Principles of Food Preservation

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Introduction

- A good method of food preservation is one that slows down or prevents altogether the action of the agents of spoilage.
- Also, during the process of food preservation, the food should not be damaged.
- In order to achieve this, certain basic methods were applied on different types of foods.
- For example in earlier days, in very cold weather condition, ice was used to preserve foods.
- Thus, very low temperature became an efficient method for preventing food spoilage.

PRINCIPLES OF FOOD PRESERVATION

- In accomplishing the preservation of foods by the various methods, the following principles are involved:
- Prevention or delay of microbial decomposition
  - By keeping out microorganisms (asepsis)
  - By removal of microorganisms, e.g., by filtration
  - By hindering the growth and activity of microorganisms, e.g., by low temperatures, drying, anaerobic conditions, or chemicals
  - By killing the microorganisms, e.g., by heat or radiation
- Prevention or delay of self-decomposition of the food
  - By destruction or inactivation of food enzymes, e.g., by blanching
  - By prevention or delay of purely chemical reactions, e.g., prevention of oxidation by means of an antioxidant
- Prevention of damage because of insects, animals, mechanical causes
  - By storing foods in dry, air tight containers the insects, worms or rats are prevented from destroying it.
- The methods used to control the activities of microorganisms usually are effective against enzymatic activity in the food or chemical reactions. Methods such as drying and the use of low temperatures, however, permit autodecomposition to continue unless special precautions are taken. For example, most vegetables are balanced (heated) to inactivate their enzymes before being frozen.

… PRINCIPLES OF FOOD PRESERVATION

- Control of microorganisms
  - Heat
  - Cold
  - Drying
  - Acids
  - Sugar and salt
  - Oxygen concentration
  - Smoke
  - Radiation
  - Chemicals (preservatives)
- Control of enzymes
  - Heat
  - Oxygen removal
  - Acids
  - Chemicals (antioxidants)
- Control of Other factors
  - Protective packaging
  - Sanitation

Prevention or delay of microbial decomposition

- **By keeping out micro-organisms (Asepsis):** Asepsis refers to keeping out the micro-organisms from the food by making use of either natural covering or providing artificial covering around the food.
- Natural barrier in foods include outer shell of the nuts (almond, walnut, pecan nut) skin/peel of fruit and vegetables (banana, mango, citrus, ash gourd etc), shells on eggs, skin or fat in meat, husk of ear corn etc.
- Similarly packaging prevents entry of micro-organisms in the food.
- For example peach or mushroom sealed in tin can, clean vessels under hygienic surroundings helps in preventing spoilage of milk during collection and processing by keeping out the micro-organisms.
- **By removal of micro-organisms (Filtration):** Filtration of liquid foods through bacteria proof filters is a common method for complete removal of micro-organisms from the foods.
- Liquid foods are passed through the filters made of suitable material like asbestos pad, diatomaceous earth, unglazed porcelain etc and allowed to percolate through either with or without nano-filtration etc works on this principle.
- Centrifugation, sedimentation, trimming away spoiled portion of food and washing etc can also be used but are not very effective.

…Prevention or delay of microbial decomposition

- **By hindering the growth and activity of micro-organisms:**
- **a. By using low temperature:** Microbial growth and enzyme activity is retarded in foods by storing them at low temperatures.
- The food commodities can be stored under cellar storage (15^{o}C) like root crops, potato, onion refrigerator or chilling temperatures (0-5^{0}C) like most fruits and vegetables, meat, poultry, fresh milk and milk products and under freezing temperature (-18^{o}C to -40^{o}C) like frozen peas, mushrooms etc.
- Methods of freezing:
- 1. Sharp Freezing (Slow freezing): This technique, first used in 1861, involves freezing by circulation of air, either naturally or with the aid of fans. The temperature may vary from –15 to –29^{o} C and freezing may take from 3 to 72 hours. The ice crystals formed one large and rupture the cells. The thawed tissue cannot regain its original water content. The first products to be sharp frozen were meat and butter.

