and salsas successfully. Consumer-driven requirements for better tasting, additive-free foods with a longer shelf life are resulting in a drive to develop high pressure processing. The main applications of high pressure processing are preservation and preparation. For preservation applications, enzymes and micro-organisms are inactivated under high pressure. This results in a preserved product while remaining fresh taste, flavour and colour. Examples are pasteurisation of fruit juices, fruit desserts and guacamole. In Japan, for example, several rice-based foods are available with novel textures induced by high-pressure treatment. Other examples are gelatinisation of starches and proteins, preparation of pectin gels (jams) and tenderisation of meat. Commercial products have now been appearing in the US and Europe.

HHP

Opportunities

- Fresh-like quality
- Retention of nutrients
- Application for acid food
- Low acid food: combined with heat or antibacterial agents (spores inactivation)

Drawbacks

- Discontinuous or semi Discontinuous or semi continuous process
- Expensive equipments
- Impact on texture, structure, appearance, functionality
- Spores are not sensitive
- Resistant bacteria

PULSED ELECTRIC FIELD TREATMENT(PEF)

Preservation of bulk products by pulsed electric field (PEF) is an emerging technology that opens new perspectives for the food and pharmaceutical industry. This process can be applied homogeneously through the product and is applicable for the pasteurisation

of pumpable products at reduced temperatures. At field strengths in the order of 15-30 kV/cm, microbial cells are inactivated by electroporation of their membranes without any considerable temperature rise and without changes in the chemical or physical composition of the food material. For adequate processing, a number of short pulses (1-100 μs) is used.

PEF treatment relies on the microbial action of intense electrical impulses on a microsecond time scale. When an electrical impulse is applied, the osmotic balance of the micro-organisms present is disturbed. If processing conditions are chosen correctly, micro-organisms are inactivated. A single pulse can establish reductions in plate counts exceeding 5 orders of magnitude.

Some examples include the PEF treatment of skim milk, resulting in an extended shelf-life. Other examples can be found in treatment of fruit juices. Treatment of fresh squeezed orange juice increased refrigerated shelf life to more that six weeks while loss of flavour compounds and vitamin C were decreased compared to traditional heat processing. For apple juice a 3-4weeks extended shelf-life (at +4°C) was reached with PEF treatment.

Modes of Operation

A natural pressure gradient exists across cellular membranes, so that when a cell is placed in an electric field, the transmembrane potential increases. If the applied electrical field exceeds a certain critical value, then cell wall rupture occurs. While the complete mechanism of cell wall breakdown in an electric field is not clearly understood, this observed phenomenon is regularly applied in order to create pores within cell membranes. The technique involved is known as electroporation and is applied in the field of biotechnology for the introduction of foreign DNA into cells. In another application, cells are fused together when placed in an electric field. This process termed electrofusion has been used in the food industry to convert non-flocculant brewer's yeast to flocculant yeast.

PULSED ELECTRIC FIELD PROCESSING FACT SHEET FOR FOOD PROCESSORS

1. What is pulsed electric field processing? Pulsed electric field (PEF) processing is a non-thermal method of food preservation that uses short bursts of electricity for microbial inactivation and causes minimal or no detrimental effect on food quality attributes. PEF can be used for processing liquid and semi-liquid food products.
2. How does this technology benefit consumers? PEF processing offers high quality fresh-like liquid foods with excellent flavour, nutritional value, and shelf-life. Since it preserves foods without using heat, foods treated this way retain their fresh aroma, taste, and appearance.
3. How does PEF work? PEF processing involves treating foods placed between

electrodes by high voltage pulses in the order of 20–80 kV (usually for a couple of microseconds). The applied high voltage results in an electric field that causes microbial inactivation. The electric field may be applied in the form of exponentially decaying, square wave, bipolar, or oscillatory pulses and at ambient, sub-ambient, or slightly above-ambient temperature. After the treatment, the food is packaged aseptically and stored under refrigeration.

4. How does PEF inactivate microorganisms? PEF treatment has lethal effects on various vegetative bacteria, mold, and yeast. Efficacy of spore inactivation by PEF in combination with heat or other hurdles is a subject of current research. A series of short, high-voltage pulses breaks the cell membranes of vegetative microorganisms in liquid media by expanding existing pores (electroporation) or creating new ones. Pore formation is reversible or irreversible depending on factors such as the electric field intensity, the pulse duration, and number of pulses. The membranes of PEF-treated cells become permeable to small molecules; permeation causes swelling and eventual rupture of the cell membrane.
5. What types of foods benefit from PEF treatment? Application of PEF technology has been successfully demonstrated for the pasteurization of foods such as juices, milk, yogurt, soups, and liquid eggs. Application of PEF processing is restricted to food products with no air bubbles and with low electrical conductivity. The maximum particle size in the liquid must be smaller than the gap of the treatment region in the chamber in order to ensure proper treatment. PEF is a continuous processing method, which is not suitable for solid food products that are not pumpable. PEF is also applied to enhance extraction of sugars and other cellular content from plant cells, such as sugar beets. PEF also found application in reducing the solid volume (sludge) of wastewater.
6. What is the shelf-life of a PEF processed product? In general, the shelf-life of PEF-treated and thermally pasteurized foods is comparable. PEF pasteurization kills microorganisms and inactivates some enzymes and, unless the product is acidic, it requires refrigerated storage. For heat-sensitive liquid foods where thermal pasteurization is not an option (due to flavour, texture, or colour changes), PEF treatment would be advantageous.
7. How are PEF processed foods stored? PEF pasteurized products currently are stored refrigerated. In some cases (for example, milk), this is necessary for safety (to prevent the growth of spores in low-acid foods). For acid foods, refrigeration is not necessary for microbial stability, but is used to preserve flavour quality for extended periods of time.
8. Is commercial scale equipment available? Yes. In the United States, the first commercial scale continuous PEF system is installed at The Ohio State University's Department of Food Science and Technology. This PEF system is part of a new food treatment system assembled by a DoD sponsored, University directed industry

consortium. Diversified Technologies Inc., Bedford, MA, builds commercial PEF systems of processing volumes ranging from 500 to 2,000 liters per hour, with The Ohio State University supplying the PEF treatment chambers.

9. Is PEF equipment safe for the environment? Yes. This process uses ordinary electricity. The facility meets electrical safety standards and no harmful environmental by-products are produced.
10. What is an integrated continuous PEF Processing System? An integrated PEF system consists of a fluid handling unit, high voltage pulse generator, PEF treatment chambers, and packaging machine. The fluid handling unit delivers stable, uniform flow with sterilize-in-place (SIP) and clean-in-place (CIP) functions. The pulse generator supplies high voltage pulses into foods flowing through PEF treatment chambers. Treated foods are packaged continuously.
11. What is a PEF treatment chamber? A PEF treatment chamber consists of at least two electrodes and insulation that forms a volume, *i.e.*, PEF treatment zone, where the foods receive pulses. The electrodes are made of inert materials, such as titanium.
12. How economical is PEF processing? PEF is an energy efficient process compared to thermal pasteurization. The PEF processing would add only $0.03–$0.07/L to final food costs. A commercial-scale PEF system can process between 1,000 and 5,000 liters of liquid foods per hour and this equipment is scalable. Generation of high voltage pulses having sufficient peak power (typically megawatts) is the limitation in processing large quantities of fluid economically. The emergence of solid-state pulsed power systems, which can be arbitrarily sized by combining switch modules in series and parallel, removes this limitation.

PEF

Opportunities

- Continuous process
- Fresh-like quality
- Retention of nutrients
- Application for acid food
- Low acid food: combined process for spore inactivation = under investigation

Drawbacks

- Up scaling of process ?
- Liquid products only
- Dependence of el. Dependence of el.conductivity of food
- Spores are not sensitive
- Potential health risk (electrolytic reaction) ?

There are a number of drawbacks of the PEF technology.

First of all, ohmic heating occurs during the PEF discharge, which cause the temperature of the sample to rise, and hence a cooling system has to be in place in order

to maintain a low temperature of the liquids. Therefore, a significant amount of energy is wasted in both unwanted heating up and cooling down the liquids.

Secondly, since the electrodes have to be immersed in the liquid, they are regarded as major contamination sources to the liquid due to the erosion of electrodes during discharge. Quality losses such as colour deterioration have been observed. PEF technology is not being used to preserve foods commercially at present.

The combinations of PEF with other preservation technologies are being investigated to increase the lethal effect of this non-thermal process and to extend its application to different liquid foods.

ULTRASOUND IN FOOD TECHNOLOGY

Nowadays, power ultrasound is considered to be an emerging and promising technology for industrial food processing.

Why use Ultrasound in Food Technology

Ultrasound is energy generated by sound waves of 20,000 or more vibrations per second. Although ultrasound technology has a wide range of current and future applications in the food industry, including inactivation of microorganisms and enzymes, presently, most developments for food applications are non-microbial.

The bactericidal effect of ultrasound is attributed to intracellular cavitation, that is, micro-mechanical shocks that disrupt cellular structural and functional components up to the point of cell lysis.

Until recently the majority of applications of ultrasound in food technology involved non-invasive analysis with particular reference to quality assessment. Such applications use techniques that are similar to those developed in diagnostic medicine, or non-destructive testing, using high frequency (>1 MHz) low power (<1 W/cm^2) ultrasound.

Examples of the use of such technologies are to be found in the location of foreign bodies in food the analysis of droplet size in emulsions of edible fats and oils and the determination of the extent of crystallization in dispersed emulsion droplets.

In recent years food technologists have discovered that it is possible to employ a more powerful form of ultrasound (>5 W/cm^2) at a lower frequency (generally around 40 kHz).

