Fundamentals of Food Science and Nutrition

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PREFACE

Fundamentals of Food Science and Nutrition is a book that focuses on the basic tenets of food-related disciplines, food composition, spoilage, preservation and nutrition. Materials in this book were drawn from a wide range of sources - lecture notes prepared over the years, from books, journals and Internet resources in the areas of Food Science and Technology, Human Nutrition and Home Economics. The simplicity of the text makes it invaluable as a resource needed for the basic understanding of food-related issues and disciplines. It also links the basic sciences to their applications to the science of food. Information has been compiled, based on current knowledge, and recent journal articles, while maintaining simplicity and clarity. Pertinent references to very important journal articles have been added.

Philippa C. Ojimelukwe

CHAPTER 1

WHAT IS FOOD?

Food is a basic human need. It is a topical issue for all mankind.

Food is that item that is eaten to obtain energy, achieve growth, repair tissues, resist infection and ensure normal functioning of the body. A food material should be able to:

- ❖ Supply nutrients
- ❖ Satisfy physiological requirements
- ❖ Have good sensory appeal and desirable attributes.

Food is the most fundamental of all human needs. Foods are heterogeneous in nature. They can be obtained from animals, plants and microorganisms. A lot of issues are involved when dealing with food. Most materials used as food were living entities before they became food; storage organs and light trapping areas of plants; whole animals and their products and microorganisms and their products are all used as food.

The science of food depends on biology, bacteriology, mycology, physics and chemistry. These basic sciences have been developed to the point where they can be exploited for proper utilization of materials as food.

Both plant and animal tissues used as food have many things in common. They possess some compounds, which are found in all of them. Some metabolic pathways are also common. For instance, the breaking down of glucose is similar in many plants and animals. The basic life processes such as respiration, feeding, excretion, reproduction and growth are common to many plants and animals and affect their potential as food sources. However, peculiarities exist among the different food materials and the unique property of each food material determines the appropriate method for its processing and preservation.

Food related professions

A profession is a well-known way of life. An occupation is a means of livelihood. To be referred to as a profession an occupational group has to meet the following criteria:

- The practice of the occupation must be based on a recognized body of learning.
- The occupational group must establish an independent body for the pursuit of its aims and objectives.
- Admission to corporate membership has to be based on standards of competence attested to by examination and by experience.
- It must be recognized that professional practice must be to the benefit of the public and members of the profession.
- A profession must be able to advance and extend the body of learning on which it is based.
- It must be concerned about the type of facilities, methods and provisions for educating and training future members and for enhancing the knowledge of its members.
- The occupational group must recognize the need for its members to conform to high standards of ethics and professional conduct set out in a published code possibly with appropriate disciplinary procedures.

To be effective as a professional body, the Institute of Food Science and Technology (IFT) has adopted several complementary objectives,

- To set and maintain high standards of eligibility for membership
- To attract to itself a great majority of qualified people so that the profession will be fully represented and there will be a financial means to operate effectively
- To ensure that it is recognized by other professional bodies, particularly those concerned with science and technology, and by the government
- To ensure that its corporate grades of membership, (implying full professional status), become recognized as meaningful firms and organizations which employ food scientists and technologists.
- To engage in appropriate scientific and educational activities.

The institute differs in character from many other institutes in its multidisciplinary nature and coverage of members.

Food science and technology

Food science is the body of organized knowledge concerned with understanding the nature and composition of foods as well as the changes that occur in them during processing. It seeks to understand the behaviour of foods under various processing and preservation conditions. Food technology applies the knowledge of food science practically. It enables the conversion of food materials into food products with good quality, stability and wholesomeness. It also enables the processing of foods into forms that would be attractive, convenient to transport and acceptable to consumers. Processing methods that optimize nutrient retention are encouraged. Food science and technology is a field of study, which uses modern science and engineering to produce, process, diversify, preserve and utilize food. In food science and technology, highly diversified scientific and technological activities are carried out.

Food science and technology should facilitate food-related matters in the following ways:

- Assemblage of large quantities of food required by diverse populations
- Provision of the types, quality and quantity of food required by consumers at all times
- Controlling the quality and uniformity of foods produced
- Improving and maintaining the nutritional value of the total food supply hence, the health of the community eating it.
- Production of new foods
- Ensuring proper packaging and transporting of foods
- Providing information and the needs of commercial catering
- Providing the information required for improving food production and other food-related matters.

People who deal with food should understand the scientific basis for food processing (both modern and traditional) and be able to apply it to the development of technological processes. Food science and technology as a field of study, contributes immensely to solving world food problems by developing methods of processing and preserving foods to improve their quality.

The food scientist/technologist has to ensure that appropriate technology is employed in food industries; otherwise, many operations and processes would be carried out with sub-optimal efficiency. Inappropriate equipment and processing affect product quality. The food scientist/technologist has to

upgrade traditional food processing technologies through the application of modern science.

