Lesson 1: Factors That Affect Food Safety and Quality

Food safety is closely related to food spoilage, but they are not always the same thing. Food becomes unsafe when pathogens, pesticides, toxins or other potentially harmful chemicals are present. Foods that appear safe may contain toxins (poisonous plants), while other foods may look and smell very bad - yet still be quite edible (Limburger cheese). Food quality is a combination of safety and aesthetic factors.

Food Spoilage

Feeding a growing population is a large task. The effort is compounded due to food spoilage. Even if an adequate food supply is produced, it must be stored and prevented from deteriorating. Several factors cause deterioration: microorganisms in the form of bacteria, yeasts, and molds; activities of natural food enzymes; insects, parasites, and rodents; temperature (both cold and hot); moisture or dryness; air; light; and time. In essence, food undergoes progressive deterioration beginning at harvest. It is critical to know how much time the deterioration process takes.

Contaminants Influence Food Safety and Quality

When microorganisms attack food, they cause many deteriorative effects. They can ferment sugars; hydrolyze starches and fats; digest proteins; and form acids, pigments and discoloration. These can lead to rancid flavors, putrid odors, gas and foam production, and poisonous toxin production.

Enzyme activity is necessary in living plants and animals; however, it continues after harvest or slaughter. Unless these enzymes are inactivated by heat, chemicals, or radiation, they continue to catalyze reactions. Some of these reactions are desirable, like continued ripening of a tomato. Unfortunately, ripening or tenderizing beyond a critical point becomes food deterioration. The weakened tissue is subject to microbial invasion and rotting, development of rancid flavors, or browning and other discoloration.
In addition, insects cause damage, which permits microbial invasion. Parasites, like worms in raw fish and the Trichina worm in uncooked pork, can infect the person who consumes them and cause nerve and muscle damage. (The Trichina worm is no longer a problem in the U.S. pork industry.) Parasites can also cause dysentery. Rodents not only consume large quantities of food, but their excrement and urine can harbor several diseases such as typhus fever, the plague, salmonellosis, and leptospirosis.

Natural dehydrating may cause skin breakage which allows bacterial invasion. Freezing causes cell swelling which causes the cell membrane to rupture.

The remaining factors, temperature, moisture, air, light, and time, can contribute to physical and chemical deterioration. These can also lead to microbial invasion.

Production Practices

If a food product is to be consumed safely, it must be safe when it arrives at the processing plant, at the grocery store, and at the place and time of consumption. Food producers are responsible for growing safe products. Many producers are following Quality Assurance programs to document their practices.

Producers of animals must follow withdrawal guidelines for antibiotics and vaccines, follow recommended injection site procedures so as not to damage muscle tissue; and must sort, load, and transport animals as gently as possible to avoid bruising (bruised tissue deteriorates more quickly). Plant food producers document proper use and timing of pesticides.

Grain grade standards regulate grain quality. Producers use honesty as their policy in grain sales. To place rodent damaged grain on the bottom or treated wheat on the sides of the truck to avoid the grain sampler is dishonest and may be unsafe.

Food Additives

Food additives are one very useful tool to maintain the safety and quality of food during processing, storage, and distribution. A food additive is any substance added intentionally or incidentally to food to improve its appearance, flavor, texture, nutritional value, or storage properties. The Food and Drug Administration (FDA) tests all potential additives over a two-year period on at least two different species of animals. The FDA has compiled a Generally Recognized As Safe (GRAS) list which can be added to or subtracted from as needed. Additives may not be used to deceive the customer or lower the nutritional quality of the food. They cannot be used to conceal spoilage, damage, or low quality. There are over 2,000 additives which perform a variety of functions. The Food Additives Amendment of 1958 provides legal standards for both intentional and incidental additives.

Antioxidants prevent the breakdown of vitamins and lipids in foods exposed to oxygen. Common antioxidants are butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), Vitamin E, ascorbic acid (Vitamin C), and lecithin.

Bleaching and maturing agents change the yellowish color of freshly milled flour to white. Hydrogen peroxide whitens milk for certain cheese manufacturing processes.

Buffers, acids, and alkalies modify the pH.

Flavoring agents include spices, herbs, plant extracts, and artificial flavors.

Food colors are used extensively. Extract of annatto, caramel, carotene, and saffron are used in carbonated beverages, candies, and gelatin. In 1976, FD & C Red No.2 and FD & C Red No.4 were banned. Reliance on natural reds from grapes, beets, and cranberries has subsequently increased.

Nitrates and nitrites contribute to the flavor and pink color in cured pork. They also are antimicrobial agents.

Non-nutritive and special dietary sweeteners are used in low-calorie soft drinks, in dietetic foods, and by diabetics.

Nutrient supplements such as Vitamin D in milk, iodine in salt, and iron in cereal products are useful supplements to diets that may otherwise be deficient in those nutrients.
Preservatives extend shelf life and prevent deterioration. Common preservatives include sodium nitrite in processed meats, sodium benzoate in soft drinks, sodium and calcium propionates in breads and cakes, sorbic acid in cheese, and chlorine as a germicidal wash on fruits and vegetables. Sulfur dioxide is used to control browning of fruits and ethylene oxide is used to fumigate spices.

Sequestrants chelate or sequester trace metals and prevent them from causing oxidation or off-coloring. Citric acid and ethylenediamine tetra acetic acid (EDTA) are examples.

Stabilizers prevent food products from changing chemically. They are also called thickeners. Pectin, casein, gelatin, carrageenan, and gum arabic are common stabilizers use to thicken gravies, pie fillings, chocolate milk drinks, jellies, puddings, and salad dressings.