Examples:

- Ultrasonic extraction of phenolic compounds from vacuolar structures by disrupting plant tissue
- Ultrasonic extraction of Betacyanin (red pigments, *e.g.* from beets) and Betaxanthin (yellow pigments)
- Ultrasonic improvement of oil extraction from oil seeds
- Cell membrane permeabilization of fruits, such as grapes, plums, mango
- Ultrasonic processing of Fruit juices, *e.g.* orange, grapefruit, mango, grape, plum

- Purees
- Sauces, *e.g.* tomato, asparagus, bell pepper, mushroom
- Dairy products
- Improve stability of dispersions, such as orange juice, *i.e.* reduce settling

Microbial and enzyme inactivation (preservation) is another application of ultrasound in the food processing.

In this case ultrasonication is often more effective when combined with other anti-microbial methods, such as:

- Thermo-sonication, *i.e.* heat and ultrasound
- Mano-sonication, *i.e.* pressure and ultrasound
- Mano-thermo-sonication, *i.e.* pressure, heat and ultrasound
- *g. for Bacillus subtilis, Bacillus coagulans, Bacillus cereus, Bacillus sterothermophilus, Saccharomyces cerevisiae*

Ultrasound is also used in the emulsification, dispersing and homogenizing as well as to improve chemical reactions and surface chemistry (sonochemistry) or to influence crystallization processes

The heterogeneous and protective nature of food with the inclusion of particulates and other interfering substances severely curtails the singular use of ultrasound as a preservation method. Although these limitations make the current probability of commercial development low, combination of ultrasound with other preservation processes (*e.g.* heat and mild pressure) appears to have the greatest potential for industrial applications.

IRRADIATION

Irradiation is the treatment of food with x-rays or gamma radiation to kill bacteria and mold. It may be combined with vacuum packing to seal out microbes. Food irradiation is effective against a wide variety of pathogens including bacteria, fungi, viruses and parasites. As with all preservation techniques, irradiation should be used to prolong the life of appropriate food which is of high quality prior to treatment.

Although irradiation is effective in killing contaminating microorganisms, it may mask the fact that the food had high levels of spoilage or insect infestation prior to treatment: the microorganisms or insects are killed but their carcasses, faeces or toxins remain.

Finally, irradiation, also not a new technology, is poised for widespread use to enhance the safety and shelf life of many foods. With proper controls, irradiation could be a valuable means of reducing Salmonella contamination of poultry and *Escherichia coli*O157:H7 contamination of ground beef.

APPLICATION

1. Irradiation to a dose of between 1 kGy and 10 kGy is an effective method of reducing the microbial load of food. *Salmonella, listeria* or other harmful

microorganisms may contaminate foods such as dried herbs and spices, chicken meat, eggs, shrimps, cheese made from raw milk, frogs legs. Some of these foods may be eaten without further heat treatment to destroy these harmful microorganisms.

2. Irradiation will extend the shelf life of food because spoilage organisms are also reduced in number, and as with heat treatment, irradiation may also inactivate enzymes that would otherwise assist food spoilage.
3. Low dose irradiation (less than 1 kGy) is also used to inhibit sprouting (*e.g.* onion, garlic, potato), delay ripening (*e.g.* of mango, papaya and other fruits) and is also used for the purpose of insect disinfestation and inactivation.

ELECTRON BEAM FACILITIES

Electron beam facilities generate e-beams with an electron beam linear accelerator. The electrons are concentrated and accelerated to 99% of the speed of light and energies of up to 10 MeV.

E-BEAM IRRADIATION

E-beam irradiation, though it uses the same term as gamma ray irradiation, is a completely different kind of treatment. High-energy electron beams are produced in an electron gun, a larger version of the cathode ray gun found in devices such as televisions and monitors. The electrons can be directed by a magnetic field to a target food. The term "irradiation" is really a misnomer, since the food not exposed to electromagnetic radiation or beta rays (electrons produced by a radioactive source). Nevertheless, the process has a similar effect to that of gamma ray irradiation. E-beam irradiation requires shielding as well, but nothing like the concrete bunkers used in gamma ray irradiation.

Because e-beams are generated electrically, they offer certain advantages:

- They can be turned on only as needed
- They do not require replenishment of the source as does cobalt-60
- There is no radioactive waste

E-beam technology also has disadvantages:

- Shallow depth of penetration
- e-beams must be converted to x-rays to penetrate large items such as carcasses
- High electric power consumption
- Complexity, and potentially high maintenance

The disadvantage of the e-beam is its short penetration depth (about an inch), preventing its application to many foods and limiting the amount of food that can be processed in bulk.

OHMIC AND INDUCTIVE HEATING

Ohmic heating (sometimes also referred to as Joule heating, electrical resistance heating, direct electrical resistance heating, electroheating and electroconductive heating)

is defined as the process of passing electric currents through foods or other materials to heat them. Ohmic heating is distinguished from other electrical heating methods either by the presence of electrodes contacting the food, frequency and waveform.

Inductive heating is a process wherein electric currents are induced within the food due to oscillating electromagnetic fields generated by electric coils.

A large number of potential future applications exist for ohmic heating, including its use in blanching, evaporation, dehydration, fermentation and extraction. The principal advantage claimed for ohmic heating is its ability to heat materials rapidly and uniformly, including products containing particulates. The principal mechanisms of microbial inactivation in ohmic heating are thermal. Ohmic heating can enhance food quality by limiting heat damage to the sauce and food particles.

High Intensity Magnetic Field Pulses

Exposure to high intensity oscillating magnetic fields has been reported to have a variety of effects on biological systems ranging from selective inactivation of malignant cells to the inactivation of bacteria on packaging materials and in foods. Treatment times are very short, typically from 25 ms to a few milliseconds, and field strengths are very high, typically from 2 Tessla to about 100 Tessla at frequencies between about 5-500 kHz.

Efficacies of treatments did not exceed about 100-fold reductions in numbers of vegetative micro-organisms inoculated into milk *(Streptococcus thermophilus),* orange juice *{Saccharomyces* spp.), bread rolls (mould spores) and no inactivation of bacterial spores has been reported, so the practical potential for the technique, as it has been developed so far, appears to be limited.

Natural Preservatives

Scientists are putting increased efforts into the discovery and purification of natural compounds for use as safe alternatives to chemical preservatives.

The new breed of protective compounds are small proteins. They are called bacteriocins and are starting to be used in a wide variety of foods. Anyone who has eaten yoghurt has been protected by bacteriocins without knowing it. Bacteriocins are produced by some good bacteria to kill competing organisms such as *Listeria monocytogenes*. The whole bacteria that produces the bacteriocin, or the purified bacteriocin itself, can be added to foods such as soft cheeses to reduce the risk of pathogen growth. An example of protection using bacteriocins is the use of nisin in crumpets to restrict the growth of *Bacillus cereus*.

Cold Plasma

A second surface technology is cold plasma. Plasma is a high-energy gas that is created when an electrical current is passed through a gas. A well-known application of this principle is fluorescent lighting.

Until recently, plasmas could only be created at relatively high temperatures in a vacuum and the use of plasma in the agro-sector and the packaging industry, was therefore impractical. In the last few years technological breakthroughs have made it possible to produce cold plasma under atmospheric conditions. Thus, it is now possible to apply the plasma technology in the food industry.

Noble gases are used when radical formation is unwanted while oxygen is used for the production of ozone in the plasma. Depending on the used gases, temperature, activity and stability of the plasma can be varied. No commercial equipment is available at the moment. Low temperature, atmospheric pressure plasmas have been shown to possess very effective germicidal characteristics. Their relatively simple and inexpensive designs, as well as their non-toxic nature, give them the potential to replace conventional sterilization methods in the near future.

Ozone in the Food Industry

Because ozone is a safe, powerful disinfectant, it can be used to control biological growth of unwanted organisms in products and equipment used in the food processing industries. Ozone is particularly suited to the food industry because of its ability to disinfect microorganisms without adding chemical by-products to the food being treated, or to the food processing water or atmosphere in which food are stored.

In aqueous solutions, ozone can be used to disinfect equipment, process water, and some foodstuff. In gaseous form, ozone can act as a preservative for certain foods products and can also sanitize food packaging materials. Some products currently being preserved with ozone include eggs during cold storage, fresh fruits and vegetables, and fresh fish.

FOOD PRESERVATION WITH OZONE

Ozone can reduce contamination on food and increase storage life. The age-enhancing hormone ethylene is instantly destroyed. This reduces spoiling and keeps the food looking fresh.

Ozone Advantages

1. Most powerful oxidizer available
2. Instantly destroys microbes
3. Eliminates chemical storage
4. Environmentally friendly
5. Stops mold spores
6. Does not affect product taste
7. No harmful by-products
8. Can be used in air and water

NANOTECHNOLOGY IN FOOD AND FOOD PROCESSING

Tomorrow we will design food by shaping molecules and atoms. Nanoscale biotech and nano-bio-info will have big impacts on the food and food-processing industries.

The future belongs to new products, new processes with the goal to customize and personalize the products. Improving the safety and quality of food will be the first step.

Nanotechnology in the Food Industry

The impact of nanotechnology in the food industry has become more apparent over the last few years with the organization of various conferences dedicated to the topic, initiation of consortia for better and safe food, along with increased coverage in the media.

The types of application include: smart packaging, on demand preservatives, and interactive foods. Building on the concept of "on-demand" food, the idea of interactive food is to allow consumers to modify food depending on their own nutritional needs or tastes. The concept is that thousands of nanocapsules containing flavour or colour enhancers, or added nutritional elements (such as vitamins), would remain dormant in the food and only be released when triggered by the consumer.

24 Most of the food giants including Nestle, Kraft, Heinz, and Unilever support specific research programmes to capture a share of the nanofood market in the next decade.

The definition of nanofood is that nanotechnology techniques or tools are used during cultivation, production, processing, or packaging of the food. It does not mean atomically modified food or food produced by nanomachines. Although there are ambitious thoughts of creating molecular food using nanomachines, this is unrealistic in the foreseeable future.

ULTRAFILTRATION (UF)

Method of producing sterile and concentrated juices with improved flavour and reduced acid:

Ultrafiltration is employed to preferentially pass an ultrafiltration (UF) permeate containing flavour and aroma components while retaining spoilage microorganisms in a UF retentate. The UF retentate is then treated to inactivate a sufficient number of spoilage microorganisms to inhibit spoilage of the juice under storage conditions. A UF permeate containing flavour and aroma components is then recombined with the UF retentate to provide a food juice suitable for storage while avoiding the loss or alteration of the desirable flavour and aroma components of fresh juice encountered in conventional juice processing.

