Describe the different ways that food spoils.

Light

Almost all foods are exposed to light from natural and/or artificial sources during processing, packaging, storage, shipping, and marketing. The exposure of foods to light can result in its deterioration (also known as photodegradation). Photodegradation usually occurs in specific food constituents, such as pigments, fats, proteins, and vitamins, resulting in discoloration, off-flavors, and vitamin loss.

Light is a form of radiant energy that is usually described as wavelength. The light we see (visible light) is only a very small part of the vast spectrum of electromagnetic energy. This spectrum includes: gamma rays, X-rays, ultraviolet rays, visible light, infrared rays, and radio waves. Most problems caused by light are in the visible and ultraviolet ranges.

In the past, most light-induced changes in food were caused by sunlight. The development of incandescent lights added only a few problems because these lamps emit low amounts of ultraviolet light. Innovations in marketing have led to the merchandising of foods in transparent and translucent packaging under high intensity fluorescent lights. This situation can result in the photodegradation of food constituents.

Sources of Light. Foods are exposed to several sources of light in their production and display. Some common light sources and their locations are:

- Sunlight Outdoors -- Store Fronts, Windows, and Skylights
- Incandescent Lamps -- Coolers, Storage Facilities
- Fluorescent Lamps -- Food Processing Areas, Display Cases, Food Preparation Areas

Incandescent lamps (regular light bulbs) have a metal filament that is heated to a glowing point. Fluorescent lights give off light when ultraviolet rays (resulting from the passage of electricity through a mercury vapor) strike certain materials called phosphors. These substances then give off visible light.

Foods are also exposed to other sources of light, such as: germicidal lamps used in walk-in coolers, storage area rooms, to reduce bacterial and mold counts, and black lights used to detect the presence of insects, rodent excreta, and other kinds of contamination in foods.

When light strikes a package of food, several things happen. The light is: reflected off the surface of the package; absorbed by the packaging material; scattered and absorbed by the food; and transmitted through the food.

The light that is absorbed by the food can cause deterioration. In most solid foods, the light only penetrates the outer layer and so deterioration occurs in this surface layer resulting in discoloration on the surface of food.

In liquid foods, light penetration can be greater and with mixing of food due to agitation, larger portions of food constituents may become deteriorated.

The light sensitivity of a food depends on many factors including the:

- light source strength and type of light that it emits;
- distance of the light source from the food;
- length of exposure;
- optical properties of the packaging materials;
- oxygen concentration of the food; and
- the temperature.

Light induced changes in food usually begin in one of two ways: 1) light is absorbed by a component in the product that will directly undergo chemical reaction or 2) one component in a food causes some other component to undergo reaction because of light.

Deterioration can occur when light sensitive constituents, like those shown below, are exposed to light.

- **Vitamins** -- Vitamin A, Vitamin B12, Vitamin D, Folic Acid, Vitamin K, Vitamin E, Pyridoxine, Riboflavin
- **Pigments** -- Anthocyanins, Carotenoids, Chlorophylls, Myoglobin, Hemoglobin
- **Amino Acids** -- Tryptophan, Phenylalanine, Tyrosine, Histidine
- **Fats** -- Unsaturated fatty acids, Phospholipids

A wide variety of foods can undergo changes in color, flavor, and nutrient composition when exposed to light. The extent of these changes depends on many factors including the composition of the food and the light source. Not all types of natural or artificial light are equally absorbed or equally destructive. The effects of light on selected foods are described below.

Milk. Increased interest in the nutritional quality of foods has led to concern about the packaging and handling of milk due to its light sensitivity. Milk is displayed in retail stores under high intensities of light that can cause considerable photodegradation of milk constituents. This exposure can result in distinct flavor changes as well as the loss of added Vitamin A, Riboflavin and Vitamin C (ascorbic acid).

The off-flavors that develop in milk when exposed to light are called sunlight flavors that result from the breakdown of amino acids and proteins. Another type of light-induced off-flavor in milk is called oxidation flavor. This defect occurs when unsaturated fatty acids in milk lipids undergo oxidation.

The light-induced changes in milk depend on the intensity of the light, the type of holding container, milk composition, agitation, and several other factors. Loss of quality is most rapid in clear glass, polycarbonate containers and polyethylene jugs. The use of opaque fiberboard containers offers almost complete protection against light. Pigmented plastic containers can also protect against light. Currently, some companies are using either white opaque or cream colored plastic jugs to protect the quality of their milk.

Milk packaged in polyethylene containers showed a 90% reduction in added Vitamin A after twenty-four hours of exposure to fluorescent light. The loss of riboflavin under the same conditions was much slower; an 8% loss in riboflavin was observed after twenty-four hours of exposure. The light induced destruction of both nutrients increases as the fat content of the milk decreases. In addition, milk exposed to light also shows a significant drop in pyridoxine, Vitamin B12 and Vitamin C.

