Food Preservation

Authors: Palshikar L. S., Gawali A. S.

A good method of food preservation is one that slows down or prevents altogether the action of the agents of spoilage without damaging food. Certain methods can be applied to acieve this preservation. Food can be preserved by three different principles

1. Removal of micro-organisms or inactivating them:

This is done by removing air, water (moisture), lowering or increasing temperature, increasing the concentration of salt or sugar or acid in foods. Preservation of green leafy vegetables by removal of water from the leaves so that micro organisms cannot survive

2. Inactivating enzymes:

Enzymes found in foods can be inactivated by changing their conditions such as temperature and moisture, when you preserve peas, one of the methods of preservations is to put them for a few minutes in boiling water. This method also known as blanching inactivates enzymes and thus, helps in preserving the food.

3. Removal of insects, worms and rats:

By storing foods in dry, air tight containers the insects, worms or rats are prevented from destroying it.

HIGH TEMPERATURE TREATMENT:

Destruction by heat denatures proteins, inactivates enzymes, most or all vegetative cells, some or all spores are killed depending on type of heat treatment.

Factors affecting heat resistance:

- Cells and spores exhibit varied resistance, most cells have medium resistance
- depends on temperature-time relationship
- initial concentration of cells, previous conditions like injured cells may be present
- culture medium effect of nutrients, inhibitors
- prolonged exposure to metabolic end products reduce heat resistance
- phase of growth – lag / log / stationary
- desiccation: dried spores are harder to kill by heat
- moisture
- pH
- salt
- colloidal substances

Thermal death time (TDT) can be described by 'D' decimal reduction time: time required to destroy 90% of cells in a population (reduction in 1 log cycle). E.g.. Reduction from 104 to 103 is 10 min; 103 to 102 is 10 min.

Heat treatments employed in processing foods:

- Less than 100^{o}C
- At 100^{o}C
- More than 100^{o}C

Pasteurization

- Temperatures below 100^{o}C
- Heating by steam/hot water/dry heat/electric current

- Purpose is to destroy all pathogens and most spoilage microbes
- Milk: 72^{o}C for 15 sec
- Basis is heat resistant pathogenic bacterium *Coxiella burnetti* (rickettsia causes Q fever)
- However bacterial spores and other thermodurics survive pasteurization.
- Pasteurization of milk is of two types: High temperature short time (HTST) such as 72^{o}C for 15 sec and low temperature long time (LTLT) at 65oC for 30 min. Ice cream mix, fruit juices, wine are also pasteurized. Wine 82oC for 1 min.

<u>Heating at 100^{o}C</u>

This treatment is sufficient to kill everything except bacterial spores in the food and often is sufficient to preserve even low and medium acid foods. Many acid foods can be processed successfully at 100^{0}C or less e.g. Sauerkraut and highly acid foods.

Various methods-

- Boiling, Blanching
- Immersion of container of food in boiling water
- Exposure to flowing steam

<u>Heating to more than 100^{o}C</u>

- Canning: in hermetically sealed containers (glass /aluminium /plastics); Temperature: 121^{o}C, 115^{o}C for various time periods (30 min)
- Ultra high temperature: 150^{o}C for 3 sec using steam by injection or infusion.
- Cooling is essential by air currents / immersion in cold water / spray of cold water
- As rapidly as possible since cool-down period leads to growth of microbes if any due to adaptive period. But cooling depends on material of packaging; glass containers crack with sudden cooling.

Approximate heat resistance levels	**D values in min**
E. coli Buffer	4 at 55^{o}C
Pseudomonas aeruginosa Nutrient agar	2 at 55^{o}C
Salmonella enterica Milk	816 at 70^{o}C
Bacillus stearothermophilus spores	5 at 121oC

DRYING:

Involves both heat and mass transfer phenomena. Hot air stream has two functions: a) transfers heat to evaporate water from raw materials and b) carries away vapor produced. Microbes affected by both temperature and water activity.

<u>Factors affecting:</u>

- size, composition of food pieces
- Time-temperature combination
- Warm-up period is critical
- Slow increase in temperature allows microorganisms to grow
- Wet heat is more lethal than dry heat
- Internal temperature may remain lower compared to surface

<u>Methods of drying:</u>

* Sun drying – grapes, figs, apricots (temperature and humidity favorable)
* Spray drying
* Drum drying

* Evaporation (60% water removed, evaporated milk)
* Freeze drying

<u>Freeze-Drying (lyophilization):</u>

- Combined method of food preservation
- Dehydration of food in frozen state through vacuum sublimation of its ice content
- Sublimation front moves to core and ice sublimates where it is formed
- Solutes remain at original location and not transported to surface
- Loss of solutes is insignificant

Rapid freezing results in less mechanical damage due to formation of small ice crystals. Freeze-dried foods are packed in vapor impermeable packages. Merits are less shrinkage of solids insignificant denaturation of proteins, prevention of undesirable, chemical reactions, lower loss of desirable, volatile constituents, for thermo labile food preservation.