A wide range of career opportunities exists for specialists in several areas of Food Science and Technology. Food engineering, food microbiology, food chemistry and analysis, food biotechnology as well as food processing and preservation are clear-cut areas of specialization on which career opportunities may be based, Ancillary areas such as Brewing Science and Technology also exist.

Food Scientists/Technologists can work in all kinds of food industries like the meat industry, flour industry, dairy industry, beverage industry, vegetable oil industry and spice-producing industries.

A Career in academics implies that the individual will further promote knowledge of food science and technology at all levels.

Specialists in food science and technology can establish viable businesses in food-related areas or consultancy services whereby they provide specialized knowledge to end users based on specific needs.

Home economics

Home economics may be defined as a field of study of knowledge and services concerned primarily with strengthening family life. It helps individuals, families, agencies and the government to make relevant decisions about all aspects of family life (social, economic, aesthetic, managerial and ethical). Home economics involves the following inter-related areas:

- Child development and family relations
- Education
- Communications
- Design and construction of clothing
- Preparation and management of food for the family and specified groups
- Interior design and decoration
- Production, design and management of textiles.
- Family and community health/welfare
- Housing and household equipment etc.

Home economics requires the knowledge of various disciplines, which include physical, biological and social sciences, psychology and arts. In the early years of introducing Home Economics through Western culture, the courses taught were cookery, mother craft, sewing and housecraft. In some parts of the world, Home Economics is referred to as Human Ecology.

Knowledge of Home Economics enables families and individuals to build and maintain systems of action, which lead to:

- Maturing and individual self-formation
- Enlightened cooperative participation
- Formulation of social goals
- Finding means of achieving personal goals and values of an individual,
- Determining personal philosophies of life.

Home economics involves a study of the following:

- ***Family/child Relationship:*** This involves studies about human growth and development, physical, emotional, intellectual and social development including the development needs of the individual throughout the life cycle. It also involves a study of the roles of interrelationships of individuals in the family at all socio-economic levels of society.
- ***Resources Management*** this entails a study of decision-making behaviour about the allocation of individual and family resources.
- ***Food and Human Nutrition***. This entails a study of the interdependence of food and nutrition in the behavior and health of individual
- ***Clothing and Textiles:*** Entails a study of the production and construction of clothing.
- ***General Education.*** This entails a study of the relationship between changing technology/ environment and human behaviour.

Career opportunities in home economics

Career opportunities may be sought in the following areas:

Child development: This involves knowledge of developmental stages from infancy to adulthood,

- ***Social Institutions***
- ***Health institutions*** where they can assist with health, welfare, recreation, family relations and integration of the individual into the society.
- ***Social welfare*** units, pre-nursery & Nursery settings and other child-related establishments'
- *Clothing,* Textiles and Related Areas: In this area, fibre and fabric production, construction and designing of clothes as well as interior designing of homes and public places are studied. Firms involved with the production/construction of fabrics as well as interior decoration can employ specialists in this area.
- The home economist can be involved *in food sales,* and the sales of household equipment. Other food-related areas in which the home economist may be involved include the development of recipes and the testing of new products for industries.
- The home economist can also have a career in *extension work,* which involves the dissemination of research results in relevant areas to end-users.
- Teaching and Research: A career can be undertaken in teaching and research in Home Economics and or any of the areas of specialization at the relevant *educational* level.
- Home economists may also be employed in other career groups such as *human/community service, business/industry and extension work.*

Home economics as a profession

Home economics is a "people's" profession. It is the only field of study concerned with all aspects of family living. It studies interaction between people at various levels in a social context. It also relates the impact of the environment on individuals within the family and in society, It is concerned with the impacts of factors such as housing/housing shortages, new products, communication, media and technology, quality and conservation, changes in size and median age of the population, new values of individuals, etc. on family life. Hotel management and Tourism is a specialized area related to home economics.

Human nutrition

Nutrition is the science of food, its nutrients and other components. It concerns itself with the action, interaction and balance of foods in health and disease. The science of nutrition studies the process by which organisms ingest, digest, absorb, transport, utilize and excrete food substances both in

health and in disease. It also concerns itself with the social, economic, cultural and psychological implications of food and eating. Nutrition is also regarded as the process of nourishing or being nourished. Living organisms assimilate food and use it for the provision of energy, growth and replacement of tissues. Nutrition deals specifically with food and nourishment especially in humans. Initially, this field of study was an integral part of Home Economics.