Further, the UF permeate can be further treated by reverse osmosis to concentrate flavour and aroma components in an RO retentate.

FOCUS ON COMBINATIONS

High pressure, pulsed electric fields, biopreservatives and radio frequency heating are examples of novel technologies, which are currently used or will be used in the near future for preservation of food products. In general these technologies are effective in inactivating vegetative cells of bacteria, yeasts, and fungi. However, inactivation of

bacterial spores and for some technologies also enzyme inactivation remains difficult using these technologies alone. To extend the use of non-thermal processing technologies in the food industry, combinations of these technologies with traditional or emerging food preservation techniques are interesting.

An often-made combination used is cold storage after a (non-thermal) pasteurization treatment. Also other consecutive or simultaneous combinations are interesting to broaden the application range of these technologies. Examples include combinations of novel technologies with elevated temperature, lowered temperature and/or biopreservatives. In general, these combinations may result in an enhanced shelf life combined with a good preservation of product quality.

NEW TECHNOLOGIES AND NEW SAFETY STRATEGIES

Food is deemed unsafe if it constitutes either a physical, chemical or biological hazard to the consumer. Non-thermal technologies have been advanced to replace conventional heat treatments. These new technologies cannot however achieve the broad microbial lethalities that are currently attainable by heat treatment. Current PEF and HPP technologies can only accomplish the equivalent of pasteurization when applied at their maximum lethal doses. The achievement of commercial sterility by these non-thermal technologies is currently not feasible.

The application of non-thermal technologies to foods is more likely to result in stress or injury than to cause the death of microorganisms. An abundance of injured microbial cells in non-thermally-processed food may create new challenges to food processors and regulatory agencies. The detection of low levels of pathogens in food is a difficult task particularly when cells are injured. The safety of the non-thermally processed product is compromised if food and storage conditions favour the recovery of injured cells. Stress of pathogens by non-thermal technologies is a concern and the adaptation of cells to such stress may constitute a microbial hazard. Non-thermal technologies therefore introduce new challenges, and thus warrant the implementation of new safety strategies.

CONCLUSION

Novel preservation technologies are an interesting option to produce high quality food products with an extended shelf life. The starting point of an evaluation of the possibilities of novel technologies will therefore be the effect on quality combined with the safety of the product after processing.

Irradiation, ultrasound under pressure, HHP and PEF are effective procedures to inactivate vegetative micro-organisms in foods, but the high resilience of spores limits their use as a sole method for food preservation. Therefore, these novel technologies are finding applications as hurdles that assure food safety through microbial inactivation

in minimally processed high quality products. To fully exploit their potential, more research effort is needed to clarify mechanisms of inactivation, especially for HHP and PEF, to better understand the effect of environmental factors, and the occurrence of stress adaptation and sublethal injury, aspects of great relevance regarding food safety.

Interest in non-thermal food processing technologies has increased appreciably in the past decade. Current limitations of emerging non-thermal technologies can be overcome when they are combined with conventional preservation methods. Especially using higher or lower temperatures than room temperature is an interesting option to increase the effectiveness of novel technologies.

6

Thermal Processing of Food

THERMAL PROCESSING

Thermal processing is defined as the combination of temperature and time required to eliminate a desired number of microorganisms from a food product.

CANNING

Nicolas Appert, a Parisian confectioner by trade, is credited with establishing the heat processing of foods as an industry. In 1810 he received official recognition for his process of enclosing food in bottles, corking the bottles, and placing the bottles in boiling water for various periods of time. In the same year Peter Durandreceived a British patent for the use of containers made of glass, pottery, tin, or other metals for the heat preservation of foods. In 1822 Ezra Daggett and Thomas Kensett announced the availability of preserved foods in tin cans in the United States. Tin-coated steel containers, made from 98.5 percent sheet steel with a thin coating of tin, soon became common. These cans had a double seamed top and bottom to provided an airtight seal and could be manufactured at high speeds. The establishment of the canning process on a more scientific basis did not occur until 1896, when the microorganism *Clostridium botulinum*, with its lethal toxin causing botulism, was discovered by Émile van Ermengem.

PRESTERILIZATION PROCEDURES

Selected crop varieties are grown specially for canning purposes. The harvesting schedules of the crops are carefully selected to conform to the cannery operations. A

typical canning operation involves cleaning, filling, exhausting, can sealing, heat processing, cooking, labeling, casing, and storage. Most of these operations are performed using high-speed, automatic machines.

Cleaning involves the use of shakers, rotary reel cleaners, air blasters, water sprayers, or immersion washers. Any inedible or extraneous material is removed before washing, and only potable water is used in the cleaning systems.

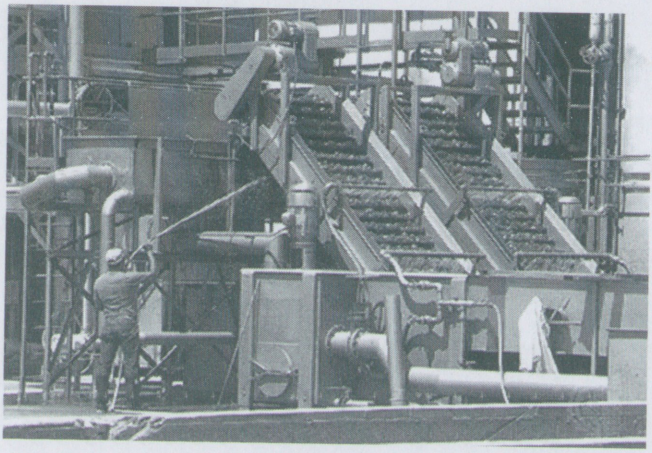


Fig. Spray washing of harvested tomatoes prior to processing.

Automatic filling machines are used to place the cleaned food into cans or other containers, such as glass jars or plastic pouches. When foods containing trapped air, such as leafy vegetables, are canned, the air must be removed from the cans prior to closing and sealing the lids by a process called exhausting. Exhausting is accomplished using steam exhaust hoods or by creation of a vacuum.

Immediately after exhausting, the lids are placed on the cans and the cans are sealed. An airtight seal is achieved between the lid and the rim of the can using a thin layer of gasket or compound. The anaerobic conditions prevent the growth of oxygen-requiring microorganisms. In addition, many of the spores of anaerobic microorganisms are less resistant to heat and are easily destroyed during the heat treatment.

THERMAL PROCESSING WITH FOOD SAFETY IN MIND

Thermal treatments are critical in controlling foodborne pathogens in ready-to-eat (RTE) meat and poultry products. Thermal processing accomplished in meat and poultry processing establishments is still one of the most useful tools to effectively eliminate or reduce to acceptable levels any pathogenic bacteria that may be potentially present in meat and poultry products. Because thermal processing has historically been so effective and, in many cases, regarded as the ultimate "safe harbour" for food safety, it can easily also be one of those technologies where a critical understanding and appropriate application of the product-specific thermal processes can be unintentionally overlooked.



Thermal processing is applied to literally hundreds of types of RTE products, from hams to jerky and from lunchmeats to hot dogs. Yet, many of these products are thermally processed using a variety of procedures, schedules and equipment. Further, almost all of these products have unique compositions, ingredients and other characteristics that can create a different response to the thermal process technology employed. Thus, it is important to understand how different thermal processing systems and schedules affect pathogen lethality, and how the products themselves can also affect overall lethality.

Lethality is defined as the reduction of a target pathogen during heating to a level, ideally zero, that renders a product safe for consumption at any point during its shelf life. There are, however, three additional nuances of lethality that must be included for practical thought and consideration: 1) The pathogen of concern must first be present for lethality to be effective, and since raw product microbial sampling is not conducted in a way to efficiently or effectively validate presence or absence, we inherently consider the pathogen is present. 2) The lethality process must be effective in reducing pathogen numbers to a safe level. This can be a bit of a sticking point as most lethality requirements are at least 5-log colony-forming unit (CFU)/g or higher. These "high" log levels are chosen to achieve a very conservative log reduction, as these levels would almost never be present on raw materials. However, if considering potential growth during the come-up time (time prior to lethality temperature conditions) of the thermal process and the potential for any survivors of the thermal process and their needed control afterwards, these "high" lethality requirements may be well justified. 3) Any variation within the manufacturing process such as differences in product thickness or variation incurred during the thermal process, such as from oven hot spots, also supports the idea of a more conservative approach.

CURRENT AND COMMON VALIDATION FOR THERMAL PROCESSING

Unless a proprietary in-plant validation has been conducted, U.S. Department of Agriculture Food Safety Inspection Service (USDA FSIS) and the Process Lethality Spreadsheet are the two most commonly utilized science-based thermal processing tools available and are employed by the meat industry to ensure and validate the thermal destruction of pathogenic microorganisms during cooking. Like all tools, neither is perfect, with both having their strengths and weaknesses.

The USDA FSIS "Compliance Guidelines for Meeting Lethality Performance Standards for Certain Meat and Poultry Products" document has been used extensively by the meat industry and universally accepted by regulatory bodies as a safe harbour to provide lethality of harmful, pathogenic bacteria in RTE meat and poultry products for many years. From research conducted by Goodfellow and Brown in 1978 on the fate of Salmonella inoculated in beef (roast beef), and since its introduction as a compliance guideline has gained widespread acceptance and application by both industry and regulatory entities. Due to the study design, death curves were able to be generated yielding important and useful time-temperature combinations designed to reduce *Salmonella* by 7 logs. Revered as a critical document for food safety, has been applied to a wide array of products beyond roast beef, including ham, hot dogs, luncheon meats and jerky, to name a few. Although widely used as validation support for thermal processes, its time-temperature tables and humidity requirements were originally developed and validated only for Salmonella in roast beef.

