Radiation Preservation of Foods

Radiation may be defined as the emission and propagation of energy through space or through a material medium.

Radiation in **Food Preservation:**

1-Nonionizing radiations

<u>Ultraviolet Light</u>

Ultraviolet (UV) light is a powerful bactericidal agent, with the most effective wavelength being about 2,600 A. It is nonionizing and is absorbed by proteins and nucleic acids, that may lead to cell death.The mechanism of UV death in the bacterial cell is due to the production of lethal mutations as a result of action on cell nucleic acids. The poor penetrative capacities of UV light limit its food use to surface applications, where it may catalyze oxidative changes that lead to rancidity, discolorations, and other reactions. UV light is sometimes used to treat the surfaces of baked fruitcakes and related products before wrapping.

2-Ionizing radiations

Ionizing radiations, defined as those radiations that have wavelengths of 2000 A or less—for example, gamma rays, beta rays and X-rays . Their quanta contain enough energy to ionize molecules in their paths. Because they destroy microorganisms without raising temperature, the process is termed **cold sterilization**.

Mechanisms of Antimicrobial Action:

Ionizing radiation produces both **direct and indirect** effects on microorganisms. The direct effect is produced from the removal of electrons from the DNA, thereby damaging them. The indirect effect is produced from the ionization of water molecules present in the cell. The hydrogen and hydroxyl radicals formed in this process are highly reactive and cause oxidation, reduction, and the breakdown of C–C bonds of other molecules, including DNA. In addition to DNA damage, ionizing radiation also causes damage in the membrane and other structures, causing sublethal injury. Some microorganisms can repair the damage to the DNA strands and are designated as radiation-resistant microorganisms.

Factors affect on the destruction of microorganisms by irradiation:

Several factors should be considered when the effects of radiation on microorganisms are considered. These are discussed in the following subsections.

1-Types of Organisms

Gram-positive bacteria are more resistant to irradiation than gram negatives. In general, spore formers are more resistant than non-spore formers . Spores of *Clostridium botulinum* appear to be the most resistant of all clostridial spores. .*Enterococcus faecium* , micrococci, and the homofermentative lactobacilli are among the most resistant of non-spore-forming bacteria. The genera *Moraxella* and *Acinetobacter* have been found to possess degrees of radiation resistance higher than for all other gram negatives. Most sensitive to radiations are the *Pseudomonads* and *Flavobacterium*, with other gram negative bacteria being intermediate.

2-Numbers of **Organisms**

The numbers of organisms have the same effect on the efficacy of radiations as in the case of heat. The larger the number of cells, the less effective is a given dose.

3-Composition of Food

Microorganisms in general are more sensitive to radiation when suspended in buffer solutions than in protein-containing media. Proteins exert a protective effect against radiations, as well as against certain antimicrobial chemicals and heat. The presence of nitrites tends to make bacterial endospores more sensitive to radiation.

4-Presence or Absence of **Oxygen**

The radiation resistance of microorganisms is greater in the absence of oxygen than in its presence. Complete removal of oxygen from the cell suspension of *Escherichia coli* has been reported to increase its radiation resistance up to threefold. The addition of reducing substances has the same effect in increasing radiation resistance as an anaerobic environment.

5-Physical State of Food

The radiation resistance of dried cells is higher than that for moist cells.Radiation resistance of frozen cells has been reported to be greater than that of non frozen cells.

6- **Age of Organisms**

Bacteria tend to be most resistant to radiation in the lag phase. The cells become more radiation sensitive as they enter and progress through the log phase and reach their minimum at the end of this phase.

Doses:

Radiation dose was originally designated as rad, and 1 rad was defined as the quantity of ionizing radiation that results in the absorption of 100 ergs of energy per gram of an irradiated material. The current unit is gray (Gy), and 1 Gy is equivalent to 100 rad. According to the international health and safety authorities, foods irradiated up to 10,000 Gy (10 kGy) are considered safe.

The relative sensitivity of microorganisms to irradiation dose is a function of their size and water content. Approximate lethal dose levels for insects and different microorganisms have been suggested as follows:

Insects, á1 kGy; molds, yeasts, bacterial cells, 0.5 to 10 kGy; bacterial spores, 10 to 50 kGy; viruses, 10 to 200 kGy.

Thus, at the recommended level of 10 kGy, *Cl. botulinum* spores are not destroyed in foods (they need 30 to 60 kGy), although cells of pathogenic (and spoilage) bacteria are destroyed.

Low dose level (<1 kGy) is used to control insects in fruits and grains, parasites in meat and fish, and sprouting in vegetables.

Medium doses(1 to 10 kGy) are used to control foodborne pathogens and spoilage microorganisms to extend safety and stability of refrigerated foods.

Higher doses (>10 kGy) to destroy spores are not used in foods except in spices that are used in very small quantities.

Specific Terms:

1. Radurization refers to "radiation pasteurization" low-dose treatments, where the intent is to extend a product's shelf life. Radiation pasteurization is mainly intended to destroy spoilage bacteria in high pH–high-*Aw* foods, especially Gram-negative psychrotrophs in meat and fish and yeasts and molds in low-pH–low-*Aw* foods. The treatment is generally milder (1kGy). The products should be packaged and chilled to prevent growth of pathogens.

2. Radicidation **:**This is the radiation of foods to destroy vegetative foodborne pathogens. The dose level used is 2.5 kGy to 5.0 kGy. Although it is effective against pathogenic vegetative bacterial cells and molds, spores of the pathogens are not destroyed.

3. Radappertization is a term used to define "radiation sterilization" which would imply high dose treatments dose (30 kGy) to destroy spores, with the resulting product being shelf-stable. However, this is not recommended for use in food.