Surface active ingredients include emulsifiers to stabilize oil-in-water, water-in-oil, gas-in-liquid and gas-in-solid mixtures. Lecithin, monoclycerides and diclycerides are commonly used.

Miscellaneous additives include yeast in breads, calcium chloride used to firm fruits and vegetables, anticaking agents in salt, and gibberellic acid to stimulate growth in barley for malting.

Monitoring Food Safety

The USDA's Food Safety and Inspection Service is responsible for inspecting and checking the quality of food products as they enter and leave processing plants. The FDA must approve processing plants and processing procedures. These include the use

of additives. Food products must be correctly labelled to show their ingredients and nutritional information.

The state, county, or local health departments have jurisdiction over food establishments and regularly inspect them for cleanliness and approved practices.

All meat must pass state or federal inspection for wholesomeness to guarantee the consumer that meat being purchased is from healthy animals, which were slaughtered and processed under sanitary conditions.
Federal inspection of meats and poultry is supervised by the USDA. Meat that passes federal inspection is stamped with a round, purple mark. State-inspected meat will have a different shaped inspection mark depending on the state. The inspection mark is placed only once on the wholesale cut, so it will not appear on every cut that is purchased.

Risk Assessment

Life is a risk. Eating is a risk. There is some level of risk associated with everything we do. You personally must assess the risk of whatever activity you wish to do, and then make a decision on whether to do the activity. Food safety is very important and is also a very popular topic. If you want to survive, you must eat. You must be rational in assessing the risk versus the cost.

Undesirable residues in the food supply is an area of popular concern. Residues may be heavy metals, pesticides, aflotoxins, hormones, etc. The food supply is randomly sampled and tested to meet safety standards. Today's testing equipment can measure in parts per trillion and beyond. In 1958, when the Delaney Clause was adopted, measurement was done in parts per million. What was once considered safe, may very well be removed from the market today. The Delaney Clause prohibited known carcinogens from being added to the food supply.

Consumers assess risk in a variety of ways. First, they use rational thinking and common sense. They consume food that has not expired; looks, smells, and tastes wholesome; is produced, processed, and retailed by reputable businesses; and meets U.S. safety standards. However, consumers are not always rational when assessing risk. Sometimes fear of a product may be more important than any assurances of safety the processor can provide. On the other hand, some people choose to ignore the risk because of the pleasure associated with the product (Consider cigarettes and raw oysters). Consumers are the final 'line of defense' in keeping foods safe for consumption. Some consumers have allowed the media to be very influential in their decision making.

Summary

Food spoilage may be caused by a wide variety of factors including microorganisms, natural enzymes, insects, parasites, rodents, temperature, air, moisture, light and time. In reality, progressive deterioration in food occurs. The critical question is how slow or fast is the process. Microbial contamination causes sugar fermentation, hydrolyzation of fats and starches, and many other negative effects. Enzymatic activity is a natural metabolic process and can be a positive or negative agent in food preservation. Insects cause spoilage which permits microbial invasion. Several other factors can influence food spoilage. One of them includes production practices used.

Our food safety is monitored by the USDA, the FDA, and health departments. Food additives are substances added intentionally or incidentally to foods to improve appearance, flavor, texture, nutritional value, or storage properties. All consumers must assess the risk associated with eating food and rely on common sense to determine their decisions.

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Lesson 2: Problems with Food Deterioration

Food is subject to physical, chemical, and biological deterioration. The most obvious to the human eye, physical deterioration, will be discussed first.

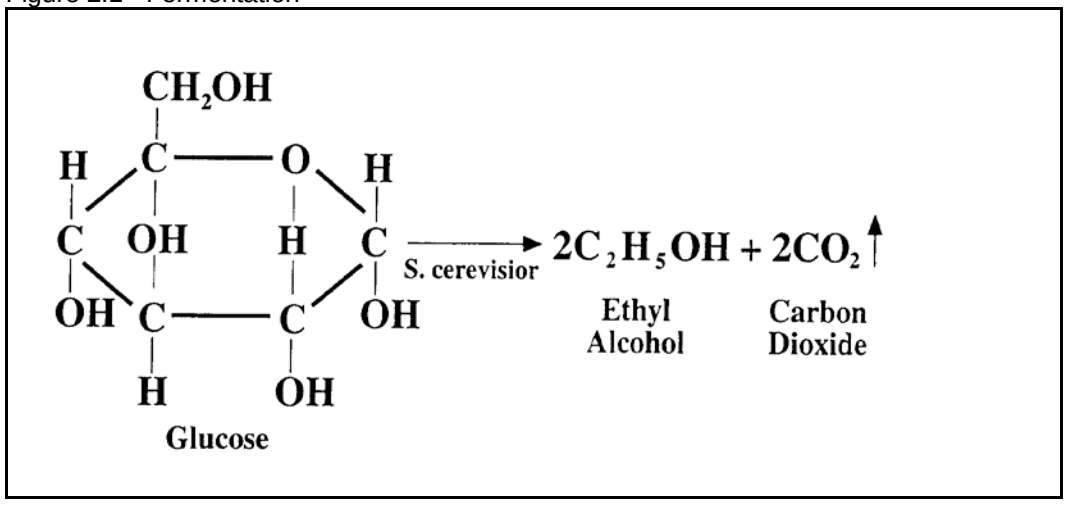
Physical Changes from Food Deterioration

When food is exposed to excessive amounts of heat, cold, or circulating air, it may become dehydrated. Cracked skin found on fruits that have been frozen and thawed is another type of physical change. A broken or separated emulsion (example, salad dressing) in liquid foods that have been frozen and allowed to thaw is a third type of physical change. A fourth is texture degradation. This can be found in fluid milk that has been frozen, which causes curdles to develop.