In a USDA-published guidance document regarding the use of Industry's widespread use of a document originally developed for roast beef has raised question about its appropriateness and validity for non-roast beef products. The USDA FSIS release of "Draft Guidance — HACCP Systems Validation" on April 2012 has strongly suggested the safety of meat and poultry products *must* be scientifically supported through validation. This draft guidance has brought into question the scientific appropriateness of support documentation for thermal processing of products that were not included in the original study.

To provide additional thermal processing tools for the meat industry, numerous research studies have been published over the past several decades to provide lethality criteria for pathogenic bacteria, but with the exception, these data have not been translated into tools the industry can easily use. Reasons for this lack of adoption include inability of laboratory studies to be translated into an industry practice/setting, study results not validated in commercial systems or in products outside the scope of the tested product (*i.e.*, studies performed in media systems) and shortcomings identified in research designs (*i.e.*, depth or complexity of experimental design). Even relevant studies are often overlooked or have only limited adoption due to the need for laborious searches and highly skilled interpretations of scientific articles. In other cases, little benefit can be realized if the scope of information is too narrow, resulting in self-restricting data, as is the case with the time-temperature tables for cooking RTE poultry. For example, tables developed for cooking chicken and turkey with different fat contents to achieve a 7-log reduction of *Salmonella* have not met industrywide needs because of the narrow fat ranges (1–12%) included in the study and therefore limit their practical use.

The "AMI Process Lethality Determination Spreadsheet," on the other hand, is much more dynamic and valuable for understanding total log reductions expected and includes additional aspects of integrated lethality if used to its maximum design potential. However, its practical usefulness has been constrained by the availability of the inputs

that must be included in the spreadsheet to perform lethality calculations. Typically found in scientific journal articles, these inputs are usually generated for limited products with specific attributes (*e.g.*, meat species, fat level, water activity, etc.). As such, studies that generate these inputs are not common and because countless combinations of intrinsic and physical factors would be needed to represent all meat products thermally processed, the spreadsheet has some limitations.

However, if a worst case-scenario approach is taken (*e.g.*, whole muscle inputs are used for a ground product), extrapolation can successfully take place. In other words, if we know what effects the intrinsic and physical attributes have on thermal processing, considerations can be made and the spreadsheet can be expanded for products that are encompassed within these factors.

VALIDATION CONSIDERATIONS

If focusing only on product-related responses to pathogen reduction via cooking, many compositional (*e.g.*, fat, moisture, protein, etc.), physical (*e.g.*, shape, size, etc.) or intrinsic (*e.g.*, pH, water activity, etc.) factors and/or differences should be understood and considered. Heat resistance of microbes is affected by several factors, including bacterial and food properties. The bacterial properties include pathogen of interest, cell concentration, phase of growth, bacterial strain and exposure to stressors such as acid or salt. The intrinsic properties of food and ingredients also influence heat resistance as some food components are protective and impart a higher heat resistance for the pathogens. For example, higher fat content, low water activity ($a_w < -0.94$) at temperatures below 127–131 °F and varying levels of solutes (*e.g.*, salt, sodium phosphates) can provide protective effects for *Salmonella*. The bacterial strains themselves also present inactivation differences. Studies completed with multiple strains of Salmonella, including serotype Senftenberg, report variable differences in log-reduction rates between *Salmonella* and *Listeria monocytogenes*, particularly when heated in different substrates, such as pork, turkey or beef products. In some cases, *Salmonella* has been shown to have greater heat resistance than *L. monocytogenes*. Current research in our laboratory, however, has shown otherwise. Thermal resistance of *Salmonella* is further increased in whole muscle product compared with ground product.13

Thermal processing systems, including the equipment used and the thermal processes followed with that equipment, are another consideration that should be carefully evaluated and/or reviewed for the ability to successfully achieve desired lethality. Meat and poultry products are heat-treated using a variety of thermal processing equipment and even an array of different thermal processes using the same equipment.

However, the efficacy of a desired pathogenic log reduction can be impacted by any of the previously described causes for several reasons such as the following:

- Improper equipment is used for the thermal processing task
- Thermal processing equipment is not being well maintained and/or validated

for performance (*e.g.*, oven balance, prevention of cold spots, proper airflow, etc.)

- Thermal processes are not adequately developed to address variations/changes in product, environment or process conditions
- The cooking equipment is not designed to meet thermal processing targets established by the plant
- Failure to understand the design of a thermal process and the impact that may have on lethality in a given scenario (or with a given piece of thermal processing equipment)
- Failure to follow a conservative cooking approach to ensure lack of thermal deviation
- Failure to understand what impact the food product's compositional, physical or intrinsic factors might have on overall lethality

One method to understand the lethality effect caused by thermal processing while also taking into consideration the various peripheral elements of lethality is to utilize D- and z-values. Considered useful tools for thermal processing, D- and z-values provide the ability to simply and accurately understand lethality—regardless of many of the peripheral factors mentioned.

A D-value is defined as the specific temperature at which a 90 percent (1-log) pathogen reduction has occurred, whereas a z-value is defined as the change in temperature necessary to increase the D-value by an additional log (factor of 10). Many of us use D- and z- values, and likely don't realize it. USDA FSIS was developed from the generation of D- and z-values from the experiments conducted. For example, following the cooking temperature of 140 °F, 12 minutes is needed to achieve a 7-log reduction of *Salmonella* (12 minutes/7 log equals a D-value of 1.71 minutes). Thus, by knowing the D-values for different pathogenic bacteria and in different products, predicted lethality can be quickly determined.

VALIDATION RESEARCH

Currently, our laboratory is completing a study funded by the AMI Foundation titled "Developing validated time-temperature thermal processing guidelines for ready-to-eat deli meat and poultry products".

The aims are to begin the collection of baseline/foundational thermal processing data and subsequent generation of thermal processing food safety knowledge and tools to contribute to thermal processing food safety. The goals of the study were to 1) measure D- and z-values for *Salmonella*, *L. monocytogenes* and Shiga toxin-producing *Escherichia coli* (STEC) in roast beef, turkey deli breast and boneless ham; 2) validate the measured D-values in commercial products and processes; and 3) generate data to a) update time-temperature tables for roast beef and b) develop new style, time-temperature tables for turkey deli breast and boneless ham product types/categories.

Table. D-values for Salmonella, L. monocytogenes and STEC in Roast beef, Turkey Breast and Boneless Ham

	(minutes)			
	130°F	**140°F**	**150°F**	**160°F**
Salmonell				
Beef	11.90	0.72	0.18	0.02
Turkey	20.83	2.42	0.24	0.03
Ham	16.67	1.50	0.25	0.02
Listeria				
Beef	55.56	7.25	1.98	0.41
Turkey	55.56	5.95	0.62	0.07
Ham	55.56	9.26	1.33	0.33
STEC				
Beef	33.33	1.63	0.21	0.02
Turkey	33.33	2.22	0.19	0.02
Ham	33.33	1.09	0.12	0.03

This research was completed in two phases. In Phase I, ground turkey breast (containing 1.5% salt, 1.5% dextrose and 20% water), ground roast beef (containing 2.0% salt, 0.35% sodium phosphates, 0.75% sugar and 20% water) and ground ham (containing 2.5% salt, 1.65% sugar, 0.35% sodium phosphates, 547 ppm sodium erythorbate, 200 ppm sodium nitrite and 20% water) were inoculated with 8-log CFU/g L. monocytogenes or *Salmonella*(5-strain mix) or STEC (7-strain mix). One-gram portions (0.5–1.0 mm in moisture-impermeable vacuum pouches) were heated at one of four temperatures (130, 140, 150 or 160 °F) in a water bath. Triplicate samples were removed and immediately chilled to less than 40 °F when the meat reached the target temperature and at seven additional times. Surviving *L. monocytogenes*, *Salmonella* or STEC were enumerated using Modified Oxford, XLD or Sorbitol MacConkey agar base, respectively, with a thin-layer overlay of non-selective media to enhance recovery of injured cells. Each study was replicated twice. Linear regressions of the data were used to calculate D- and z-values for each treatment combination (three product types × three pathogens × four temperatures; Tables 1 and 2). From these data, treatment combinations were selected for validation using commercial production processes. The treatment combinations used for validation in Phase II.

Table. Z-values for Salmonella, L.monocytogenes and STEC in Roast Beef, Turkey Breast and Bonelss Ham

	(°F)		
	Salmonella	**Listeria**	**STEC**
Turkey	10.37	10.42	9.39
Ham	10.71	13.31	9.93
Beef	10.86	14.39	9.72

Table. Treatment combinations used for Phase II validation

Product	Pathogen	Final cooking temperature (°F)
Turkey	Salmonella	160
Roast beef	Salmonella	130
Roast beef	Salmonella	145
Roast beef	Salmonella	160
Roast beef	STEC	130
Roast beef	STEC	145
Roast beef	STEC	160
Ham	Listeria	145
Ham	Listeria	160

In Phase II, turkey breast, roast beef and ham were manufactured according to the same formulations used in the first phase, inoculated with 8-log CFU/g of the designated pathogen cocktail and stuffed into 4-inch-diameter casings.

Treatments were then cooked to one of three target temperatures (130, 145 or 160 °F) using either a step-up steam (turkey breast and roast beef) or wet bulb/dry bulb (ham) thermal process. Triplicate samples were removed from the core, midpoint and surface of each chub for enumeration of surviving pathogens at three predetermined time points during each thermal process (130 °F - sampled at 130, 130 +1 h, and 130 °F +2 h; 145 °F - sampled at 130, 145, and 145 °F +5 min; 160 °F - sampled at 130, 145, and 160 °F).

Additional samples were processed after chilling to less than 40 °F to account for integrated lethality during cooling. Thermal process profiles were generated for each treatment combination by measuring product core, midpoint and surface temperatures as well as environmental (wet-bulb/dry-bulb) conditions. Surviving *L. monocytogenes*, *Salmonella* or STEC were enumerated using Modified Oxford, XLD or Sorbitol MacConkey agar, respectively, with a thin-layer overlay of non-selective media to enhance recovery of injured cells.