Presently it is a field of study on its own. Nutritionists promote the physical and mental efficiency of individuals by conveying information about the relationship between food and health. By advocating good food habits, they contribute to the control of diseases and prolonging of life. Community nutritionists strive to improve the nutritional status of a community through education. They cooperate with government agencies and non-governmental organizations to promote sound nutrition. They can work in community centres, public/private health offices, and international, commercial and welfare agencies where they share their knowledge of nutrition.

Dieticians are nutritionists who specialize in the analysis and interpretation of human nutritional needs. They determine the nutritious diets to help individuals maintain good health or recover from illnesses. Administrative dieticians plan menu cycles for patients and personnel and supervise the quality and quantity of food they consume. They select, train and supervise food service workers. They prepare the budget for food supplies and equipment, purchase food, and ensure that the relevant sanitation and safety regulations are kept. They need good knowledge of chemistry, microbiology, human physiology, biochemistry, economics, sociology, computer, psychology, statistics, and nutrition, as well as a liberal professional education. Knowledge of finance and business management is also essential.

Clinical dieticians modify diets to suit the nutritional requirements of patients in hospitals and supervise food services to suit the nutritional requirements of such patients. They need a strong scientific background to decipher the complementary role of nutrition to medical treatment in diverse disease conditions. Nutrition and Dietetics also require the conduct, evaluation, and dissemination of research findings about nutrition, health, disease, food management, food service and food equipment. They are concerned about food intake, food quality, acceptability, and food utilization in the body.

The **experimental nutritionist** conducts research related to nutrient intake, nutrient requirements and metabolism in man, while the **nutrition educator**

teaches at various levels of learning (secondary schools, polytechnics, universities etc.), non-governmental agencies, media houses, private consultancy and the like.

Agriculture/food and nutrition interphases

Activities in the field of Agriculture are needed to:

Provide food security at the family, community, national and international levels.

Provide a modicum (solid basis) for economic security.

Provide a solid basis for fabricating a framework for proper sustainable development.

In the field of agriculture, efforts have to be made to:

Intensify food production

Develop effective means for field pest management

Override climatic fluctuations and variability in soil and vegetation types to boost food production.

Technological advances are being made in agriculture to achieve the following:

Ecologically sustainable production

Management of nutrient depletion in soils

Development of tools and equipment

Integrated pest management

Integration of animal production with crop production

Genetic breeding to produce crops with relatively high yields and desirable sensory and nutritional qualities etc.

The food scientist/technologist ensures the continuity of the job of the producer. The practice of Food science and technology ensures that produced food gets to the consumer in the most acceptable, nutritious, safe and wholesome condition. It seeks to understand the nature of foods,

determine the sources of production, effects of diseases and pests of food crops on nutrient composition and the nature and effects of food spoilage on composition utilization. It then seeks to use different transformations of food to nullify the effects of seasonal production and ensure availability. It ensures the proper distribution of foods and the avoidance of wastage in countries and regions. Effective processing and preservation complement intensive efforts in production used in modern agriculture. New nutritious foods are developed to improve the diet of the population and prevent malnutrition as well as to take care of the dietary needs of vulnerable groups of the population. New scientific knowledge in agriculture is applied to produce more food while modern developments in food science and technology are used to preserve, process and distribute the food produced by the agriculturist. Proper interaction between the agriculturist and the food scientist/ technologist generates necessary feedback information for improving production, selection of superior crop and animal varieties, adoption of good harvesting techniques and storage systems, good post-harvest handling, and grading arid pack house operations.

Availability of food is a key factor in nutrition. While the agriculturist is concerned with production, the food scientist/technologist is concerned with proper post-handling treatment to ensure availability and distribution at all levels. Access to food determines intake, nutrient utilization and ultimately the nutrition status, physiological function and work capacity of an individual. Food is a fundamental human need and is at the centre of family life. Food is therefore the focal point for these disciplines of study and career development. Nutrition activities should be integrated into agricultural programmes and projects to improve nutrition. Agricultural credit programmes could incorporate nutrition education and food processing/ preservation packages. Agricultural extension services could be made to include nutrition and food security messages.

Food security

Food security refers to a situation where all people at all times have both physical and economic access to the basic food they need. Countries, regions, communities and households achieve food security if they are able to meet their annual food requirements through domestic production, storage and international trade. It means that people have access at all times to enough food for active healthy living. The essential elements are the availability of food and the ability to acquire it.

Food insecurity on the other hand is the lack of access to sufficient food. It may be chronic or transitory. Chronic food insecurity results from a continuous lack of resources to produce or acquire food, which ultimately leads to an inadequate diet. Transitory food insecurity is a temporary decline in access to food and. commonly results from instability in food production and food prices or income. The worst type of transitory food insecurity is famine. Food insecurity negatively affects the dietary intake and nutritional status of adults leading to poor health and increased risk for the development of chronic diseases. It also negatively affects children's health and psychological and cognitive functions.