Methods of freezing

- 2. Quick freezing In this process the food attains the temperature of maximum ice crystal formation (0 to – 4^{o} C) in 30 min or less. Such a speed results in formation of very small ice crystals and hence minimum disturbance of cell structure. Most foods are quick frozen by one of the following three methods:
  - a) By direct immersion Since liquids are good heat conductors food can be frozen rapidly by direct immersion in a liquid such as brine or sugar solution at low temperature. Berries in sugar solution packed fruit juices and concentrates are frozen in this manner. The refrigeration medium must be edible and capable of remaining unfrozen at –18^{o} C and slightly below.
  - b) By indirect contact with refrigerant Indirect freeing may be defined as freezing by contact of the product with a metal surface which is itself cooled by freezing brine or other refrigerating media.
  - c) By air blast In this method, refrigerated air at –18 to –34o C is blown across the material to be frozen.
- 3. Cryogenic freezing Although most foods retain their quality when quick frozen by the above methods, a few require ultrafast freezing. Such materials are subjected to cryogenic freezing which is defined as freezing at very low temperature (below –60o C). The refrigerant used at present in cryogenic freeing are liquid nitrogen and liquid CO2.
- 4. Dehydro-freezing This is a process where freezing is proceded by partial dehydration. In case of some fruits and vegetables about 50% of the moisture is removed by dehydration prior to freezing.
- 5. Freeze drying: In this process food is first frozen at –18^{o} C on trays in the lower chamber of a freeze drier and the frozen material dried (initially at 30^{o} C for 24 hrs and then at 20^{o} C). Under high vacuum (0.1 mm Hg) in the upper chamber. Direct sublimation of the ice takes place without passing through the intermediate liquid stage. Mango pulp, orange juice concentrate, passion fruit juice and guava pulp are dehyderated by this method.

By hindering the growth and activity of micro-organisms:

- **b. By drying of food commodity:** Removal of water from the food to a level at which micro-organisms fails to grow is an important method of preservation. Moisture can be removed by the application of heat as in sun drying and in mechanical drying or by binding the moisture with addition of sugar (as in jams, jellies) or salt (high salt in raw mangoes) and making it unavailable to the micro-organisms. Examples include osmotic dehydration, dried grapes (raisins), apricots, onion, cauliflower etc.
- **c. By creating anaerobic conditions:** Anaerobic condition can be created by removal or evacuation of air/oxygen from the package, replacement of air by carbon dioxide or inert gas like nitrogen.
- Lack of oxygen prevents growth of any surviving bacteria and their spores under such conditions.
- Production of carbon dioxide during fermentation and its accumulation at the surface makes the conditions anaerobic to prevent the growth of aerobes.
- Carbonation of drinks and storing fresh food under controlled atmospheres serves the same purpose.
- Canned food in which the food is sealed after removal of air (exhausting) illustrates this principle.
- Anaerobic bacteria and their spores present however, need to be killed to prevent the food from being spoiled.
- A layer of oil on top of any food prevents growth of microbes like moulds and yeasts by preventing exposure to air.

By hindering the growth and activity of micro-organisms:

- **d. By use of chemicals:** Chemical preservatives are intentional food additives incorporated into food to prevent or retard food spoilage caused by microbiological, enzymological, or chemical reactions.
- These chemical preservatives should be nontoxic to humans or animals.
- Chemical preservatives come under the food additives generally recognized as safe (GRAS).
- Chemical preservatives can also be termed antimicrobials.
- The main purpose of using chemical preservatives is to inhibit the growth and activity of foodborne pathogens and spoilage microorganisms.
- Chemical preservatives used in food can have both bacteriostatic and bactericidal properties per the concentration used.
- **Role of chemical preservatives**
- Interferes with the cell wall, cell membrane, enzymatic activity, nucleic acids, etc., to prevent microorganisms' growth and activity.
- Retard, prevent or control undesirable changes in flavor, color, texture, or consistency of food and nutritive value of food.
- Control natural spoilage of food

Classification of chemical preservatives

- Class I: Traditional preservatives (natural)
- Class II: Chemical preservatives (Artificial)
- **Class I:** Traditional Preservatives: These include preservatives like wood, smoke, sugar, honey, salt, spices, alcohol, vinegar, vegetable oil, spices, etc which are commonly used in our kitchen in past.
- These chemical preservatives are not restricted to use and there is no imposed limitation on their use. These naturally occurring preservatives are regarded as safe for human health.
- **Class II:** Chemical preservatives: These are synthetic chemical preservatives that are made in the laboratory. For e.g nitrites, propionates, parabens, benzoates, acetates, sorbates, sulfur dioxide, etc.
- **Microbial preservatives:** These include antimicrobial preservatives like bacteriocins (e.g. nicin) which are produced by some strains of lactic acid bacteria and inhibit the growth of food spoilage or pathogenic bacteria. E.g nisin, produced by *Lactococcus lactis* inhibits the growth of *Clostridium tyrobutyricum*, *C. botulinum*, and, *Listeria monocytogenes* in cheese, other dairy products meats, fish, etc.
- Using bacteriocins like microbial preservatives help reduce the use of chemical preservatives like nitrates, sorbates, and benzoates which consumers consider bad.