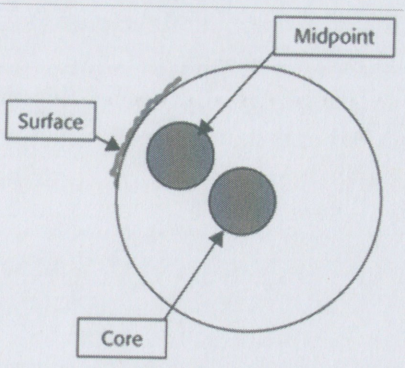


Fig. A cross-sectional cutaway of sausage sampling protocol for Re-moving surface, midpoint and center samples

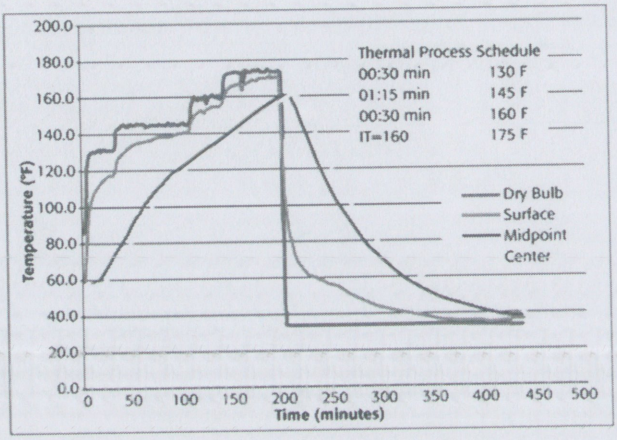


Fig. Theraml process profile chart for Deli-style turkey Breast chubs (4.25-inch diameter) during cooking to 130, 145 and 160 °F

In all product types investigated, inactivation rates for STEC were similar to Salmonella at 140, 150 or 160 °F, and were comparable to or less than times reported in USDA FSIS. In contrast, *L. monocytogenes* showed greater thermotolerance than *Salmonella*and STEC under all conditions. For example, a greater than 5-log reduction of *Salmonella* and STEC in turkey was achieved instantaneously at 160 °F, whereas *L. monocytogenes* was inactivated within 10 seconds. At 145 °F, a greater than a 5-log reduction of *L. monocytogenes* required 30 and 50 minutes in turkey and ham, respectively, as compared with less than 12 minutes for *Salmonella* and STEC. At the lowest temperature tested (130 °F), a greater than 5-log reduction of *Salmonella*, STEC and *L. monocytogenes* in all product types was achieved in less than 2, 2.8 and 4.6 hours, respectively. Preliminary results from Phase I support as an acceptable tool for *Salmonella* and STEC lethality, and as expected, *L. monocytogenes* was more thermotolerant than either Salmonella or STEC. Since Phase I data were generated using model systems and 1-g meat samples, only immediate lethality was measured, whereas integrated lethality was not accounted for to determine expected total lethality in a commercial process. Validation during Phase II confirmed that cooking to 160 °F was sufficient to kill more than 6 logs of the three pathogens in all the products tested. STEC and *Salmonella* were similarly inactivated in roast beef when cooked to 145 °F, but the additional lethality contributed during cooling was necessary to inactivate more than 6 logs of *L. monocytogenes* in ham cooked to a final temperature of 145 °F. At the time of this writing, final experiments are currently being conducted for *Salmonella* and STEC 130 °F roast beef treatments.

SOLVE EFFICIENCY PROBLEMS DURING THE THERMAL PROCESSING OF FOOD AND BEVERAGE

There are many ways to waste time and energy during the thermal processing of food and beverage.

TEMPERATURE OVERSHOOT

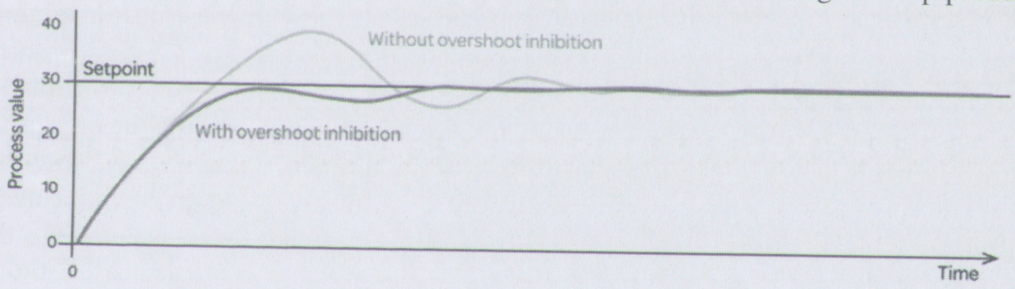
During cooking and cooling processes, whenever the temperature of a product overshoots or undershoots, energy is being wasted. Some products can also be damaged by overheating or overcooling and then need intervention for quality assessment.

For processes where energy is being wasted in this way, one solution is to replace the simple temperature controller with a precision PID temperature controller. Intelligent models have specific algorithms embedded in the control strategy that automatically take care of common heating and cooling problems.

Useful features in this case are inbuilt algorithms that stop the temperature overshooting when heating up (overshoot inhibition). Default values are typically already set for easy configuration.

When operating temperatures are outside the desired setpoint, the result is:

- Wasted time and energy
- Under or over cooked product
- Possible non-conformance to critical temperature limits leading to scrap product



TEMPERATURE INSTABILITY

Certain processes need critical temperature control, for example oil temperature in fryers can be difficult to control. With poor control, the oil temperature can oscillate from too hot to too cold, wasting time and energy in the process. The temperature variation can also lead to irretrievable undercooked or overcooked product creating waste and potential damage to the oil itself if overheated.

One solution is to use a precision PID controller. Special features to look for include a set point programmer for setting up your ideal temperature profile with temperature ramps and dwells (soaks) specified by rate or time and intelligent PID algorithms that control the temperature of the product to the specified set point. To control other setpoints at the same time, like humidity and pressure, this type of controller can typically be purchased with multiloop options and dedicated algorithms that aid the application. Autotune functions are available that will automatically set a range of parameters to optimise the process when enabled on your specific equipment.

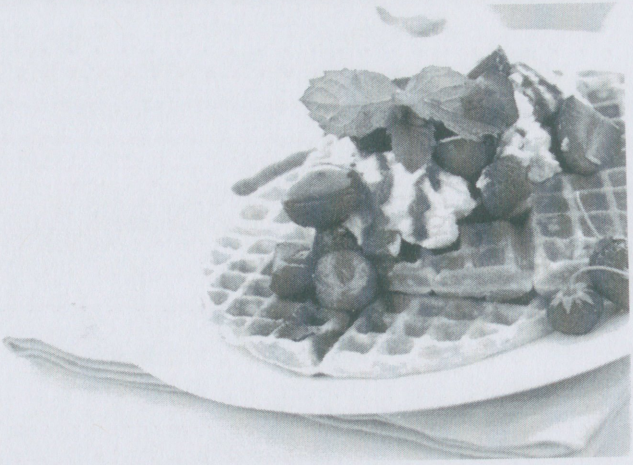
In this case, using a better controller will result in a consistently cooked product that maximises the life of the cooking oil - this practice is relevant to all cooking processes.



PRODUCT INCONSISTENCY

Poorly controlled processes can waste time and energy through non- uniform mixing, cooking and cooling of the product. One of the common problems we find is some human intervention in the process where operators are tweaking the control manually, causing uncontrolled changes to the product. In a recent example, during the process of browning waffles, where colour of the product was important, operators were found to be modifying the heating settings to get the right colour by eye. Certain operators had a knack for adjusting the controls, while others didn't, bringing inconsistency into the finished product.

Automation of the process is better at achieving consistent results than manual intervention. A modern PID control system will ensure all of the zones in the oven are controlled to the right temperature for that particular product. Look for models with recipe functions that allow the whole setup to be saved and recalled when you need to manufacture the same product again and again.



Compliance to critical temperature limits

In food and beverage processes that follow GMP and HACCP guidelines, you could be wasting energy simply by using basic or standard controllers. The problem with these controllers is the wide variation in accuracy levels. When you are not sure of the accuracy, you over compensate by a degree or two to make sure you are always within your critical limits.

By investing in Precision PID control with accurate Inputs and Outputs, and better rejection to noise, you can be sure that the temperature you set is the temperature you get, and that you are meeting your limits while getting ROI by reducing your energy bills over the lifetime of the controller. Other useful features to look for are alarms and communication protocols that help to inform you when a critical limit has been reached. Modern control products with embedded Ethernet communications are available with SMTP server functionality for sending e-mails when an alarm has triggered and have webservers built in so you can view what's going on from a PC, tablet or Smartphone using a web browser. It is worth mentioning that in some processes the data needs to be securely recorded and stored for a length of time. While this is much simpler nowadays using a digital data logger, recent innovations built into precision PID control products include secure recording along with crystal clear colour TFT displays and wash down fronts. Ideal for food and beverage applications like dairy and meat processing where recording is required, this type of all in one box solution can be the most cost effective solution.

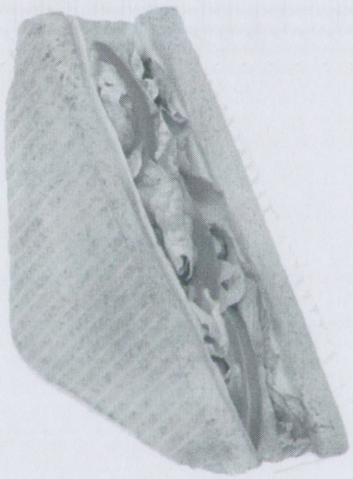
To help maintain accuracy levels in your process year round, several reputable companies also provide services such as Calibration, Temperature Uniformity and System Accuracy Tests (SATs) at regular intervals, to ensure that temperature measurement products and systems are not drifting over time. These issues are even more important for manufacturers and processors who export product, for example to the US who need compliance to standards such as FDA 21CFR Part 11 and FDA 21CFR Part 113.