Food is the most fundamental human need. Adequate nutrition has been globally recognized as a fundamental human right. Ideally, the whole population should have access to sufficient quantity and quality of food at all times. To guarantee access to food, people should have adequate resources; either to produce food or to obtain it in exchange for other things.

Factors that affect the food situation are the *production, consumption* and *imports.* These factors also depend on the agricultural policies in the environment. Some of the factors that encourage production are:

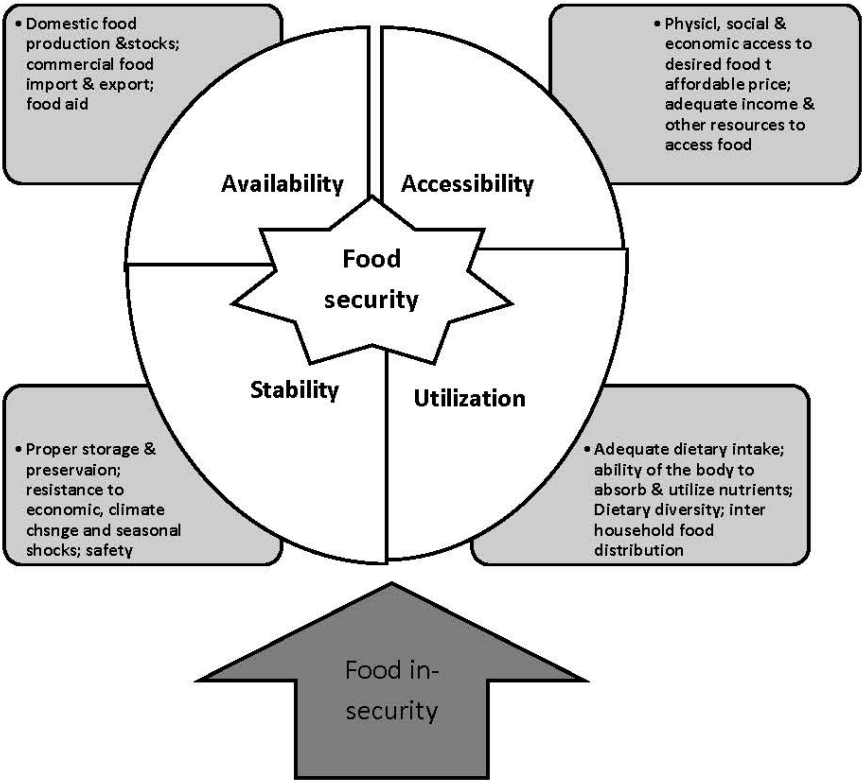
Adequate incentive for farmers: a sufficient reward for food production is very essential for agricultural growth. This implies the following:

Efficient marketing of farm produce

Agricultural support services (e.g. research in agricultural production, agricultural extension services, credit schemes, input delivery).

The peasant farmer has to appreciate why he must produce more and more and should be certain that he can sell.

Food insecurity negatively affects the dietary intake and nutritional status of individuals leading to poor health, and increased risk for the development of chronic diseases. It also negatively affects the health, psychological and cognitive functions of children. Figure 1 shows the effects of processing, distribution and consumption on food security.


• Domestic food production &stocks; commercial food import & export; food aid
• Physicl, social & economic access to desired food t affordable price; adequate income & other resources to access food
Availability
Accessibility
Food security
Stability
Utilization
• Proper storage & preservaion; resistance to economic, climate chsnge and seasonal shocks; safety
• Adequate dietary intake; ability of the body to absorb & utilize nutrients; Dietary diversity; inter household food distribution
Food in-security