Lumping, caking, or crystallization may result from an excess of moisture. Surface pitting on fruit is the result of storage temperatures that were too cold.

External off-color development may be the most obvious physical change caused by food deterioration. Meat exposed to fluorescent or incandescent light too long develops a brownish-red color. Meat color is determined by its predominant pigment, myoglobin. Myoglobin is a purple red pigment due to its iron constituents. When exposed to air, myoglobin adds two oxygen atoms and becomes oxymyoglobin. Oxymyoglobin is responsible for an intense red color. Oxygen permeable wrapping is preferred on meat cuts to promote this appealing color. If insufficient amounts of oxygen are available, however, oxymyoglobin oxidizes to metmyoglobin, a brownish-red pigment. Mold growth on the surface comes in a rainbow of colors. Some fruits, when stored at low temperatures may develop internal browning.

Figure 2.1 - Fermentation



Chemical Changes

Chemical deterioration is due to a change in the chemical, or molecular structure, of food. Fermentation of sugars is a chemical change that, under controlled conditions, is a beneficial process in the production of bread, buttermilk, and yogurt. Fermentation can cause deterioration in uncontrolled environments. Fermentation splits a glucose molecule into two ethyl alcohol and two carbon dioxide atoms. (Figure 2.1)

Carbohydrates (starches) and proteins may undergo hydrolysis. Hydrolysis is defined as the splitting of a molecule by the uptake of a molecule of water. Corn syrup is produced by the hydrolysis of cornstarch with hydrochloric acid. The end product is called corn sugar. Hydrolysis of proteins is usually undesirable in foods.

A third type of chemical reaction that can cause deterioration is called lipolysis, or the reaction of a water and fat molecule that releases a fatty acid in the presence of heat or the lipase enzyme. This process alters the flavor and aroma of fats or oils and creates a rancid odor.
Proteins also can denature, losing their unique structure. If the protein is an enzyme, it loses its ability to be a catalyst. Often a denatured protein is less soluble. Denatured proteins often coagulate. Think about what happens when you fry an egg. The proteins in the egg white denature when heating. The once clear liquid becomes an opaque rubber solid. Denatured proteins may be more easily digested by microorganisms resulting in development of undesirable flavors, odors, or textures.

Toxin production is the sixth chemical change resulting from food deterioration. A food intoxication results from a toxic substance being produced in a food item before consumption. Certain molds can produce mycotoxins, which are poisonous. One well known mycotoxin is aflatoxin. Aflatoxins may be found on moldy grains and peanuts. Ergot is a mold toxin that can cause hallucinations. It may have been responsible for the Salem witch trials.

Enzymatic reactions are the advanced stage of normal enzymatic reactions. While the plant or animal is alive, enzymes are busy catalyzing chemical reactions. These reactions are kept in control by the living system. However, when the tissue is dead, these enzymes continue to work and ultimately cause degradation. These chemical changes may be inactivated by heat, chemicals, and/or radiation.

Pigment conversion is an eighth example of deteriorative chemical changes. For example, as the green pigmented chlorophyll molecule in plants is transformed into the pheophytin molecule, the bright green is converted to greenish-gray and olive green. A magnesium ion is replaced by hydrogen. Similarly, the oxymyoglobin molecule in red meat is chemically changed to metmyoglobin.

Environmental Conditions for Bacterial Growth

Bacteria, along with yeasts and molds, prefer warm, moist growing conditions. Most bacteria are mesophilic. Mesophilic bacteria survive in temperatures ranging from 60°-100°F. There are also cold-loving (psychrophilic) bacteria, which survive at temperatures down to 32°F. Conversely, thermophilic bacteria can grow in temperatures up to 180°F. Because moisture is required for bacterial growth, a zero or very low water activity level is the reason why salted and/or dehydrated foods are not overcome by bacteria. Because there are aerobic and anaerobic bacteria, the need for oxygen depends on the type of bacteria.

Microorganisms that Contribute to Food Deterioration

An important point to remember is that microorganisms are generally not found within the living tissue of a healthy plant or animal. Milk, for instance, is sterile when secreted. Fruits, vegetables, grains, and nuts become contaminated when their protective skin or shell is broken or weakened.

Bacteria - Not all bacteria cause food spoilage. Many types of bacteria are used to preserve food, like the lactic-acid producing organisms of cheese, sauerkraut, and certain types of sausage. Others are used for flavor production.

Bacteria are found everywhere from the hides and feathers of animals, to shells of nuts, in the soil, water, and air, and on processing equipment that has not been sanitized.

Bacteria are unicellular organisms; they are cells without a nucleus, known as procaryotes. They are classified based on their shape: spherical shapes are cocci; rod shapes are bacilli; and spiral forms are spirilla and vibrios. Many bacteria move by means of a flagella, a whip-like tail. Others produce spores, which are seedlike and incredibly resistant to heat, chemicals, and other adverse conditions. Bacterial spores are more resistant than yeast or mold spores. They resist most processing conditions to a greater extent than natural food enzymes. Needless to say, sterilization processes are aimed at these bacterial spores.

Bacteria are small, one to a few micrometers (um) in length, and can penetrate the smallest openings. Most bacteria multiply at 60°-100° F, the temperature range of mesophilic bacteria. Recall, however, that psychrophilic bacteria multiply at very low temperatures while thermophilic bacteria can withstand very high temperatures. Some bacteria are aerobic, while others are anaerobic.