PACKAGING PROBLEMS

Some types of packaging are difficult to bond together such as when bonding film to plastic. The time, temperature and pressure are crucial to the heat sealing process to

ensure a quality seal that retains its integrity, and basic controllers are not up to this job which can lead to wastage of time, product and packaging. The temperature at the point of the seal needs to be accurate and uniform in combination with the mechanical pressure and time of contact. A precision PID controller is the best choice for repeatable reliable seals and often, along with the temperature controller, a Programmable Logic Controller (PLC) is used to provide the control of the machine. PLCs are now available with precision control built in and these all in one box solutions are the most cost efficient way to create a repeatable packaging process which optimises the output of the machine.



BOILER EFFICIENCY

The energy used to supply hot water and steam is one of the biggest contributors to costs in food and beverage manufacture. As the UK government moves towards carbon-free energy generation it is expected that companies will move towards Electric Boilers as a solution to reduce carbon emissions. Basic boiler control can be inefficient if water and steam are not required constantly so spending a bit more for tighter control that can deal with demand when you need it will give better efficiency. Some food manufacturers have already made the decision to move to electrically heated boilers to help reduce their carbon footprint. Used in combination with modern power controllers that provide firing modes to suit different types of heaters and algorithms to better manage boiler loads across the plant, they are the way forward for companies who are serious about their commitment to green initiatives and directives like ESOS.

PLANT ENERGY USAGE

The food and drink processing industry is the fourth highest industrial energy user in the UK. Energy suppliers provide energy on a tariff and in badly managed plants it is

possible to draw more energy at certain times than your tariff allows. This can result in hefty fines. The simple answer is better power control and modern thyristor controllers are the key. These new smart devices are available with a large variety of industrial communications which allows them to communicate with each other across the plant. Special algorithms for managing and spreading loads across the plant help make the best use of your energy and keep your finance managers happy by operating within your specified tariff.

Make the most of your energy

Eurotherm have designed 50 years of control knowledge into our products which gives us the leading edge in precision control. The clever bit is done by intelligent algorithms embedded in our control strategies that take care of common heating and cooling problems automatically, giving you peace of mind and reducing waste in your process. From discrete products to full automation solutions we can help you improve your efficiency.

POTENTIAL OF HIGH PRESSURE THERMAL PROCESSING TECHNIQUES IN THE FOOD INDUSTRY

Food and Nutritional Sciences looks at the use of high-pressure thermal (HPT) processing techniques in the food industry. HPT processing uses a combination of elevated temperatures and high pressures to inactivate bacterial spores, thereby making some progress in eliminating the bacteria which are responsible for a range of foodborne illnesses, whilst maintaining the protective qualities of barrier packaging materials. The different high pressure processes, target microorganisms for inactivation, and example food categories:

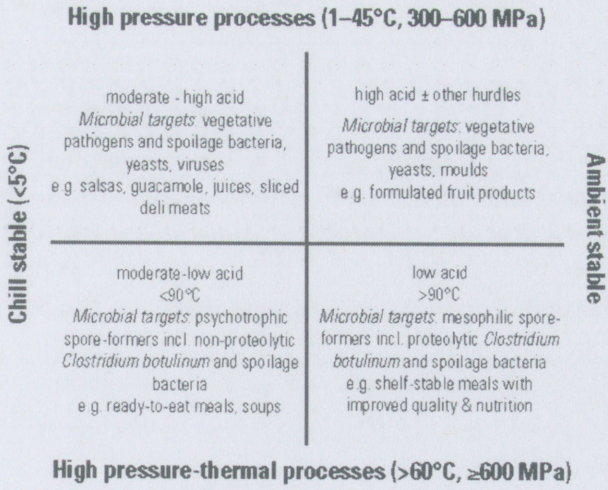


Fig. High pressure processes, target microorganisms for inactivation and example food categories

Why use HPT processing? Both heat and pressure have long been used independently as means of preserving food. For example, high pressure processing (HPP) at low or ambient temperatures can prevent the growth of bacterial spores, and is an effective means of preservation in moderate and high acid foods. However, low acid foods (LAF) remain impervious to standard pressure processing at these temperatures, which allow the *Bacillus* and *Clostridium* strains of bacteria to flourish, and have traditionally been preserved through thermal processing. But this technique requires relatively long periods of heating to ensure that all the food within the target pack has been heated to the minimum temperature – and the longer the heating period is, the greater the risk of degradation to the food quality attributes (flavour, texture, nutrient content and colour). How HPT works Food products are put through a pre-heating, holding and cooling process in order to achieve the desired result. The equipment used is designed to enable maximum compression heating which is vital for bacterial spore inactivation. It must be able to maintain temperatures of up to 90°C, at pressures of 600-800 MPa or higher (up to 1,500 MPa).

- Firstly, the food product is placed in a holding unit and heated to a set temperature.
- The holding unit is then pressurised, and the temperature is increased. The extent of these increases depends upon the composition of the food product and its reaction to heat.
- Once the required temperature has been reached it is maintained for a period of time long enough to inactivate bacterial spores.
- Decompression then takes place which cools the food product quickly, avoiding degradation in terms of colour, taste, texture and nutritional value.

The advantage of HPT processing lies in the reduced thermal load applied to products due to:

1. The accelerated heating/cooling times of food products during (de)pressurisation; and potentially
2. Reduced processing temperatures and/or times through the synergistic effect of heat and pressure on bacterial spore inactivation.

It's that reduced thermal load and more precise heat application that creates less heat damage to the food and its packaging. How successful is HPT? The results show that HPT processing is effective at preventing reactivation in most – but not all – types of pathogenic bacteria.

Spore reaction Bacteria spores show different responses to HPT processing – even between strains of the same species. For example, proteolytic *Clostridium botulinum* strains were more HPT resistant compared to the non-proteolytic strains. Curiously, those bacterial spores which are heat-resistant differ in their response to the combined application of heat and pressure.

- The very heat-resistant *Bacillus amyloliquifaciens* strains are highly pressure HPT-sensitive.

- The very heat-sensitive *Bacillus coagulans* strains are the most HPT-resistant under a variety of conditions.
- While *Clostridium thermosaccharolyticum* strains are generally more than 10-fold more heat-resistant than *C. botulinum*, with the introduction of pressure they become far less HPT-resistant.

The intrinsic properties of the underlying food also play a part; research suggests that spore inactivation may be affected by the food's water content, or its pH levels. Impact of packaging The effect of HPT processing on food products also varies according to the barrier properties used. Ideally, food packaging needs to be able to withstand changes in volume, (de)compression, and temperature without any degradation of its aesthetic appeal. However, HPT processing causes degradation to a certain extent in all forms of food packaging

- This is more visible in barrier materials such as vapour-deposited nylon and oxide film, but
- Aluminium foil and PVDC-MA film are the least affected.

Further work is needed The use of HPT processing to sterilise low acid, shelf-stable foods remains a long term research challenge, although a more realistic goal is that of prolonging the shelf life of low acid chilled foods. Further work needs to be undertaken into bacterial spore inactivation in these chilled LAFs, in particular into the non-proteolytic *C. botulinum* strain, which can germinate and produce toxin at refrigeration temperatures. Other areas to be addressed include:

- Improving pressurisation equipment to ensure optimum temperature distribution,
- Developing food packaging to better withstand HPT processing, and
- Better understanding the kinetics and mechanisms of spore inactivation through HPT.

PASTEURIZATION

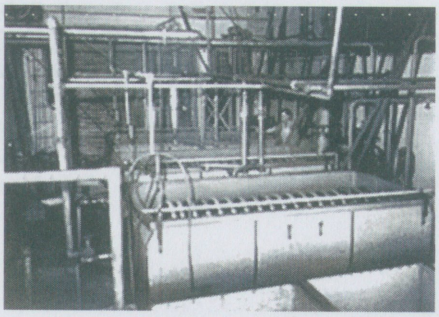


Fig. Cream pasteurizing and cooling coils at Murgon Butter Factory, 1939

Pasteurization or pasteurisation is a process that kills microbes (mainly bacteria) in food and drink, such as milk, juice, canned food, and others.

It was invented by French scientist Louis Pasteur during the nineteenth century. In 1864 Pasteur discovered that heating beer and wine was enough to kill most of the

bacteria that caused spoilage, preventing these beverages from turning sour. The process achieves this by eliminating pathogenic microbes and lowering microbial numbers to prolong the quality of the beverage. Today, pasteurization is used widely in the dairy industry and other food processing industries to achieve food preservation and food safety.

Unlike sterilization, pasteurization is not intended to kill all microorganisms in the food. Instead, it aims to reduce the number of viable pathogens so they are unlikely to cause disease (assuming the pasteurized product is stored as indicated and is consumed before its expiration date). Commercial-scale sterilization of food is not common because it adversely affects the taste and quality of the product. Certain foods, such as dairy products, may be superheated to ensure pathogenic microbes are destroyed.

ALCOHOLIC BEVERAGES

The process of heating wine for preservation purposes has been known in China since 1117, and was documented in Japan in the diary *Tamonin-nikki*, written by a series of monks between 1478 and 1618.

Much later, in 1768, an Italian priest and scientist Lazzaro Spallanzani proved experimentally that heat killed bacteria, and that they do not reappear if the product is hermetically sealed. In 1795, a Parisian chef and confectioner named Nicolas Appert began experimenting with ways to preserve foodstuffs, succeeding with soups, vegetables, juices, dairy products, jellies, jams, and syrups. He placed the food in glass jars, sealed them with cork and sealing wax and placed them in boiling water. In that same year, the French military offered a cash prize of 12,000 francs for a new method to preserve food. After some 14 or 15 years of experimenting, Appert submitted his invention and won the prize in January 1810. Later that year, Appert published *L'Art de conserver les substances animales et végétales* (or *The Art of Preserving Animal and Vegetable Substances*). This was the first cookbook of its kind on modern food preservation methods.