Factors affecting the effectiveness of chemical preservatives

- **Chemical preservative properties**
- Solubility
- Toxicity
- **Microbial factors**
- Microbial inherent resistance to chemical preservatives
- Initial microbial load
- Growth rate and phase of microorganisms
- Stress reaction of microorganisms
- Homeostasis ability of microorganisms
- Use of additional preservative methods

- **Intrinsic factors of food**
- pH of the food
- Water activity of food
- **Extrinsic factors**
- Storage time and temperature
- Gas composition
- Atmosphere and relative humidity

Different chemical preservatives and their application in the food industry

S.N	Chemical preservatives	Targeted microorganisms	Mode of action	Advantages	Disadvantag
1	Sulfur dioxide (SO_2)	Yeast, mold	Increase pH and imbalance cellular metabolic process, alter the enzymatic system,	Antioxidant properties, prevent browning, preserve color, cheaper and easily available	The intense pungent odo and corrosive property makes it unuseful in canning
2	Sorbates(Sodium sorbate and Potassium sorbate)	Yeast, Mold, Bacteria	Disturb enzyme system, inhibit many enzymes involved in TCA cycle		
3	Benzoic acid and benzoates	Yeast, molds	Disturb enzymatic system	Most active against yeasts and molds. Used to preserve colored fruit juices	Risk of respiratory disease
4	Parabens (p-hydroxybenzoic acid)	Yeast, Mold, bacteria	Destroy complex structure of the cell and denature protein inside the cell		
5	Propionic acid	Mold, yeast, and a few bacteria	Disturb enzyme system		
6	Nitrate and nitrite	Anaerobic bacteria (*Clostridium botulinum*), other pathogenic microbes	Inhibit metabolic enzyme	Preserve the color of red meat by forming nitrosomyoglobin	The formatior of carcinogen nitrosamines i triggering extensive research
7	Phosphates	More against gram-positive bacteria (*Bacillus, clostridium*)	Chelating metal ions		
8	Sulfites	More Bacteria, less effective to yeast and mold	Target to the cytoplasmic membrane, DNA replication, protein synthesis, and enzymatic actions	Acts as antioxidants and inhibit enzymatic browning	
9	Sodium chloride (NaCl)	Bacteria	Osmotic shock to Plasmolysis	Better preservation if used as a pretreatment before canning, pasteurization, or drying	Weak against *Staphylococcu* and *listeria monocytogen*
10	Wood smoke (Traditional method)	Bacteria, fungi	The release of different phenolic compounds, ketones, aldehyde, and alcohol, which serves as an antimicrobial preservative	Easy to use	
11	Nisin	Clostridium botulinum and other bacteria			

By use of chemicals

- **Sodium benzoate** is only partially soluble in H2O hence its salt, sodium benzoate is used.
- One part of sodium benzoate is soluble in 1.8 parts of water at ordinary temperature.
- In the long run benzoic acid may darken the product.
- It is, therefore, mostly used in coloured products of tomato, jamun, pomegranate, plum, watermelon, strawberry, coloured grapes etc.
- **Organic acids** like Acetic acid, benzoic acid, lactic acid, propionic acid, sorbic acid, etc., are effective as preservatives for foods with a pH of less than 5. So, they are the best for preserving acidic foods.
- At acidic pH, protonated or uncharged organic acid crosses the cell membrane and enters the cytoplasm.
- In neutral cytoplasmic pH, organic acids dissociate and release the proton that acidifies the cytoplasm.
- This cell uses ATP to pump protons out of the cell to deacidify the cytoplasm, which makes energy unavailable for their growth.

iv) By killing the micro-organisms

- **a) Use of heat:** Coagulation of proteins and inactivation of their metabolic enzymes by application of heat leads to destruction of micro-organisms present in foods.
- Exposure of food to high temperature also inactivates the enzymes present in the food.
- Foods can be heated either at temperature below 100^{o}C (pasteurization) at 100^{o}C (boiling) or at temperature above 100^{0}C (sterilization).
- **i) Pasteurization (heating below 100^{o}C):** It is a mild heat treatment given to the food to kill most pathogenic micro-organisms and is used in the food where drastic heat treatment cause undesirable changes in the food.
- It is usually supplemented by other methods to prolong shelf life.
- Pasteurization is most commonly used in treatment of milk and other dairy products either as low temperature long time (LTLT) or high temperature short time (HTST) process.
- Heat treatment of milk at 62.2^{o}C for 30 minutes refers to LTLT process.
- Heating at 72^{o}C for 15 seconds is termed as HTST process.
- Grape wine is pasteurized at 82-85^{o}C for 1 minute and beer is pasteurized at 60^{0}C.
- Carbonated juice is heated at 65.6^{o}C for 30 minutes in bottles and vinegar in bulk is held at 60-65^{o}C for 30 minutes.

a) Use of heat:

- **ii) Boiling (heating at 100oC):** Cooking of food including vegetables, meat etc by boiling with water involves a temperature around 100^0C.
- Boiling of food at 100^oC kills all the vegetative cells and spores of yeast and moulds and vegetative cells of bacteria.
- Many foods can be preserved by boiling (e.g. milk).
- Canning of acid fruit and vegetables (tomatoes, pineapple, peaches cherries etc) is carried by boiling at about 100^oC.
- **iii) Heating above 100^0C:** Heating by steam under pressure is used to obtain temperature above 100^0C by using steam sterilizer or retort. The temperature in the retort increases with increase in steam pressure.
- For canning of mushrooms and other non-acid vegetables the processing temperature of 121.1^0C at 15 psi pressure are used.
- For sterilization of milk and other liquid foods like juices, ultra high temperature (UHT) process is used.
- In UHT process, the food is heated to very high temperature (150^0C) for only few seconds by use of steam injection or steam infusion followed by flash evaporation of the condensed steam and rapid cooling.
- The process is also used for bulk processing of many foods.

b) Use of radiation:

- Irradiation consists of exposing the food to either electromagnetic or ionizing radiations to destroy the micro-organisms present in the food.
- Examples of irradiation include use of ultraviolet lamps in sterilizing slicing knives in bakeries.
- Gamma (γ) radiation from cobalt -60 or cesium 137 source have been used for irradiation of many fruits like papaya, mango and onion, spices, fish etc.
- They are also used for inhibition of sprouting in onion and potatoes.
- In 1964 an international group of microbiologists suggested the following terminology for radiation treatment of foods:
- **Radappertization** Is equivalent to radiation sterilization or "commercial sterility," as it is understood in the canning industry. Typical levels of irradiation are 3(MK) kGy.
- **Radicidation** Is equivalent to pasteurization— of milk, for example. Specifically, it refers to the reduction of the number of viable specific nonsporeforming pathogens, other than viruses, so that none is detectable by any standard method. Typical levels to achieve this process are 2.5-10 kGy.
- **Radurization** May be considered equivalent to pasteurization. It refers to the enhancement of the keeping quality of a food by causing substantial reduction in the numbers of viable specific spoilage microbes by radiation. Common dose levels are 0.75-2.5 kGy for fresh meats, poultry, seafood, fruits, vegetables, and cereal grains.

2. Prevention or delay of self decomposition of food

- **i) By destruction or inactivation of food enzymes (blanching or boiling):** Blanching is a mild heat treatment given to vegetables before canning, freezing or drying to prevent self decomposition of food by destroying enzymes.
- Blanching is carried out by dipping the food commodity either in boiling water or by exposing than to steam for few minutes followed by immediate cooling.

ii) By prevention or delay of purely chemical reactions (use of antioxidants to prevent oxidation): Foods containing oils and fat turn rancid and become unfit for consumption due to oxidation.

- Addition of appropriate quantity of antioxidants like butyl hydroxy anisole (BHA), butyl hydroxyl toluene (BHT), tertiary butyl hydroxy quinone (TBHQ), lecithin etc prevents oxidation and preserves the food.

3. Prevention of damage by insects, animals, rodents and mechanical causes: Use of fumigants in dried fruits, cereals etc checks the damage caused by insects and rodents.

- Wrapping of fruits, providing cushioning trays, using light pack and good packaging material checks the damage to fresh food commodities during handling and transportation.

Methods of food preservation on the basis of food preservation principles.

Physical method	Method
a)By removal of heat (Preservation by low temperature)	Refrigeration, Freezing preservation, dehydro-freezing, carbonation
b. By addition of heat (preservation by high temperature	Pasteurization (LTLT, HTST), sterilization, UHT Processing, microwave.
c. By removal of water	Drying (open sun, solar/poly tunnel solar), Dehydration (mechanical drying), Evaporation/concentration, Freeze concentration, reverse osmosis, freeze drying, foam mat drying and puff drying
d. By Irradiation	UV rays and gamma radiations
e. By non-thermal methods	High pressure processing, pulsed electric fields

Chemical methods	
a. By addition of acid (acetic or lactic)	Pickling (vegetable, olive, cucumber, fish, meat)
b. By addition of salt/brine	Salted mango/vegetable slices, salted and cured fish and meat i. Dry salting ii. Brining
c. By addition of sugar along with heating	Confectionary products like jams, jellies, preserves, candies, marmalades *etc*.
d. By addition of chemical preservatives.	i) Use of class II preservatives like Potassium meta-bi-sulphite, sodium benzoate, sorbic acid in food products. ii) Use of permitted and harmless substances of microbial origin like tyrosine, resin, niacin as in dairy products.
iii. By fermentation	i. Alcoholic fermentation (wine, beer) ii. Acetic acid fermentation (vinegar) iii. Lactic acid fermentation (curd, cheese, pickling of vegetables).
iv. By combination method	i. Combination of one or more methods for synergistic preservation. ii. Pasteurization combined with low temperature preservation. iii. Canning: heating combined with packing in sealed container. iv. Hurdle technology like low pH, salting, addition of acid, use of sugar, humectant and heating.