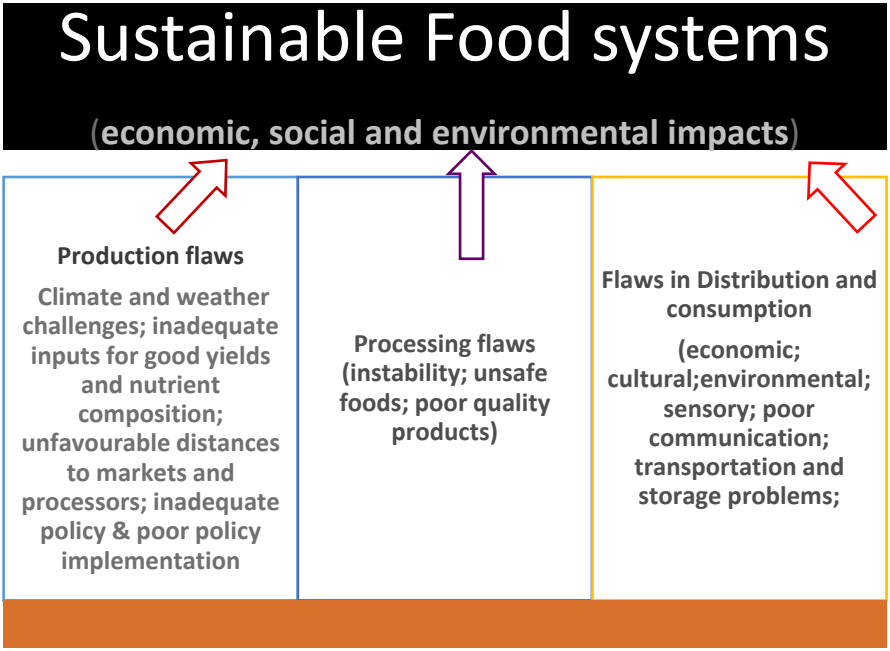


Figure 1: Sustainability in production, processing, distribution, and consumption enhance food systems and promote food security (Adapted from Ojimelukwe *et al.,* 2023).

Methods of evaluating food security

Food security and nutritional status can be monitored by developing standard indicators and survey instruments relating to food consumption, security and nutritional status. Surveys should strive to obtain information about food expenditures, food assistance, program participation, food sufficiency, food security, strategies for coping with food shortages, life experiences, behaviours and self-perception which indicate household hunger and food insecurity. It should be noted that:

- *Economic security* is a prerequisite to the attainment of food security. Access to funds is a key issue in food security. Food intake is usually reduced as a result of financial constraints. Economic security therefore can be used as an indirect index of food security:
- *Creating awareness* about hunger and food insecurity through alert signals and by providing measures to check food insecurity is very

essential. The media can be used to promote food security education by providing information about healthy dietary habits, breastfeeding, nutrition promotion, maximization and maintenance of nutrition education resources. Under nutrition and growth retardation could be monitored periodically to provide information needed for policy modification. Indices of domestic food insecurity and hunger should also be monitored periodically.

- *Local food systems* should be developed and sustained while post-harvest losses should be greatly minimized. Food security is enhanced when post-harvest losses are curtailed to the barest minimum.
- *Food safety* should be promoted through the promotion of food safety education and by promoting the integration of pest management to boost production. It is an integral part of food security.

Food policy

Government policies have a profound effect on the intensification of food production and proper cooperation of agricultural development/food and nutrition programmes. At the national level, the three central issues in the food policy of any country are:

- The target food consumption level (usually computed annually)
- The ability of the country/region to maintain this annual food consumption level
- The effectiveness of available food in the maintenance of adequate nutrition and promotion of good health.

These make it imperative for the government to articulate:

- Economic policies especially those relating to food and making them dynamic.
- Sustainable actions regarding food and nutrition and put such actions on its priority agenda
- Special programmes that give priority consideration to the nutrition of vulnerable groups.

Government should:

- Promote financial access to food, as this will enable the populace to find jobs and keep these jobs.
- Find means of encouraging enhanced education.

- ❖ Conduct periodic research to improve household and community economic security.

At the national level, food safety should be a shared responsibility involving the government, the food industry and the consumer. The safety of foods sold in the market is a World Health Organization (WHO) concern, which encourages the concerned groups to get involved in ensuring food safety. Access to nutritionally adequate and safe food is a right of each individual.

Government policies should incorporate the following aspects of food safety:

- ❖ Diseases caused by contaminated food and drinking water.
- ❖ Promotion of safety and quality of foods.
- ❖ Reduction of pre-harvest and post-harvest losses.
- ❖ Adaptation and improvement of traditional foods and processes.
- ❖ Beneficial application of biotechnology and other new technologies to food.
- ❖ Development and dissemination of improved knowledge of food composition
- ❖ Promotion of domestic and international food trade
- ❖ Development of food materials with improved functionality.
- ❖ Development of more efficient and environmentally sustainable food production and processing systems
- ❖ Education in nutrition, food science and technology at all levels.
- ❖ Feedback (information) obtained about food needs should be linked to the planning and implementation of food policies.
- ❖ Governments should develop appropriate statistical procedures for providing estimates by using data obtained from national and state surveys.

Codex Alimentarus (Food Code)

The Codex Alimentarius is the code concerned with nourishment. It provides standards for food, beverages, drinks, condiments, raw materials and utensils used in handling foods. The United Nations Organization for Food and Agriculture and the World Health Organization established it in 1962. Its mandate is to develop international standards and safety practices for foods and agricultural products. The objectives of the joint FAO/WHO Food Standards programme are as follows:

- To protect the health of the consumers.
- To ensure fair practices in the food trade.
- To coordinate food standard outputs from national, international and non-governmental organizations.
- To determine priorities, and initiate and guide the preparation of draft standards with the aid of appropriate organizations.
- To finalize standards to be presented to governments.
- After acceptance by governments, publish the standards in a Codex Alimentarius as regional or worldwide standards.