La Maison Appert (English: The House of Appert), in the town of Massy, near Paris, became the first food-bottling factory in the world, preserving a variety of food in sealed bottles. Appert's method was to fill thick, large-mouthed glass bottles with produce of every description, ranging from beef and fowl to eggs, milk and prepared dishes. His greatest success for publicity was an entire sheep. He left air space at the top of the bottle, and the cork would then be sealed firmly in the jar by using a vise. The bottle was then wrapped in canvas to protect it, while it was dunked into boiling water and then boiled for as much time as Appert deemed appropriate for cooking the contents thoroughly. Appert patented his method, sometimes called *appertisation*, in his honour.

Appert's method was so simple and workable that it quickly became widespread. In 1810, British inventor and merchant Peter Durand, also of French origin, patented his own method, but this time in a tin can, so creating the modern-day process of canning foods. In 1812, Englishmen Bryan Donkin and John Hall purchased both patents and

began producing preserves. Just a decade later, Appert's method of canning had made its way to America. Tin can production was not common until the beginning of the 20th century, partly because a hammer and chisel were needed to open cans until the invention of a can opener by an inventor named Yates in 1855.

Appert's preservation by boiling involved heating the food to an unnecessarily high temperature, and for an unnecessarily long time, which could destroy some of the flavour of the preserved food.

A less aggressive method was developed by the French chemist Louis Pasteur during an 1864 summer holiday in Arbois. To remedy the frequent acidity of the local wines, he found out experimentally that it is sufficient to heat a young wine to only about 50–60 °C (122–140 °F) for a brief time to kill the microbes, and that the wine could subsequently be aged without sacrificing the final quality. In honour of Pasteur, the process became known as "pasteurization". Pasteurization was originally used as a way of preventing wine and beer from souring, and it would be many years before milk was pasteurized. In the United States in the 1870s, it was common for milk to contain substances intended to mask spoilage before milk was regulated.

MILK

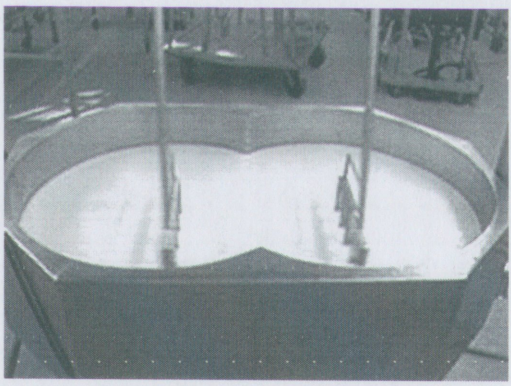


Fig. 180 kg of milk in cheese vat

Milk is an excellent medium for microbial growth, and when stored at ambient temperature bacteria and other pathogens soon proliferate.

The US Centers for Disease Control (CDC) says improperly handled raw milk is responsible for nearly three times more hospitalizations than any other food-borne disease source, making it one of the world's most dangerous food products. Diseases prevented by pasteurization can include tuberculosis, brucellosis, diphtheria, scarlet fever, and Q-fever; it also kills the harmful bacteria *Salmonella*, *Listeria*, *Yersinia*, *Campylobacter*, *Staphylococcus aureus*, and *Escherichia coli* O157:H7, among others.

Pasteurization is the reason for milk's extended shelf life. High-temperature, short-time (HTST) pasteurized milk typically has a refrigerated shelf life of two to three weeks, whereas ultra-pasteurized milk can last much longer, sometimes two to three

months. When ultra-heat treatment (UHT) is combined with sterile handling and container technology (such as aseptic packaging), it can even be stored unrefrigerated for up to 9 months.

History

Before the widespread urban growth caused by industrialization, people kept dairy cows even in urban areas and the short time period between production and consumption minimized the disease risk of drinking raw milk. As urban densities increased and supply chains lengthened to the distance from country to city, raw milk (often days old) became recognised as a source of disease. For example, between 1912 and 1937 some 65,000 people died of tuberculosis contracted from consuming milk in England and Wales alone. Because tuberculosis has a long incubation period in humans, it was difficult to link unpasteurized milk consumption as the cause to the effect of disease. In 1892, chemist Earnest Lederle experimentally inoculated milk from tuberculosis-diseased cows into Guinea pigs, which caused them to develop the disease. In 1910, Lederle, then in the role of Commissioner of Health, introduced mandatory pasteurization of milk in New York city.

Developed countries adopted milk pasteurization to prevent such disease and loss of life, and as a result milk is now widely considered one of the safest foods. A traditional form of pasteurization by scalding and straining of cream to increase the keeping qualities of butter was practiced in Great Britain before 1773 and was introduced to Boston in the British Colonies by 1773, although it was not widely practiced in the United States for the next 20 years. It was still being referred to as a "new" process in American newspapers as late as 1802. Pasteurization of milk was suggested by Franz von Soxhlet in 1886. In the early 20th century, Milton Joseph Rosenau established the standards (*i.e.* low temperature, slow heating at 60 °C (140 °F) for 20 minutes) for the pasteurization of milk while at the United States Marine Hospital Service, notably in his publication of The Milk Question (1912). States in the U.S.A. began enacting mandatory dairy pasteurization laws with the first in 1947, and in 1973 the U.S. Federal Government required pasteurization of milk used in any interstate commerce.

Process

Older pasteurization methods used temperatures below boiling, since at very high temperatures, micelles of the milk protein casein irreversibly aggregate, or *curdle*. Newer methods use higher temperature, but shorten the time. Among the pasteurization methods listed below, the two main types of pasteurization used today are high-temperature, short-time (HTST, also known as "flash") and extended shelf life (ESL):

- HTST milk is forced between metal plates or through pipes heated on the outside by hot water, and the milk is heated to 72 °C (161 °F) for 15 seconds. Milk simply labeled "pasteurized" is usually treated with the HTST method.
- UHT, also known as ultra-heat-treating, processing holds the milk at a

temperature of 140 °C (284 °F) for four seconds. During UHT processing milk is sterilized and not pasteurized. This process lets consumers store milk or juice for several months without refrigeration. The process is achieved by spraying the milk or juice through a nozzle into a chamber filled with high-temperature steam under pressure. After the temperature reaches 140 °C the fluid is cooled instantly in a vacuum chamber, and packed in a pre-sterilized airtight container. Milk labeled "ultra-pasteurized" or simply "UHT" has been treated with the UHT method.

- ESL milk has a microbial filtration step and lower temperatures than UHT milk. Since 2007, it is no longer a legal requirement in European countries (for example in Germany) to declare ESL milk as ultra-heated; consequently, it is now often labeled as "fresh milk" and just advertised as having an "extended shelf life", making it increasingly difficult to distinguish ESL milk from traditionally pasteurized fresh milk.
- A less conventional, but US FDA–legal, alternative (typically for home pasteurization) is to heat milk at 63 °C (145 °F) for 30 minutes.

Pasteurization methods are usually standardized and controlled by national food safety agencies (such as the USDA in the United States and the Food Standards Agency in the United Kingdom). These agencies require that milk be HTST pasteurized to qualify for the pasteurized label. Dairy product standards differ, depending on fat content and intended usage. For example, pasteurization standards for cream differ from standards for fluid milk, and standards for pasteurizing cheese are designed to preserve the enzyme phosphatase, which aids cutting. In Canada, all milk produced at a processor and intended for consumption must be pasteurized, which legally requires that it be heated to at least 72 °C for at least 1 seconds, then cooling it to 4 °C to ensure any harmful bacteria are destroyed. The UK Dairy Products Hygiene Regulations 1995 requires that milk be heat treated for 15 seconds at 71.7 °C or other effective time/temperature combination.

Some older references point to one or multiple cycles of heating and cooling (to ambient temperature or below) as either a definition of pasteurization or a general method thereof.

A process similar to pasteurization is thermization, which uses lower temperatures to kill bacteria in milk. It allows a milk product, such as cheese, to retain more of the original taste, but thermized foods are not considered pasteurized by food regulators.

Microwave Volumetric Heating

Microwave volumetric heating (MVH) is the newest available pasteurization technology. It uses microwaves to heat liquids, suspensions, or semi-solids in a continuous flow. Because MVH delivers energy evenly and deeply into the whole body of a flowing product, it allows for gentler and shorter heating, so that almost all heat-sensitive substances in the milk are preserved.

Efficacy against Pathogenic Bacteria

During the early 20th century there was no robust knowledge of what time and temperatures combinations would inactivate pathogenic bacteria in milk, and so a number of different pasteurization standards were in use. By 1943, both HTST pasteurization conditions of 72 °C for 15 seconds, as well as batch pasteurization conditions of 63 °C for 30 minutes, were confirmed by studies of the complete thermal death (as best as could be measured at that time) for a range of pathogenic bacteria in milk. Complete inactivation of *Coxiella burnetii* (which was thought at the time to cause Q fever by oral ingestion of infected milk) as well as of *Mycobacterium tuberculosis* (which causes tuberculosis) were later demonstrated.

For all practical purposes, these conditions were adequate for destroying almost all yeasts, molds, and common spoilage bacteria and also to ensure adequate destruction of common pathogenic, heat-resistant organisms. However, the microbiological techniques used until the 1960s did not allow for the actual reduction of bacteria to be enumerated.

Demonstration of the extent of inactivation of pathogenic bacteria by milk pasteurization came from a study of surviving bacteria in milk that was heat treated after being deliberately spiked with high levels of the most heat-resistant strains of the most significant milk-borne pathogens.

The mean $\log_{10}$ reductions and temperatures of inactivation of the major milk-borne pathogens during a 15-s treatment are:

- *Staphylococcus aureus* >6.7 at 66.5 °C
- *Yersinia enterocolitica* >6.8 at 62.5 °C,
- Pathogenic *Escherichia coli* >6.8 at 65 °C
- *Cronobacter sakazakii* >6.7 at 67.5 °C
- *Listeria monocytogenes* >6.9 at 65.5 °C, and
- Salmonella ser. Typhimurium >6.9 at 61.5 °C.