Bacteria multiply in an exponential fashion. Under favorable conditions, their numbers can double every 30 minutes.

Bacteria are also classified based on their staining characteristics. Gram-positive bacteria retain a dark violet or purple color after a purple dye/iodine mixture is applied followed by an alcohol treatment in an attempt to decolorize. Gram-negative bacteria lose the dark violet color after the alcohol is applied. The Gram method of bacterial identification is one of the most important methods used. While this method is not absolute, it does provide valuable information in determining which bacteria are present. Thus, a corresponding method of treatment or sanitation can be established.

Fungi - Fungi, or yeasts and molds, are also helpful/harmful agents in food science, depending on which specific ones are present. Yeasts are necessary in making bread, wine, and beer because of their fermentation qualities. Molds are used to ripen Danish blue, Roquefort, and Camembert cheeses. They are also used to manufacture soy sauce and citric acid. The mold penicillium produces the antibiotic penicillin.

Yeasts and molds are found everywhere and can cause food spoilage. Yeasts and molds like warm, moist growing conditions. Yeasts are larger than bacteria, around 20 micrometers in length. Most yeasts are spherical or ellipsoidal in shape. Yeasts reproduce asexually in the form of spores. Most yeast colonies are creamy white in color and slimy in appearance.

Molds are larger than yeasts and grow by hairlike fibers call mycelia. Mold spores create the blackness of bread mold and the blue-colored veins in blue cheese. All molds are aerobic.

Organisms That Can Cause Diseases

Camphylobacter - The camphylobacter bacteria are responsible for causing camphylobacteriosis, which is the leading cause of acute gastroenteritis (inflammation of the stomach and intestines) in humans. Only a few bacteria are required to cause illness. This bacterium has been found primarily in raw milk and poultry, but it has also been found in cake icing, eggs, beef, and contaminated drinking water.

Clostridium botulinum - Botulism is caused by these bacteria, which are present throughout the environment. The bacteria can be found in damaged canned foods and home-processed foods that were not properly processed. Also, other foods such as potato salad, sauteed onions, chopped garlic, raw cabbage, and hazelnut yogurt have been found to contain the botulism bacteria. Infant botulism can be caused by honey, which often contains botulinum bacteria. That is why it is recommended that infants not be given honey. The most common symptoms of botulism are fatigue and blurred vision. Few people have the usual gastrointestinal symptoms of food poisoning. Death is common for people getting botulism.

Escherichia coli - These bacteria, commonly called E. coli, live naturally in the human intestinal tract. They are responsible for causing diarrhea in infants and travelers. One uncommon strain causes two life-threatening conditions: hemorrhagic colitis and hemolytic uremic syndrome. Bacteria found in raw and undercooked ground beef and raw milk have been linked to these illnesses. The bacteria can be controlled by cooking meat thoroughly and keeping cooked meat away from uncooked meat.

Hepatitis A virus - The hepatitis A virus can be contracted from food not properly prepared by a person infected with hepatitis or from eating contaminated raw shellfish or contaminated mollusks. Cooking does not always kill the virus. Hepatitis symptoms at onset of illness include: malaise, appetite loss, nausea, vomiting, and fever. As the illness progresses, the patient develops jaundice with darkened urine, and may have liver damage.

Listeria - Listeriosis disease is caused by the listeria bacteria. While the bacteria infect shellfish, birds, spiders, and mammals all over the world, it is uncommon in humans. Although there are not nearly as many cases of listeriosis as there are salmonellosis, it is a very deadly disease especially for fetuses, newborns, and people with weakened immune systems. People can get listeriosis by eating foods contaminated with the bacteria such as soft cheese, unpasteurized milk, seafood products, cooked shrimp, and cooked surimi (fish, sausage, artificial crab). The disease is also transmitted by direct contact with mud, sewage, or soils contaminated with the organism and by inhalation of contaminated dust particles. This tough bacteria can grow at refrigeration temperatures and can survive mild heat.

Salmonella - This bacteria causes salmonellosis. Very low levels of bacteria can cause this disease. More than 40,000 illnesses are reported each year, but experts believe there are many more cases that are not reported. Nearly half the reported cases of salmonellosis require hospitalization, and one to two percent result in death. The salmonella bacteria have been found on many foods, particularly on raw meats, poultry, dairy products, pasta, and chocolate. Symptoms range from none to very severe but most often include nausea and diarrhea.

Staphylococcus - Staphylococcal infections are caused by the staphylococcal bacteria. Staphylococcal bacteria are found in the nose and mouth and on the skin of healthy people. The bacteria multiply at warm temperature, which produces the toxin that causes illness. Infected people who prepare or handle food can spread the illness to others if proper hand washing and utensil cleaning are not followed. Also, the bacteria can multiply quickly if leftover food is not promptly refrigerated.

Toxoplasma - Cats frequently are infected with this parasite, which can be transferred to humans by contacting contaminated cat feces or by eating improperly cooked meat or poultry. The animals received the infection from infected cats. Infants can acquire the

parasite from their mothers before birth. Severe mental retardation may result. Meat, particularly lamb and pork, should be cooked thoroughly to kill the parasite. Individuals with a weak immune system are particularly susceptible to toxoplasmosis.

Trichinella - This parasite causes trichinosis. It is commonly found in animals that eat human garbage. It is mostly transmitted to humans by eating undercooked pork or bear. Symptoms include abdominal pain, nausea, fever, diarrhea, muscle pain, and fatigue. There are few cases of trichinosis in the United States.