Meats. Fresh meats exposed to oxygen usually have a desirable, cherry red color. When exposed to visible light for long periods, the pigment at the surface of the meat slowly changes to a brownish gray color. Ultraviolet light causes a rapid fading of fresh meat color as well as accelerates the development of rancidity in the meat fat.

Cured meats like ham and luncheon meats undergo a more rapid light-induced color change than do fresh meats. Cured meat contains nitrite, which combines with natural meat pigments, to give these products their characteristic pink color. On exposure to light in the presence of oxygen, these nitroso-compounds are converted to a brownish gray color. This undesirable color is called light fading and it can be prevented by vacuum packaging the meat. Packaging it in oxygen impermeable films or by using opaque packaging materials.

Fats and Oils. Exposure to sunlight and/or fluorescent light accelerates the degradation of vegetable oils, butter, lard, and similar products. Light appears to accelerate the autoxidation of fats and oils, resulting in flavor and odor changes. It is believed that light-absorbing compounds in these foods sensitize them to visible and ultraviolet light. Fats and oils have different sensitivities to light depending on their composition, different amounts and types of sensitizers present, and the protective effect of other constituents.

Beer and Wine. When beer is exposed to light, it develops an undesirable flavor (and odor) called sunstruck flavor. This is why most beer is bottled in dark containers. The light-induced flavor is caused when constituents of the hops used to make the beer react with breakdown products of sulfur-containing amino acids. The resulting compounds are responsible for the sunstruck flavor. One company has developed a unique process to prevent sunstruck flavor and has successfully packaged beer in clear bottles.

Light often causes color changes in wine that reduces consumer acceptance. The sensitivity of wines depends on the type of wine and the color of the bottle in which it is packaged.

Snack Foods. Snack foods (like potato chips), prepared by deep fat frying in oil are susceptible to photodegradation and develop off-odors and off-flavors on exposure to light. Snack foods in opaque packages retain their quality longer than those packaged in clear, polyethylene bags.

Several things that can be done to reduce the photodegradation of foods include:

- reducing the exposure of sensitive foods to light;
- packaging foods in selectively absorbent or opaque packaging materials;
- reducing the oxygen concentration to very low levels;
- decreasing the level of light in display cases;
- choosing lights that have low photochemical activity.

By following some of these recommendations, shelf-life can be improved and product quality can be maintained for longer times.

Oxygen

Another important cause of food deterioration and spoilage is air and oxygen. Because air is colorless, odorless, and tasteless, it often taken for granted and often overlooked when food deterioration is discussed.

Air is a mixture of gases that compose the atmosphere of the earth. Air consists of: 78% nitrogen, 21% oxygen, and 1% a mixture of other gases. While oxygen is essential for life, it also can cause food deterioration. Oxygen can have deteriorative effects on fats, food colors, vitamins, flavors, and other food constituents. Basically, oxygen can cause food deterioration by providing conditions that will enhance the growth of microorganisms and causing damage to foods with the help of enzymes. Oxygen alone can also affect foods. Each of the ways oxygen deteriorates food is discussed below.

Microorganisms. Oxygen can provide conditions that enhance microbial growth. Some bacteria require oxygen for growth (aerobes) while others can grow only in the absence of oxygen (anaerobes). Many bacteria can grow under either condition and are called facultative anaerobes. Mold and most yeast require oxygen to grow. They can often be found growing on the surface of food when air is present.

Enzymes. Certain natural food enzymes are known as oxidizing enzymes. These enzymes catalyze (speed up) chemical reactions between oxygen and food components, and this leads to food deterioration. Although there are many oxidizing enzymes, two that cause darkening in diced and sliced vegetables are catalase and peroxidase. The browning of vegetables caused by these enzymes is often accompanied by off-flavors and odors. A simple heat treatment (blanching) is used to inactivate these enzymes.

Oxygen. Oxygen can also cause deterioration of foods spontaneously, by itself. This process is called atmospheric oxidation or autoxidation (self oxidation). Oxidative

deterioration is the primary cause of quality loss in fats and fatty portions of foods.

Temperature

Hot and cold temperatures are often used to preserve or extend the shelf life of food. However, when temperature is not properly controlled, it can cause food to deteriorate and spoil.

Chemical Reaction Rates Increase

For every 18°F rise in temperature within the moderate temperature range (50°F-100°F) where most food is handled, the rate of chemical reactions is approximately doubled. As a result, excessive temperatures will increase the rate of natural food enzyme reactions and the reactions of other food constituents.

- Protein will breakdown or denature.
- Emulsions will break – a product like mayonnaise will separate.
- Some vitamins will be destroyed.
- Moisture will be lost and foods will dry out.
- The color, flavor and odor of some products may be affected.