The World Trade Organization (WTO) recognizes the Codex standards, guidelines and recommendations as its benchmark for international trade. Extensive scientific evidence is utilized in the formulation of Codex standards. The Codex Alimentarius Commission (CAC) is regularly provided with scientific advice from the following:

- The joint FAO/WHO committee on food additives (JECFA).
- Joint FAO meeting on pesticide residues.
- Other bodies such as the International Commission on Microbiological Specification for Food,
- Panels and experts who converge temporarily to address specific issues.

These inputs are used in the establishment of standards for:

- foods
- limits for ingredients
- food additives
- veterinary drug residues
- food contaminants

These standards are published in several volumes that contain the following information:

- General requirements
- Labeling
- Food additives
- Contaminants
- Irradiated foods.
- Import/export inspection
- Food hygiene
- Standards and codes of practice are compiled on a commodity basis.

Terminologies relating to the food situation

- ***Food security*** refers to the availability, accessibility, affordability and satisfactory use of culturally acceptable food by all individuals/ at all times to achieve good nutrition for a healthy and happy life.
- ***Food insecurity without hunger:*** There is a reduction in the quality of the diet, but little reduction in the quality of food intake.
- ***Food insecurity with hunger:*** There is reduced food intake and: hunger for adults but not for children.
- ***Food insecurity with severe hunger.*** Both the adults and children in the household experience the physical sensation of hunger.
- ***Food Sufficiency*** measures the amount and kind of food that is available. It is defined as a country's ability to provide its entire population with sufficient food from domestic production (IPBES, 2018) as well as an adequate standard of nutrition that would guarantee a balanced diet.
- ***Household Food Sufficiency*** considers the ability of households within a community to access sufficient food supplies for its members.
- ***Community food security*** considers the ability of all persons in the community to obtain a nutritionally adequate and culturally acceptable diet at all times through local non-emergency sources.
- ***National food self-sufficiency*** refers to the ability of a country to produce adequate food for its citizens. It does not guarantee household food security. The critical factor in household food security is the household's ability to obtain food.
- ***The world's food supply*** should be at par with population growth. Food distribution should be efficient. New scientific knowledge should be used to boost agricultural production while appropriate technology should be applied to preserve, process and distribute food.
- ***Food Self-reliance:*** This implies putting greater emphasis on meeting the need for staple foods from domestic production instead of from imports. A food-reliant country would be politically co-milled to the use of agriculture to boost domestic food production.
- ***Food security*** means that there is no or minimal evidence of food insecurity. Adequate food (in terms of quantity, quality, supply and socio-cultural acceptability) is available, accessible, affordable and satisfactorily utilized by all individuals/ at all times to achieve good nutrition for a healthy and happy life.

CHAPTER 2

FOOD SPOILAGE

Definition

Food spoilage may be defined as deterioration, which leads to undesirable changes in the organoleptic characteristics of food. These are adverse changes that are largely attributable to biological factors. Deterioration leads to changes in food quality induced by physical, chemical and biochemical reactions occurring within the food. Spoilt food may have the following characteristics.

- An offensive smell
- A mouldy surface
- A sharp flavour
- A changed colour
- A slimy surface
- A strong sour flavour
- Gas development (production of gas).

Causes of food spoilage

- Microorganisms such as yeasts, moulds and bacteria may cause spoilage in foods.
- Physiological life processes such as chemical reactions within the food (which may be enzyme-catalyzed)
- Attack by insects and rodents, which consume the food/feedstuff and contaminate the rest with their excreta.
- Cold temperature and uncontrolled freezing may induce "freeze burns" which make food undesirable.
- Sensitivity to light is another source of food spoilage. Certain nutrients in food are sensitive to various types of radiation. Exposure to such radiation not only leads to loss of nutrients but also initiates reactions that accelerate deterioration.
- Humidity
- Oxygen

The nature of microorganisms involved in the spoilage of foods

Bacteria (Class Schizomycetes)

Bacteria are small single-celled organisms. They may be spherical, rod-like, or branched. Their cells may be united into filaments. They may be motile, non-motile, aerobic or anaerobic. Chromatin granules represent the nucleus in bacteria. The cell wall is made up of chitin, proteins and carbohydrates. Some forms also have flagella. The flagella of the motile bacteria usually originate from the cytoplasm. Inside the cell wall, there is a thin plasma membrane. The cytoplasm contains many small vacuoles, stored food granules such as volutin, glycogen and fats, and sometimes sulfur.

The classification of bacteria has been revolutionized by molecular genetics. Sometimes molecular genetics is still used in combination with the older methods such as cell wall analysis and serological profiles. Some of the new methods based on molecular genetics are:

- DNA homology and the guanine + cytosine (purine bases found in the DNA molecule) content.
- Similarities in the sedimentation pattern of the ribosomal RNA molecule.
- The nature of oligonucleotides present.
- Soluble proteins.
- Morphological and biochemical characteristics.
- Cellular fatty acids.
- Serotyping (use of specific antibodies (antiserum) to identify homologous antigens.