Vibrio parahaemolyticus - Vibrio parahaemolyticus bacteria cause vibrio gastroenteritis, which can cause water diarrhea, abdominal cramps, vomiting, headache, chills, and fever. This organism can be ingested in contaminated uncooked or undercooked shellfish. The bacteria can also enter the human body when an individual with open wounds comes in contact with infected coastal waters. A very closely related microorganism, vibro cholera also can be transmitted by seafood, salt water, but it is most commonly found in areas with poor water treatment facilities.

Yersinia - Yersinia bacteria cause the plague. The rat is the primary carrier. If an infected rat leaves droppings in grain, for example, those contaminated droppings could get into the food supply for humans, thus spreading the disease. Unproperly cooked pork or raw milk may have the Yersinia bacteria present. Yersinia can grow at refrigeration temperature, but heating kills the bacteria.

Using a thermometer when cooking meat can reduce the incidences of these food-borne diseases.

Summary

Foods are a perishable commodity. Foods are subject to both physical and chemical deterioration. Dehydration, a cracked skin, a broken emulsion, off-colors, and a change in the texture are all physical deterioration examples. Chemical reactions that lead to deterioration include fermentation hydrolysis, toxin production, enzymatic reactions, and pigment conversions. Moisture and warm temperatures are necessary for growth of bacteria, yeasts, and mold. Bacteria, yeasts, and molds are the organisms responsible for the majority of food deterioration. A variety of human diseases result from microbial invasion. Examples include botulism, salmonella, trichinosis, campylobacteriosis, etc.

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Lesson 3: Nutritional Properties of Foods

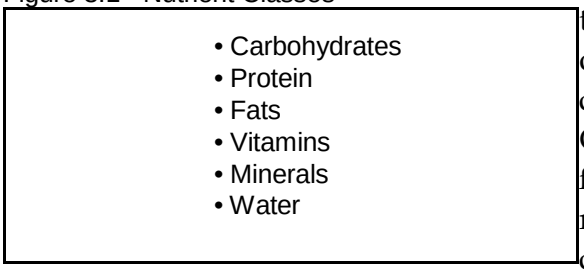
Major Food Groups

A complete meal has five parts. Meats, breads and cereals (also called grains), fruits, vegetables, and dairy products are the five major food groups. Fats, oils, and sweets should be used sparingly.

Six Classes of Nutrients

The five food groups can be divided into six classes of nutrients. These essential nutrients consist of: carbohydrates, proteins, fats, vitamins, minerals, and water.

Figure 3.1 - Nutrient Classes



Carbohydrates are energy-rich compounds that supply the majority of the body's energy, or caloric needs. Carbohydrates consist of carbon, hydrogen, and oxygen atoms in a $C_1H_2O_1$ ratio. Sugars, starches, and plant fibers provide carbohydrates with glucose, a monosaccharide, being the simplest form of carbohydrate.

Protein supplies the body with molecules that contain nitrogen. Eight essential amino acids are the building blocks of protein and consist of: leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine, along with histidine for childhood growth.

Fats (also called lipids), are the most energy-rich compounds. They provide necessary fatty acids for normal metabolism. They are also needed for transporting fat-soluble vitamins.

Vitamins are organic molecules that are needed in small amounts but can make big differences in one's health. Vitamin D can be synthesized by a healthy body, while the remaining vitamins must be supplied in the diet. At times, Vitamin D may also need to be a part of the diet to meet necessary levels. Vitamins are broken into two groups: fat-soluble and water-soluble. Vitamins A, D, E, and K are fat-soluble, while vitamins C and B complex are water-soluble.

Minerals are inorganic molecules needed in small amounts. The major minerals include Calcium (Ca), Phosphorus (P), Magnesium (Mg), Cobalt (Co), Sodium (Na), Chloride (Cl), Potassium (K), and Sulfur (S). The trace minerals consist of Selenium (Se), Fluorine (F), Iodine (I), Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Chromium (Cr), and Molybdenum (Mo).

Water is also a necessary nutrient. A person may survive several days, possibly weeks without food. However, without water, you can live only a few days.

Nutritional Characteristics

Meats are a primary source of protein. They also contribute carbohydrates, fats, vitamins, and minerals.

Breads and cereals are a primary source of carbohydrates. They also contribute protein, fat, vitamins, and minerals.

Fruits are a primary source of vitamins and minerals.

Vegetables are a good source of minerals and vitamins. Carbohydrates and protein are also supplied by fruits and vegetables.

Dairy products are excellent sources for all nutrient categories.

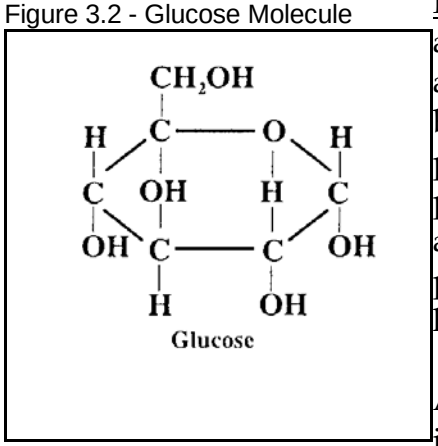
Fats and Sweets - Foods containing high amounts of fats and sweets tend to have very limited amounts of essential nutrients (vitamins, minerals, and protein). They are sometimes called empty calories.

Functions of Each Nutrient Class

Scientists use the terms "Kilo-calories" and "calories" in their discussions about nutrition. A Kilo-calorie (Kcal) is 1000 calories. One calorie (with the lowercase "c") is the amount of heat (i.e., energy) needed to raise the temperature of one gram of water one degree Celsius. Frequently, "Calories" with an uppercase "C" is used to indicate the number Kilo-calories in foods. Technically, these Calories are actually Kilo-calories. Throughout the discussion of nutrition in this manual, the number of Kilo-calories in a food will be identified as Calories.