LOW TEMPERATURE PRESERVATION:

The method is based on the fact that metabolic activities of microbes are slowed down at temperatures above freezing, metabolic reactions generally stopped at freezing temperatures, for every 10^{o}C fall in temperature, twofold decrease in rate of reaction.

However, psychrotrophs and psychrophiles are able to grow at low temperatures.

Bacterial psychrotrophs include *Pseudomonas, Flavobacterium, Enterobacter, Listeria, Alcaligenes, Aeromonas* etc. Spoilage during refrigeration (0^{o}C to 7^{o}C).

Preparation of foods for freezing (e.g. vegetables) include selecting, sorting, washing, blanching and packaging.

Freezing of foods and effects: Quick freezing: -20oC within 30 min (air-blasts of frigid air, direct immersion in refrigerant or indirect contact), slow freezing: 3 to 72 h to attain desired temperature.x Milk, eggs, meat, seafoods, poultry are stored at low temperatures.

Low temperature storage for raw foods

Apricots	0^{o}C
Tomatoes	4^{o}C to 10^{o}C
Lemons	14^{o}C

Types:

Chilling not far above freezing:

Refrigeration 4oC to 10oC, freezing 0^{o}C to 18^{o}C.

Freezing of foods and effects: Quick freezing results in small ice crystals, suppresses metabolism, no protective effect, brief exposure to adverse constituents. On the other hand, slow freezing results in large ice crystals long exposure to injurious factors, gradual adaptation to low temperatures and no shock effect is exerted. Cells viable at freezing may gradually die at frozen sate. Proportion of cells surviving independent of rate of freezing, decline in numbers is rapid at just below freezing point (-2^{o}C) and less at lower temperatures.

Storage stability of frozen foods:

- nutrient concentration
- pH

- aw (water activity)
- packaging: improper leads to freeze burn due to loss of moisture at surface, and product becomes more porous

Cryofreezing:

- Cooling food stuffs in cryogenic gases
- Liquid nitrogen, liquid carbon dioxide
- -196°C in the case of liquid nitrogen
- Different freezers with controls
- Benefits include: Fast in-line freezing and cooling, thus preserving flavor, higher quality of the frozen product compared with slower methods, reduced drip loss on defrosting, less dehydration resulting in a higher yield, lower space requirements, different types of freezers available to suit the requirements of different foodstuffs.

PRESERVATION BY RADIATION:

Radiation is emission and propagation of energy through space or through material medium. Electromagnetic spectrum – radiations used in food preservation are microwaves, ultraviolet rays, gamma rays and X rays, electron beams.

Factors to be considered:

- type of organisms: Gram positive more resistant, spores are resistant, pseudomonads, flavobacters sensitive (*Deinococcus* most resistant)
- number of organisms: Larger the number, less effective
- composition of suspending food: proteins exert protective effect
- oxygen: Radiation resistance is greater in absence of oxygen
- physical state of food: Dried cells are resistant than moist ones
- frozen cells are resistant than nonfrozen cells
- age of organisms: Bacteria resistant to radiation in lag phase, in log phase they are sensitive.

Processing of food for irradiation:

- Selection: freshness and overall desirable quality
- Cleaning: visible dirt and debris to be removed
- Packing: foods to be irradiated packed in containers to prevent post contamination
- Blanching: to inactivate enzymes

Merits:

- sources of radiation are 60Co and 137Cs gamma radiations employed for food preservation by irradiation
- relatively inexpensive, but emits rays in all directions
- electron beams: high efficiency, monodirectional
- processing of small, intricate or non-uniform shapes

Demerits: color changes, and / or off odors

Methods:

- Radicidation: no vegetative cells are detected by standard method (2.5 to 10 kGy)

poultry, fish, condiments
- Radurization: equivalent to pasteurization; substantial reduction of spoilage microbes (0.75 to 2.5 kGy) sea foods, vegetables, fruits
- Radappertization: sterilization (30 to 40 kGy) bacon, beef, chicken

<u>Preservation by Radiation:</u>

	Dose ranges of radiation (Rads)
Enzyme inactivation	3x107
Virus inactivation	107
Radappertization of foods	4x106
Radurization of foods	4x105

<u>Effects of irradiation on foods</u>:
- Free radicals are formed, radiolysis
- Proteins most sensitive (ammonia, hydrogen, carbon dioxide, amides, hydrogen sulphide)
- Storage stability: Depends on dosage

MICROWAVES:
- Increasingly popular
- Between infrared and radio waves
- Specific frequencies 915 megacycles
- Heat produced by microwaves as they pass through food molecules
- Result of extremely rapid oscillation of food molecules to align with electromagnetic field

<u>Preservative effect:</u>

It is due to a function of heat generated by excitation of food molecules that results in microbial destruction.