Growth of Microorganisms

Temperature also affects the growth of microorganisms present in food. Various temperature ranges support the growth of specific types of microorganisms. Bacteria are usually classified according to the temperature at which they grow.

- Pyschrotrophic (cold loving) bacteria are those that are capable of growing at 32°F-45°F, but their optimum growth range is from 68°F-86°F. These bacteria cause off-flavors and defects in food.
- Mesophilic (medium temperature loving) bacteria are capable of growing at 60°F-110°F. Most foodborne pathogens grow at these temperatures.
- Thermophilic (hot loving) bacteria grow at higher temperatures such as 110°F-150°F.

The growth of microorganisms is a result of many chemical reactions. Increases in temperature increase the rate of these reactions, so microorganisms grow more quickly at higher temperatures.

Product Deterioration and Spoilage

Exposing foods to uncontrolled cold temperatures will also cause deterioration. Fruits and vegetables that accidentally freeze and thaw have their texture and appearance affected. Skins and surfaces of these products will often crack, leaving them susceptible to exposure from microorganisms. Some foods that become frozen may also be adversely affected. The emulsion of mayonnaise will break if it freezes and so the components will separate. Milk that is allowed to freeze will also have some defects. The fat will separate and the milk

proteins will be damaged (denatured) causing it to curdle. The freezing of products should be intentional and done under controlled conditions.

Deterioration is caused in many foods by temperatures that are not extreme. Cold damage of several fruits and vegetables can occur at common refrigerator temperatures (35°F-45°F). Defects in produce exposed to cold temperatures include off-color development, surface pitting, and a variety of decays. Fruits and vegetables, such as bananas, lemons, squash, and tomatoes, should be held at temperatures no lower than 50°F for best quality. These products are certainly exceptions to the general rule that cold storage preserves all foods and the colder, the better.

Water

Water is one of the most common substances on earth and is an essential component of all foods. The water content of a food influences its appearance, texture, and flavor. All organisms, as well as foods, contain water in varying amounts. Water makes up about 70% or more of the weight of most raw foods; fruits and vegetables might contain 90-95% water. Even foods that seem dry, such as beans, flour, and cereals, contain small amounts of water.

Water Content of Select Foods

- Apples -- 84%
- Bread -- 32-37%
- Butter -- 16%
- Corn Flakes -- 4%
- Flour -- 12%
- Green Beans -- 92%
- Lettuce -- 96%
- Mayonnaise -- 15%
- Milk -- 88%
- Peaches -- 89%
- Peanut Butter -- 2%
- Preserves -- 29%
- Raisins -- 18%
- Strawberries -- 90%
- Sugar -- 0.5%

Although the water content of a food is expressed as a percent, this number does not reflect how the water exists in the food. Water in food is classified according to its availability, or biological activity, and is either free or bound. Free water is not bound to any components in a food. Microorganisms can use free water to grow. It is also available for chemical

reactions. Bound water is physically bound to components in the food. It is not available for microbial growth and it cannot be used in chemical reactions.

Water exists in foods in many ways. It can be present in:

- solutions (orange juice, fruit drinks),
- emulsions (butter, mayonnaise),
- colloidal dispersions (gelatin desserts),
- suspensions (starch in puddings).

Water greatly affects the shelf life of food. Excessive moisture can result in product deterioration and spoilage by:

Microorganisms. Microorganisms need water to dissolve the food they use. Water allows the food to enter bacterial, yeast and mold cells where it is used for energy and growth. Water also allows waste products to escape from the cells.

Chemical Reactions. Water in food also allows chemical reactions to occur between food components.

Water pickup can occur when there are slight changes in relative humidity. Water can condense on the surface of a food and this can result in many common food defects. The molding of grain, soggy cereals, and the caking and lumping of dry products, such as powders and cake mixes, can result from excessive moisture. Other defects such as mottling, crystallization, and stickiness have also been observed. Water condensing on the surface of a food can also provide an environment for bacteria and molds to multiply.

Physical defects such as cracking, splitting and crumbling occur when excessive moisture is lost from foods.

Controlling the water content of food is a common way to preserve foods. It is done by:

Drying (dehydration), concentration and evaporation – by removing water to a certain level, deteriorative reactions can be reduced or prevented. Examples of foods preserved by drying include dry milk, potato flakes, drink mixes, evaporated milk, beef jerky, and many other foods.

Freezing –the freezing of foods changes water from liquid to solid form and makes water unavailable to microorganisms and for chemical reactions. Meat, vegetables, and many other foods are frozen for this purpose.

Food Additives – salt and sugar are used in many products to bind water making it less available for microbial growth and chemical reactions. Jams, jellies, and cured hams are examples of these products.

SOURCE:

The information found in this backgrounder was adapted from a series of fact sheets developed by Dr. Robert Gravani, Cornell University.

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