Carbohydrates supply 4 Calories per gram of energy. Ninety-eight percent of sugars and starches are digested and fully oxidized into cellular energy. Carbohydrates are needed for body heat, tissue synthesis, and energy for work and play. Carbohydrates also supply carbon, which helps the body use fat efficiently, spare proteins from being converted to a major energy source, provide fiber, and promote vitamin B synthesis. Complex carbohydrates are long-chain molecules of glucose.

Figure 3.2 - Glucose Molecule



Proteins provide 4 Calories per gram of energy, but are only 70 percent digested and oxidized, on the average. Their primary roles are to supply nitrogen-based molecules necessary for tissue synthesis and to provide the essential amino acids needed for enzyme production. A complete protein contains all eight amino acids: leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, plus histidine for childhood growth.

Animal proteins are complete. Plant proteins are incomplete, meaning they are missing at least one of the essential amino acids. Most wheat, rice, and corn grains lack lysine. Legumes lack methionine. A lack of protein in early childhood can lead to retardation. A critical point is not how much protein is consumed, but rather a combination of the amount and the quality. Not all protein is digestible or palatable. A raw soybean is not digestible, but a processed soybean is digestible.

Fats provide 9 Calories per gram of energy. Approximately 95 percent of this is digested and oxidized. Fats provide essential fatty acids to the human diet. Linoleic acid is one essential fatty acid that promotes normal growth and prevents skin disorders. Research also suggests that linoleic acid, when present in high proportions compared to other dietary fats, may lower blood cholesterol. Dietary fat allows vitamins A, D, E, and K to be transported and absorbed. Fats contribute to phospholipid production and function. They help insulate and protect the body and store excess energy.

Vitamins serve a required function in enzyme systems which metabolize proteins, carbohydrates, and fats.

Vitamin A, or retinol, occurs only in foods from animal sources. Plants do contain beta-carotene, which is a precursor to vitamin A. Beta-carotene can be converted to vitamin A and is found in orange, yellow, and green leafy vegetables. A deficiency in vitamin A can lead to night blindness, abnormal bone and tooth development, or diseases of the epithelial cells.

Vitamin D can be formed in an animal's skin by ultraviolet sunlight activating cholesterol or ergosterol. Eggs, dairy products, liver, and fish oils are good food sources of vitamin D. This vitamin increases the absorption of calcium and phosphorus from the intestinal tract. A lack of vitamin D can lead to a bone defect condition.

Vitamin E favors iron absorption and serves as an antioxidant, which spares vitamin A and carotene from oxidation. Vegetable oils are good sources.

Vitamin K is essential for normal blood clotting and is prevalent in cabbage and spinach.

Vitamin C, or ascorbic acid, prevents scurvy, bone joint diseases, teeth loosening, and fragile capillary walls. It is needed for normal protein collagen formation. It favors iron absorption. Good sources are citrus fruits, tomatoes, cabbage, and green peppers.

Nine specific B vitamins make up the B complex group. All are abundant in liver, yeast, and cereal grain bran. Thiamine, or B_1, is needed to oxidize glucose. Riboflavin, or B_2, is needed for cellular growth and tissue maintenance. Niacin is used for tissue respiration and oxidation of glucose. B_6 is needed for enzyme systems. Pantothenic acid is needed for mental health. B_{12} helps prevent anemia and is required for nucleic acid formation. Folacin also helps prevent anemia and is required for nucleic acid formation. Biotin helps metabolize fatty acids and amino acids.

Several minerals are necessary for growth and metabolism. Calcium (Ca) is needed for blood clotting, bone and tooth development, enzyme function, and to control fluid movement through membranes. Phosphorus (P) is required for normal metabolism, acid alkaline blood reactions, and phospholipid production. Milk and dairy products are excellent Ca and P sources. Magnesium (Mg) is required to help metabolize Ca and P for muscle contractions, electrical potential in nerves, and enzyme systems.

Iron (Fe) is needed for blood hemoglobin, the O_2 carrier, and muscle myoglobin, the O_2 storehouse. Iron is abundant and readily available in red meat. Copper (Cu) helps manufacture hemoglobin and aids in iron utilization.

Cobalt (Co) is a part of vitamin B_{12}. Zinc (Zn) is needed for enzyme production. Sodium (Na) is needed for osmotic equilibrium and body fluid volume regulation. Chlorine (Cl) exists as the chloride ion and is used to produce hydrochloric acid.

Potassium (K) is used to regulate osmotic pressure, equilibrium, and pH. Cellular enzymes need potassium.

Iodine (I) is needed for thyroid hormone production. Fluorine (F) prevents tooth decay. Manganese (Mn) is needed for bone structure, central nervous system function, and reproduction. Chromium (Cr) is used for glucose metabolism. Molybdenum (Mo) is required for protein metabolism.

Water is a vital nutrient although its functions are often overlooked. Besides comprising about 60 percent of a human's body weight, it serves as a chemical solvent for reactions in the body, it transports media to cells, removes body waste, regulates body temperature, and is essential for a controlled metabolic rate.

Nutrient Sources

To list every source of the six nutrients would require a listing of every food source known to man. Rather, an abbreviated list of foods that are particularly rich in a specific nutrient follows.
Carbohydrates come from potatoes, rice, flour, and dairy products.

Protein is found in meat, poultry, fish, eggs, legumes, and dairy products.