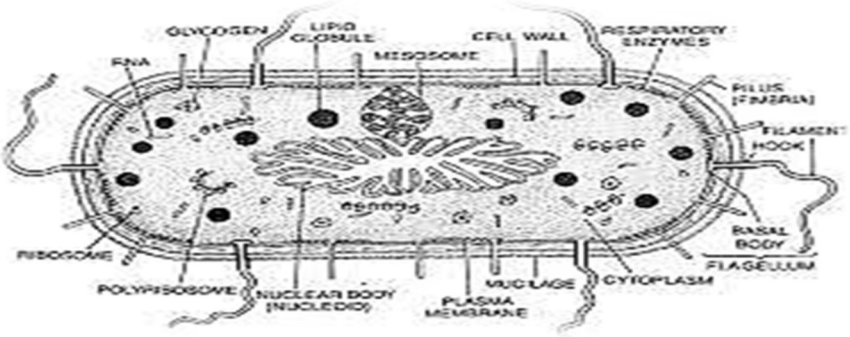


Figure 2. The bacterial cell. (Source: Banniogidad, 2014; Dorr *et al.,* 2019)

Bacterial nutrition

Bacteria require energy for life. They may be autotrophic (a small number), heterotrophic, photosynthetic (some of them have a pigment closely related to chlorophyll) or chemosynthetic. Chemosynthetic bacteria obtain energy for their synthetic process by oxidation of some inorganic compounds such as sulfur iron and nitrogen. Saprophytic bacteria live in water or soil containing dead plants and animals and in fruits and vegetables. Parasitic bacteria absorb food products from their hosts by enzyme secretion and digestion. Some bacteria are pathogenic and are found in large numbers in the human system even though their activities are not clearly understood. A good number of them have beneficial effects in one way or another. These include:

- Assisting decay of organic compounds
- Conversion of proteins in dead decaying organic compounds into ammonia (ammonification) and nitrites /nitrates (nitrification) which green plants can absorb readily. Many bacteria can convert waste products into sources of nutrients (especially nitrogen) for growing plants thereby enriching the soil.
- Nitrogen fixation. Many soil bacteria (e.g. *Acinetobacter* and *Clostridium)* fix free nitrogen in the air into their bodies.
- Disease control. Some antibiotics for disease control are obtained from bacteria. Penicillin is isolated from a mould *Penicillium notatum* while streptomycin is isolated from *Streptococcus griseus,*
- Industrial uses. Many bacteria have industrial uses. Fermentation reactions in the food industry are carried out with bacteria and bacterial enzymes. Examples include the fermentation of tobacco leaves; tea leaves, ripening of teas, retting of fibres, and manufacture of vinegar.

Spore formation

Under unfavourable conditions, some bacteria such as Bacillus species form endospores. The protoplasm withdraws from the wall and clothes itself with a fresh firm wall, which can resist the action of high temperatures and many poisonous substances. When the conditions become favourable, the spores germinate in a suitable medium. The wall of the mother cell decays and the tough coat of the spore splits to release the protoplasm into the surrounding medium.

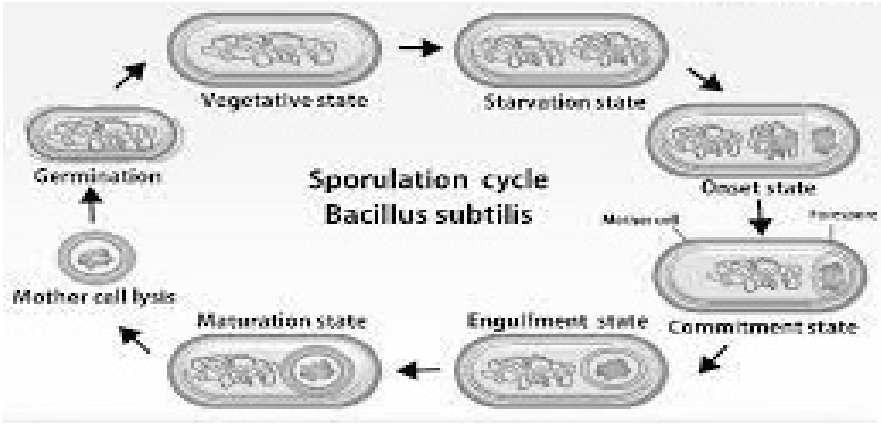


Fig. 3: Spore formation in bacteria (Source: Cho ***et al.,*** 2020)