<u>Legal status of irradiation:</u>
- safe, nutritious, wholesome
- radiolytic compounds have same effect as those of heat treatment
- approved by 60 countries
  applicable to fresh, raw, dry and frozen foods
- American Council on Science and Health supports use of irradiated foods
- science based technology; safe and effective

In 1983 and 2005, U.S. Food and Drug Administration (FDA) approved the use of irradiation for antimicrobial treatments for spices and dried vegetable seasonings The Irradiated food sold with label with internationally recognized irradiation logo:

"Treated by Irradiation"
"Treated by Ionizing Radiation"

OTHER PHYSICAL METHODS:

Smoking

Wood smoke is used for,

- Preservation and flavor enhancement through drying and deposition of chemicals
- Phenols and aldehydes are released
- Antimicrobial properties are rendered
- Meat, cheeses, fish, poultry are smoked generally.
- Chemical compounds include phenols, cresols, carbonyls, organic acids like formic, acetic, propionic, butyric, isobutyric inhibit bacterial growth
- Promote coagulation of proteins on surface
- Carbonyls form brown furfural compounds by combining with free amino groups impart desirable flavor.

Uses of smoke:

- Flavor addition
- Germicidal effect, aid preservation
- Drying
- Chemicals in smoke inhibit mainly bacterial growth
- Hams, dried beef, bacon, soybeans
- Gloss finish outside
- Tenderizing action on meat tissues
- Burning hard wood such as Hickory, Apple wood, Oak, Maple, Beech, Birch, Walnut, Mahogany; even corncobs are used

Effects:

- Temperature 43 to 71oC few hours/ 2-3 days
- Elicits formaldehyde (most effective), acetaldehyde, aliphatic acids – capric, primary and secondary alcohols, ketones, waxes, resins, methyl and propyl isomers of guaiacol, catechol, pyrogallol and other pyroligneous compounds are released.
- Vegetative cells more affected
- Spores are relatively resistant

Liquid smoke:

- Consists of smoke condensates that are produced through the controlled burning of wood chips or sawdust.
- Solution of chemicals similar to those in wood smoke
- To improve flavor and aid preservation

Baking:

Baking serves to kill yeasts during bread making and other effects are,

- Adds flavour to product
- Drives away alcohol
- Inactivates enzymes
- Expand the gas and sets structure
- Moisture removed

Baking process:

- 180oC to 230oC for 20 to 40 min
- Some bakery products in hermetically sealed moisture impermeable packages
- Mold spores on surface are killed
- Preservative effect due to lack of sufficient moisture for growth of bacteria

- Cakes with preservative effect due to high concentration of sugars
- Favors mold growth e.g. Bread mold *Rhizopusstolonifer*
- Another common spoilage of bakery products is ropiness caused by *Bacillus subtilis*
- Toppings with fruits, custard, frostings, sauces more prone to spoilage
- Bacterial endospores survive baking

Frying:

Cooking in oil or fat medium results in much higher temperatures than 100^{o}C- (175^{o}C) at atmospheric pressure, depends on time of frying. Characteristic crispiness, texture and flavour are rendered to the product. Types of frying are stir, pan, shallow and deep frying. Food emerges dry with all vegetative cells killed and longer shelf life is attained at room temperature.

PRESERVATION BY CHEMICALS

Chemical preservatives are considered as food additives. A food additive is a substance or substances other than the basic food stuff which is present in food as a result of any aspect of production, processing, packaging or storage. Those food additives which are specifically added to prevent microbial spoilage are referred to as chemical preservatives.

Organic acids:

Acetic, lactic, propionic, sorbic, benzoic, citric, caprylic, malic, fumaric acids are used. When an acid is added to food, equilibrium favors RCOO-, H+ then acidifies cytoplasm. Little evidence on effect of organic acids on protein synthesis or cell wall synthesis. Undissociated form penetrates cell membrane more easily once inside, acid dissociates since cell interior has higher pH than exterior.

Organic acids inhibitory to *Bacillus, Campylobacter jejuni, Clostridium spp., Escherichia coli, Listeria monocytogenes, Pseudomonas, Salmonella, Staphylococcus aureus.*

Acetic acid and Acetates: (CH3COOH, pKa 4.75, molecular mass 60.05 Da)

Acetic acid is a primary component of vinegar. Na, K, Ca salts, Na, K, Ca diacetates dehydroacetic acid are used. Concentration of 0.1% in bread, pH 5.1, shelf life 6 days at 30^{o}C; inhibits *Bacillus subtilis* growth sodium acetate 1% increases shelf life of catfish by 6 days at 4^{o}C.