Fats are found in meat, poultry, grain oils, nuts, and dairy foods.

Vitamins come in fruits, vegetables, and dairy products.

Minerals are obtained from meat, fruits, vegetables, and dairy foods.

Water comes in beverages and high water-content foods.

Summary

Meats, breads and cereals, fruits, vegetables, and dairy products are the five main food groups. The body digests these foods into six major nutrient categories: carbohydrates, proteins, fats, vitamins, minerals, and water. Each nutrient serves an essential role in the body's health. These nutrients are found in a variety of food sources and are essential for a healthy diet.

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Lesson 4: Processing Influences Nutritional Value

This lesson will examine four variables that can cause food to lose part of its nutrients during processing. The enhancement of food nutrients will likewise be examined.

Temperature Affects Nutrient Availability

Consumers who are nutrition conscious realize that purchasing nutritious food is only the first step in a healthy diet. The manner in which this food is stored and prepared determines the nutrients that will be available when the food is eaten. Temperature is one such variable. The organic nutrients: carbohydrates, fats, proteins, and vitamins, contain enzymes that are constantly being produced and then degraded. When, for example, a peach is harvested its natural enzymatic activity begins to degrade tissue. At room temperature, a significant vitamin loss could occur. Therefore, chilling is necessary to slow the enzymatic processes. Another control for fruit and vegetable enzyme activity is blanching. Blanching or boiling briefly stops enzymatic activity.

High temperatures can likewise be detrimental to proteins. Proteins tend to toughen when exposed to high temperatures. But they are usually more easily digested after heating. High temperatures and long cooking times tend to destroy vitamins.

Light Affects Nutrient Availability

Fluorescent light and the ultraviolet rays of the sun can destroy riboflavin in foods. It is for this reason that milk is no longer retailed in transparent glass containers, but rather it is sold in opaque plastic or cardboard. Vitamins, in general, are susceptible to light breakdown.

Water Content Affects Nutrient Availability

Foods that have a high water content need to be prepared in a different manner in order to preserve their nutrients. Vegetables that are cooked in water can lose nearly one-half of their water-soluble vitamins to the water. It is for this reason that steaming vegetables is often suggested. If food is to be prepared in water, think of ways to use the "pot juice," like in soup or to cook rice.

Oxidation Affects Nutrient Availability

Oxidation is the chemical reaction that takes place in the presence of oxygen. When it is controlled in the body cells, oxidation results in the breakdown of nutrients and the release of energy. However, when foods are overcooked, burned, or charred, nutrients are oxidized to carbon and oxygen gas and are not available for digestion. Protein molecules release nitrogen as N_2 or Nitrous oxide. Similarly, fruits that have been exposed to air and are dried out have lost some of their nutrients. For example, vitamin

C is lost from oranges. Transition BHA and BHT are commercial antioxidants. Vitamins C and E are natural antioxidants.

Table 4.1 - Nutrients in 2 oz Serving of Dry Spaghetti Pasta - % Daily Values*

Type of Spaghetti Pasta	Iron	Calcium	Thiamin	Riboflavin	Niacin	Vitamin B	Folacin	Fiber	Fat
Whole Wheat	10%	2%	20%	6%	15%	6%	8%	25%	1%
Enriched	15%	2%	40%	15%	25%	4%	2%	10%	1%
Unenriched	4%	2%	4%	2%	6%	4%	2%	6%	1%

*Based on 1994 USDA Percent Daily Values

Processes Used to Enhance Nutritional Value

The twentieth century has seen a nutritional revolution. Modern processes were invented to convert wheat into white bread rather than the standard whole wheat bread. This process, and similar ones, produce foods that are more pleasing to the taste buds; however, some nutrients may be reduced or even eliminated. The Enrichment Act of 1942 standardized the return of necessary nutrients to commercial flour. Enriched bread was supplemented with iron, niacin, thiamin, and riboflavin. Scores of food products today are enriched. Table 4.1 compares whole wheat spaghetti pasta, spaghetti pasta-enriched, and spaghetti pasta-unenriched.

Another means of nutrition enhancement is called fortification. This is very similar to enriched foods except that fortified foods have added nutrients that may or may not have originally been there. Examples of fortified foods include milk fortified with vitamins A & D, salt with iodine, and soft drinks with added vitamin C or calcium.

Nutritional supplements are slightly different from fortified foods. Supplements contain nutrients, usually vitamins and minerals, in amounts greater than 50 percent of the RDA. The most common form of supplements are vitamin pills, but many sport drinks are now on the market that could be considered to be supplements.

Sometimes foods have been fortified or supplemented with vitamins and minerals because the addition of these vitamins and minerals may be needed to help the body utilize vitamins and minerals naturally occurring in the foods. For example, vitamin D increases the absorption rate of calcium and phosphorous.

Many processing techniques are useful in maintaining nutrients. These range from quick cooling fresh fruits and vegetables to proper cooking temperatures and cooking length. Some types of produce are waxed or packaged to prevent dehydration.

Summary

Temperature is an important environmental variable that determines the nutrient availability of food. Organic molecules break down faster at high temperatures than at low temperatures. Fluorescent lights and ultraviolet rays break down riboflavin. High water content foods are likely to loose many of their nutrients when boiled or cooked in a liquid. Oxidation decreases levels of many vitamins. Careful control of storage and processing conditions is necessary to assure the maximum nutritional value of food products.

Enrichment and fortification may be used to enhance the nutritional status of food. Occasionally foods are formulated to contain relatively high levels of individual nutrients. These foods are called supplements.