Fungi

Fungi are thallophytes that lack chlorophyll. They may have other pigments in their cell walls or cell cavities. They have a variety of shapes and sizes. They may be saprophytes or parasites and store their reserve carbohydrates as glycogen (not starch). They can disintegrate or dissolve anything they attack by secreting enzymes. The plant body (except unicellular forms) is commonly made of an interwoven mass of delicate threads referred to as hyphae. Collectively, several hyphae are called mycelium. The wall of the hyphae may be made of chitin or cellulose. During vegetative reproduction, the body of the fungus is fragmented or detached by budding or by the formation of special bodies called sclerotia. A sclerotium is a compact (usually hard) rounded mass of hyphae with, sometimes, a dark outer covering layer but no spore in it. The sizes vary but they develop into a mycelium or fruiting body. Asexual reproduction in fungi involves spore formation. Several types of spores can be formed for instance we have:

- Ciliate spores (zoospores)
- Ordinary spores (gonidia) which are often borne in large numbers in a case called sporangia
- Conidia, formed singly or in groups or chains by specialized hyphae or conidiophores
- Chlamydospores, which are thick, walled resting spores formed singly or in chains by some vegetative hyphae.
- Oidia, which are short segments of vegetative hyphae functioning as spores.

- ❖ Ascospores which are usually eight in number, formed inside one sac called ascus.
- ❖ Basidispores. These are spores usually four in number formed externally by a club-shaped basidium in short slender stalks called sterigmata.

Apart from these, other types of specialized spores also exist.

There are three distinct phases in sexual reproduction of fungi

- ❖ Plasmogamy- this method involves the fusion of two protoplasts without the fusion of nuclear material.
- ❖ Karyogamy. Two nuclei fuse and a zygote nucleus is formed followed by meiosis, which causes the organism to revert to the haploid condition.
- ❖ Development of gametangia and gametes. They may be isogamous, anisogamous or oogamous.

Yeasts and moulds

The terminology "fungi" refers to yeasts and moulds. Yeasts are unicellular fungi. Yeasts are an important group of spoilage organisms but no yeast is an important food pathogen. Some yeasts produce mycelia at varying degrees. Their cell size is larger than that of bacteria. They may be oval, elongated, elliptical or spherical in shape. They may be 5-8m in diameter or even larger. The older a yeast culture gets the smaller the cell size. Most of the yeasts are important in foods and divide by budding or fission. Yeasts can grow over a wide range of pH in the acidic region and tolerate up to 18% ethanol. They grow in 55-60% sucrose. The ascospores and arthrospores of some yeasts are quite heat resistant to high temperatures. The toxicity of moulds is a safety concern in foods. Exposure of several moulds to 300 MPa at 25°C led to the inactivation of vegetative forms within a few minutes but the ascospores required 600 Mpa at 60°C and 60 minutes for elimination, except the ascospores of *Byossochlamys nivea* and *Eupenicillum.* Cells at the exponential growth phase are generally more susceptible to injury and inactivation than cells at the stationary growth phase. Old cultures are more resistant to inactivation than new ones.

Spoilage caused by microorganisms

Most sources of human foods are plants and other animals. Microorganisms are naturally found in these food sources and even non-food sources. In a

bid to sustain their own lives, many of them transform organic matter (such as carbohydrates, proteins and lipids) into energy and inorganic compounds. To carry out many complex chemical reactions essential to their perpetuation, microorganisms obtain nutrients from organic matter. Some of these organic matters constitute our food supply.

Major sources of microorganisms found in foods, soil and water

Many bacteria and fungi found in foods are commonly found in soil and water. Organisms in the soil may enter water through rain, air, contact and the action of wind. Many organisms found in the soil may also be found in water. However, some exceptions exist (e.g. some marine water organisms like *Alteromonas* are not usually found in soils). Examples of microflora that abound in soil and water also include *Pseudomonas* and *Vibrio* (primarily water species).

Plants

Lactic acid bacteria and some yeast can adhere to plant surfaces where they are not easily washed away. Many other microorganisms do not find the plant environment suitable for their- existence. Plants and plant products are important sources of *Pedicoccus, Erwinia,* and *Enterobacter* species as well.

Animal sources

The organisms in animal feed are spread throughout the animal environment. Faecal animal wastes also re-contaminate the animal and its environment when not properly disposed of. Salmonella in poultry and hysteria in dairy products usually originate from animal sources.

Air and dust

Many gram-positive organisms are natural flora of air and dust. Bacillus, Clostridium and Microcosms species are some examples. Generally, the types of organisms in air and dust are those that are constantly found in a particular environment, Mould and Yeasts (particularly their spores) are also associated with air and dust.

Summary of common bacteria found in foods

Acinetobacter: They are widely distributed in soils and water and may be found in many foods such as refrigerated fresh products. Most are gram-