The Codex Alimentarius *Code of Hygienic Practice for Milk* notes that milk pasteurization is designed to achieve at least a 5 $\log_{10}$ reduction of *Coxiella burnetii.* The Code also notes that: "The minimum pasteurization conditions are those having bactericidal effects equivalent to heating every particle of the milk to 72°C for 15 seconds (continuous flow pasteurization) or 63°C for 30 minutes (batch pasteurization)" and that "To ensure that each particle is sufficiently heated, the milk flow in heat exchangers should be turbulent, *i.e.* the Reynolds number should be sufficiently high." The point about turbulent flow is important because simplistic laboratory studies of heat inactivation that use test tubes, without flow, will have less bacterial inactivation than larger scale experiments that seek to replicate conditions of commercial pasteurization.

As a precaution, modern HTST pasteurization processes must be designed with flow-rate restriction as well as divert valves which ensure that the milk is heated evenly, and no part of the milk is subject to a shorter time or a lower temperature. It is common for the temperatures to exceed 72 °C by 1.5 °C or 2 °C.

Effect on Vitamins

According to a systematic review and meta-analysis, it was found that pasteurization appeared to qualitatively reduce concentrations of vitamins B12 and E, but it did increase concentrations of vitamin A. Given the available literature, it was not possible to quantitatively measure the effect of pasteurization on vitamins A, B12, and E.

Milk is not an important source of vitamins B12 or E in the North American diet, so the effects of pasteurization on the adult daily intake of these vitamins is negligible. However, milk is considered an important source of vitamin A, and because pasteurization appears to increase vitamin A concentrations in milk, the effect of milk heat treatment on this vitamin is a not a major public health concern. Results of meta-analyses revealed that pasteurization of milk leads to a significant decrease in vitamin C and folate, but milk also is not an important source of these vitamins. However, a significant decrease in vitamin B2 concentrations was found after pasteurization. Vitamin B2 is typically found in bovine milk at concentrations of 1.83 mg/litre. Because the recommended daily intake for adults is 1.1 mg/day, milk consumption greatly contributes to the recommended daily intake of this vitamin. With the exception of B2, pasteurization does not appear to be a concern in diminishing the nutritive value of milk because milk is often not a primary source of these studied vitamins in the North American diet.

The natural concentrations of vitamins in bovine milk samples can differ significantly as a result of a number of factors, including cow breed, season, country, vitamin concentrations in feed, and frequency of milkings. However, changes resulting from pasteurization are likely dependent on the time and temperature of pasteurization conditions. Meta-regression was used to assess the roles of time and temperature in between-study heterogeneity. The duration of pasteurization was positively correlated with folate concentrations, and a direct inverse relationship was found between pasteurization temperature and vitamin C concentrations. Multivariate analysis of time and temperature revealed a significant negative correlation between these variables and vitamin B2 concentrations. These results indicate a likely relationship between time, temperature, and vitamin concentrations in milk; however, further research is needed to tease apart these effects because they appear to differ by vitamin.

Another possible source of heterogeneity among study results is the variation in techniques used to assess vitamin concentrations in milk. HPLC was selected as the "gold standard" method for determination of fat-soluble vitamins by AOAC International. No gold standard has been identified for water-soluble vitamins; fluorescence spectroscopy, chromatography, and microbiological methods are all referenced in the AOAC official methods. Metaregression for vitamin B1 and folate studies revealed a significant association between study and method used to quantify vitamins; however, this variable was not significant for other vitamins. Analytic methods must take into consideration separation of vitamers for each vitamin, the methodology used for calibration of external standards, retention of vitamer conformation, and successful recovery. The solvents, standards, execution of extraction procedures, and

equipment used to carry out these analyses may differ among investigators and can introduce variation among studies. Hollman et al. investigated 18 laboratories that were asked to analyze water-soluble vitamin contents in selected foods. These authors reported that in contrast to the fat-soluble vitamins a wider range of methods was used for water-soluble vitamins and that results from different methods did not always agree for vitamins B2 and C.

According to studies from 1933 and 1943, soluble calcium and phosphorus levels decrease by 5%, thiamine (vitamin B_1) and vitamin B_{12} (cobalamin) levels by 10%, and vitamin C levels by 20%. These losses are not significant nutritionally.

Verification

Direct microbiological techniques are the ultimate measurement of pathogen contamination, but these are costly and time-consuming (24–48 hours), which means that products are able to spoil by the time pasteurization is verified.

As a result of the unsuitability of microbiological techniques, milk pasteurization efficacy is typically monitored by checking for the presence of alkaline phosphatase, which is denatured by pasteurization. B. tuberculosis, the bacterium that requires the highest temperature to be killed of all milk pathogens is killed at ranges of temperature and time similar to those that denature alkaline phosphatase. For this reason, presence of alkaline phosphatase is an ideal indicator of pasteurization efficacy.

Phosphatase denaturing was originally monitored using a phenol-phosphate substrate. When hydrolysed by the enzyme these compounds liberate phenols, which were then reacted with dibromoquinonechlorimide to give a colour change, which itself was measured by checking absorption at 610 nm (spectrophotometry). Some of the phenols used were inherently coloured (phenolpthalein, nitrophenol) and were simply assayed unreacted. Spectrophotometric analysis is satisfactory but is of relatively low accuracy because many natural products are coloured. For this reason, modern systems use fluorometry which is able to detect much lower levels of raw milk contamination.

Unpasteurized milk

According to the United States Centers for Disease Control between 1998 and 2011, 79% of the dairy-related outbreaks were due to raw milk or cheese products. They report 148 outbreaks and 2,384 illnesses (284 requiring hospitalizations), as well as two deaths due to raw milk or cheese products during the same time period.

LOW MOISTURE FOODS

According to a study from the Grocery Manufacturers Association, "There is a common misconception that low numbers of Salmonella are not a problem in low-moisture foods because these products do not support *Salmonella* growth. However, low numbers of *Salmonella* in foods can cause illness, and the presence of the organism in low-moisture ready-to-eat foods must be prevented."

Foods with low water activity (*i.e.* low-moisture foods such as peanut butter, chocolate, and cereals) require longer thermal deactivation steps. For instance, a strain of *Salmonella Typhimurium* took 816 minutes while being processed at 66°C in order to kill 90% of the bacteria in chocolate. For peanut butter, one study showed that heating at 90°C for approximately 42 minutes killed 99.999% of *Salmonella*.

CONSUMER ACCEPTANCE

Although pasteurization has been practiced for a long time, some consumers contend that they should have the right to buy and sell unpasteurized milk if they want to.

Some consumers also point out that government-enforced pasteurization law has been used as a tool for large business to shut out competition from smaller producers.

BLANCHING (COOKING)



Fig. The first step in blanching green beans



Fig. Freshly blanched pistachios for dessert cookery



Fig. Blanched almonds

Blanching is a cooking process wherein the food substance, usually a vegetable or fruit, is scalded in boiling water, removed after a brief, timed interval, and finally plunged into iced water or placed under cold running water (shocking or refreshing) to halt the cooking process.

The meaning of *blanch* is "to whiten", but this is not always the purpose of blanching in cooking. Food is blanched to soften it, or to partly or fully cook it, or to remove a strong taste (for example of cabbage or onions).

When almonds or pistachios are blanched, the skin of the nut (botanically the seed coat surrounding the embryo) softens and can be easily removed later.

Other Definitions

Blanching may simply mean boiling in water for an extended period to remove unpleasant flavours such as tannins. For example, a recommended treatment for African yam bean (*Sphenostylis stenocarpa*), is dehulling followed by blanching in water for 40 minutes at 100 °C.

It is recommended that protein-rich salads to be eaten cold (*e.g.*, tuna, turkey, ham, shrimp, lobster, and chicken) be prepared by immersing these protein foods in boiling water for 30 seconds followed by fast chilling. In addition celery, "which is almost always a component of these salads…should be treated so as to minimize its bacterial content".

In the case of French fries, blanching consists of pre-cooking the French fries in oil at a lower temperature prior to finishing them at a higher temperature. The blanching step cooks the interior of the potato, while the second step at the higher temperature crisps the outside.

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FOOD MICROBIOLOGY AND FOOD PROCESSING

The scope of food microbiology is vast and spreading very rapidly. The study of microorganisms which have both positive and negative effects on the quality and safety of raw and processed foods. Microbiology and Food Safety course will provide the fundamentals of food microbiology and provide an understanding of how microorganisms behave and how to control them. It will raise awareness of the importance of process control, hygiene, and sanitation in the food processing environment. Bacteria are the most important microorganisms to the food processor. Most are harmless, many are highly beneficial, some indicate the probable presence of filth, disease organisms, spoilage and a few cause diseases. There are thousands of species of bacteria, but all are single-celled and fall into three basic shapes: spherical, straight rods, and spiral rods. Food processing is a procedure in which food is prepared for consumption. People often use this term to refer specifically to making packaged foods, but technically anything which transforms raw ingredients into something else is a form of food processing, ranging from grilling vegetables in the backyard to making television dinners in a food manufacturing facility. The food processing sector employs large numbers of people, many of whom are unskilled laborers. This book will be proved as a useful reference to get first hand information of food microbiology for the people who are working in food-processing industries, state and local government agencies and in academic institutions.

Contents: 1. Scope of Microbiology, 2. Ecology of Microorganisms: Microflora of a Soil, Water, Air Methods of their Examination, 3. Microbial Food Spoilage and Food Borne Diseases, 4. Food Processing, 5. Food Processing and Preservation, 6. Thermal Processing of Food.

Alfonso Manning is Professor Emeritus in the Department of Biological Science. He has worked with several national and international organizations. Alfonso Manning is a consultant to the food industry and has served as author or editor of numerous books in food science technology, including the Encyclopedia of Food Science and Technology; Introduction to Food Microbiology; Handbook of Food Science, Technology, and Engineering; and Food Processing: Principles and Applications. Author Alfonso Manning has assembled over fifty acclaimed academicians and industry professionals to create this indispensable reference and text on food biochemistry and the ever-increasing development in the biotechnology of food processing.

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