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Lesson 5: Biotechnology in the Food Industry

In the food industry, biotechnology has likely made an impact on food you have consumed. This lesson will define biotechnology, examine its effect on food production, discuss examples of bioengineered foods, and look at biotechnology's future.

What is Biotechnology?

Biotechnology can be defined in many ways. The use of microorganisms, animal cells, plant cells, or components of cells such as enzymes to produce products or carry out processes for human benefit is the detailed definition. A more concise way of defining biotechnology may be the use of living organisms or their enzymes to make commercial products.

Biotechnology's Effects on Food Production

People using principles of biotechnology have made dramatic impacts on global food production. A greater variety of foods is the first result. A tangelo is a bioengineered hybrid between tangerine and grapefruit trees. Potatoes prefer cool climates, but may soon be produced in hot, humid climates. Soybeans are one of the brightest stars of current food biotechnology research.

A second result of biotechnology's effect on food production is the increased shelf life/safety of food. Food preservatives and fermentation are some of the areas in which food scientists have applied biotechnology toward food safety and shelf life enhancement. This area holds great promise in reducing the need for synthetic pesticides and food additives.

Another area of biotechnological advances has been harvested to benefit greater efficiency in food production. Crop production benefits from biotechnology produced fertilizers, pesticides, genetic-engineering, and hydroponics. Animal agriculture benefits from new vaccines, nutritional advances, embryo transplant programs, feed additives, and growth hormone research.

Bioengineered Foods

One only has to browse through a grocery store to find hundreds of food products that are a result, to some degree, of bioengineering. Enzymes, low-calorie foods, waste management, biological monitoring, casings, and insulin will be evaluated in this section.

Rennet and lactase are enzymes used in the dairy fermentation industry. Naturally, the enzyme rennet is used to coagulate casein during cheese-making, and is consumed in each batch. Bioengineered, immobilized rennet improves its stability and allows easy separation from the cheese, thus it can be recycled and reused. Lactase cleaves lactose to glucose and galactose. It too can be immobilized and recycled.

Low-calorie foods may contain non-nutritive sweeteners like aspartame, thaumatin, or monellin. These compounds are taste active proteins. The genes that code for these compounds may be isolated and transferred to non-harmful bacteria. Since bacteria reproduce so quickly, bacteria with these sweetener genes can be added to food products in a fermentation process and transfer the taste. Low-calorie foods are also one of the goals of soybean and rapeseed research. By reducing the oil content of the seed, more protein would be produced per seed. Genetic engineering may soon produce extra-lean pork and beef carcasses, resulting in red meat that fits better into a healthy diet.

In waste management, the waste from food processing, particularly the whey from cheese making, can be consumed by a bioengineered yeast. This particular yeast produces a grape aroma and could be used as a flavor component in the wine and food industries.

Biological monitoring is another prospect for bioengineered foods. DNA fragments from disease-causing microbes can be coded, isolated, and hybridized to detect the presence of the same microbe in food.

Bioengineering is responsible for manufactured casings used as a substitute for natural casings. Cellulose casings are produced from cotton lint and paper pulp. Collagen casings are made from the inedible portions of the beef carcass.

Businesses Involved in Biotechnology Research

Anyone who has been involved in selective breeding programs has been involved in biotechnology. However, the new technologies that allow scientists to work at the cellular or chromosomal level require expensive equipment. Major advances in biotechnology have been the result of the cooperative efforts of many business enterprises.

The United States Department of Agriculture (USDA), universities, food processing companies, commodity organizations, the National Live Stock and Meat Board, and other food related companies are active in biotech research.

Future Influence

The Green Revolution, which is the widespread adoption of high-yielding grain varieties along with an expanded use of fertilizers and irrigation, started in the late 1960's. Will the Green Revolution continue? As long as there are hungry people to feed, science and agriculture will continue to strive to feed them. The need for better weed control, less insect damage, enhanced nutritional quality and safety, greater disease resistance, and improved genetics will fuel the machine to continue the biotechnology revolution. Look for a longer shelf life, new vaccines, less dependence on petroleum-based oil, further advances with soybean- and corn-based products, a greater dependence on biological control of insects, and new resistant varieties of fruits and vegetables. Herbicide-resistant corn, greater reliance on hydroponics, possibly grasses that fix their own nitrogen, soy-based coatings to keep food from dehydrating or oxidizing, and natural antifreeze sprays to prevent citrus trees from freezing are just a few samples of what the future may hold. Herbicide-Resistant Corn is a genetically engineered corn variety that is tolerant to previously lethal herbicides.

Factors Influencing New Developments

To name every factor that may influence new developments in food biotechnology would be similar to forecasting next year's weather. Some factors are known while several remain unknown.

Generally, the greatest need receives the most attention and effort. "Where there is a will, there is a way" is the old saying. If there is semi-drought growing conditions in the Midwest for five consecutive years, drought-resistant crops will be developed and planted. If a new strain of grasshopper invades the South, a new insecticide will likely be developed.

Finances always play a role. Research takes money, whether it is federal, state, or private funds. The need for talented, committed, educated researchers will need to be met. Biotechnology takes some specific facilities and equipment. The weather will play a part in research of plants, insects, animals, etc. Time is also a factor. New releases must be thoroughly tested before release. The Food and Drug Administration and Environmental Protection Agency require extensive testing.

Summary

The biotechnology revolution will continue to make major impacts on human lives. The use of microorganisms, animal cells, plant cells, or components of cells such as enzymes to produce products or carry out processes for human benefit will increase in the future. Whether it is protein derivatives; resistant varieties, or low-calorie foods, biotechnology will continue to impact a growing population.

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