Effects of radiation on Foods

Radiation doses heavy enough to affect sterilization have been found to produce undesirable "side reactions," or secondary changes, in many kinds of foods, causing undesirable colors, odors, tastes, or even physical properties. Some of the changes produced in foods by sterilizing doses of radiation include:

(1) In meat, a rise in pH, destruction of glutathione, and an increase in carbonyl compounds, hydrogen sulfide, and methyl mercaptan.

(2) In lipids, destruction of natural antioxidants, oxidation followed by partial polymerization, and increase in carbonyl compounds.

(3) In vitamins, reduction in most foods of levels of thiamine, pyridoxine, and vitamins B12, C, D, E, and K: riboflavin and niacin are fairly stable.

*Preservation of Foods by Drying

The preservation of foods by drying is based on the fact that microorganisms and enzymes need water in order to be active. In preserving foods by this method, one seeks to lower the moisture content to a point where the activities of food-spoilage and food-poisoning microorganisms are inhibited. Some microorganisms are destroyed in the process of drying, this process is not lethal to microorganisms, and many types may be recovered from dried foods, especially if poor-quality foods are used for drying and if proper practices are not followed in the drying steps.

Dried or low moisture (LM) foods are those that generally do not contain more than 25% moisture and have a water activity (a_w) between 0.00 and 0.60. Bacteria require relatively high levels of moisture for their growth, with yeasts requiring less and molds still less. Because most bacteria require a_w values above 0.90 for growth, they play no role in the spoilage of dried foods. The most troublesome group of microorganisms in dried foods are osmophiles and xerophiles yeasts and molds.

Intermediate Moisture Food

Intermediate moisture foods (IMF) that have a_w values of 0.60 to 0.85 (with moisture contents of 15 to 50%). They can be eaten without rehydration, but are shelf-stable for a relatively long period of time without refrigeration and considered microbiologically safe. Some of the traditional IMFs includes salami, dry sausages, dried fruits, jams and jellies, and honey. Microorganisms can survive in the products, but because of low a_w, bacteria cannot grow. However, yeasts and molds can grow in some. To inhibit their growth, specific preservatives, such as sorbate and propionate, are added.

Mechanisms of Drying Effect on Microorganisms:

Microorganisms need water for transport of nutrients, nutrient metabolism, and removal of cellular wastes. In a food, the total water (moisture) is present as free water and bound water; the latter remains bound to hydrophilic colloids and solutes and is not available for biological functions. Thus, only the free water (which is related to a_w)is important for microbial growth. Microorganisms also retain a slightly lower a_w inside the cells than the external environment to maintain turgor pressure, and this is important for cell growth. If the free water in the environment is reduced, the free water from the cells flows outside in an effort to establish equilibrium. The loss of water causes an osmotic shock and plasmolysis, during which the cells do not grow.

Methods of Drying:

A. Natural Dehydration

Natural dehydration is a low-cost method in which water is removed by the heat of the sun. It is used to dry grains as well as to dry some fruits , vegetables, fish, meat, milk, and curd (from milk), especially in warmer countries. The process is slow; depending on the conditions used, spoilage and pathogenic bacteria as well as yeasts and molds (including toxigenic types) can grow during drying.

B. Mechanical Drying

Mechanical drying is a controlled process, and drying is achieved in a few seconds to a few hours. Some of the methods used are:

1- **Tunnel drying** (in which a food travels through a tunnel against flow of hot air that removes the water).
2- **Drum drying** (inwhich a liquid is dried by applying a thin layer on the surface of a roller drum heated from inside).
3- **Spray drying** (in which a liquid is sprayed in small droplets, which then come in contact with hot air that dries the droplets instantly).

Milk is dried as either whole milk or nonfat skim milk. The dehydration may be accomplished by either the drum or spray method. Eggs may be dried as whole egg powder, yolks, or egg white. Spray drying is the method most commonly employed.

Liquids may be partially concentrated before drying by evaporation, reverse osmosis, freeze-concentration, and addition of solutes. Depending on the temperature and time of exposure, some microbial cells can die during drying, whereas other cells can be sublethally injured. Also, during storage, depending on the storage conditions, microbial cells can die rapidly at the initial stage and then at a slow rate. Spores generally survive and remain viable during storage in a dried food.

C. Freeze-Drying

The acceptance quality of food is least affected by freeze-drying, as compared with both natural and mechanical drying. However, freeze-drying is a relatively costly process. It can be used for both solid and liquid foods. The process initially involves freezing the food, rapidly at a low temperature, and then exposing the frozen food to a relatively high vacuum environment. The water molecules are removed from the food by sublimation (from solid state to vapor state) without affecting its shape or size. The method has been used to produce freeze-dried vegetables, fruits, fruit juices, coffee, tea, and meat and fish products. Microbial cells are exposed to two stresses — freezing and drying that reduce some viability as well as induce sublethal injury. During storage, especially at a high storage temperature and in the presence of oxygen, cells die rapidly initially and then more slowly. Spores are not affected by the process.

D. Foam-Drying

The foam-drying method consists of whipping a product to produce a stable foam to increase the surface area. The foam is then dried by warm air. Liquid products, such as egg white, fruit purees, and tomato paste, are dried in this manner. The method itself has very little lethal effect on microbial cells and spores. However, a concentration method before foaming, the pH of the products, and low a_w cause both lethal and reversible damages to microbial cells.

E. Smoking

Many meat and fish products are exposed to low heat and smoke for cooking and depositing smoke on the surface at the same time. The heating process removes water from the products, thereby lowering their a_w. Many low-heat-processed meat products (dry and semidry sausages) and smoked fishes are produced this way. Heat kills many microorganisms. The growth of the survivors is controlled by low a_w as well as the many types of antimicrobial substances present in the smoke.