Benzoic acid and Benzoates:

They are used as antifungal agent. Effective against *Talaromyces, Pichia* 0.1% level, pH 3.6 to 4.0. Reduces *E. coli* by 3 to 5 log in 7 days at 8oC. *para*-hydroxybenzoic acid esters (parabens), alkyl esters of benzoic acid are also used. They are antimicrobial, esterification of carboxyl group of benzoic acid retains in undissociated upto pH 8.5.

Effective range of pH 3.0 to 8.0. Methyl, propyl, heptyl parabens are used. As alkyl length increases antimicrobial property increases. They are more effective against molds and yeasts and to gram positive bacteria. They interfere with function of cell membrane and have permeabilizing effect and induce potassium efflux related to porin expression in outer membrane of *E. coli.*

Lactic acid and Lactates: (CH3CHOHCOOH) Lactic acid is naturally produced by lactic acid bacteria. It is antimicrobial and flavouring agent in food products. Sodium lactate at 0.2 – 2.5% levels reduce contamination in beef, pork, poultry, fish. At pH 4.0 it is inhibitory to *E. coli.*

Sodium lactate inhibits *Cl. Botulinum, Cl. sporogenes, Yersinia enterocolitica, Listeria monocytogenes and Staphylococcus aureus.* Mixtures of sodium and calcium lactates (1.25 to 6%) are effective in inhibiting *L. monocytogenes* in sea foods.

Propionic acid and Propionates:
Upto 1% propionic acid is naturally produced in Swiss cheese by *Propionibacterium freudenreichii.* Undissociated form is most effective (11 to 45 times more effective than dissociated). Activity of propionic acid depends on pH of substance to be preserved.
Used to inhibit molds mainly; and to inhibit yeasts and bacteria. Propionates retard the growth and concentration used is 0.1 to 5%. Added to bread to prevent *Bacillus subtilis* causing ropiness. It is used for preservation of baked foods and cheeses.

Sorbic acid and Sorbates:
Sorbic acid and sorbates are used as antimicrobial additive in foods as spray, dip, coating on packing materials. They are widely used in cheeses, baked items, beverages, fruit juices, dried fruits, pickles, margarine. they inhibit yeasts and molds; less effective against bacteria. They are effective at low pH; 4 to 6.5 range is used potassium sorbate which is readily soluble in water. Yeasts inhibited are *Candida, Debaryomyces, Saccharomyces, Pichia, Cryptococcus* etc. Fungi like *Alternaria, Aspergillus, Botrytis, Geotrichum, Fusarium, Cephalosporium, Pullularia* and *Mucor.*

Fatty Acid Esters:
Glyceryl monolaurate is active against gram positive bacteria like *Bacillus, Micrococcus, L. monocytogenes.* They inhibit spores of *Bacillus* at100 μg/ml concentration.

Nitrites:
They are used as curing solutions for meats. Nitrite decomposes to nitric acid and forms nitrosomyoglobin with heme pigments in meats. So stable red color is imparted. Nitrites react with amines to form nitrosamines (carcinogenic). They are inhibitory to *Clostridium botulinum* and used for preservation of bacon, ham. Sodium nitrite and potassium nitrite are employed and nitrates have limited effect and not considered as good chemical preservatives and act probably as reservoirs for nitrites.

Sulfur dioxide and Sulfites:
They are used as disinfectants. Salts of SO2 like potassium sulfite and sodium sulfite are used for preservation of fruits and vegetables by controlling spoilage and fermentative yeasts and molds in wine, acetic acid bacteria and malolactic bacteria. Sulfites are employed as antioxidants and to inhibit enzymatic and nonenzymatic browning. The impacting factor is pH, sulfurous acid formed as SO2.H2O form and pH 4.0; it is 500 times more active. It is used to inhibit *E. coli*, yeasts and fungi like *Aspergillus.*

Ethylene and Propylene Oxides:
Ethylene oxide exists as gas. It acts as an alkylating agent and employed as fumigant. It is applied to dried fruits, nuts, spices etc. Hydroxyl ethyl group blocks reactive groups within microbial proteins and inhibits them. Labile H atoms are needed which are supplied from –COOH, -NH2, -SH and –OH. Ethylene oxide is used as gaseous sterilantat 500 to 700 mg/L and used for flexible and semirigid containers. Destruction of *Clostridium botulinum, Cl. porogenes,*

Bacillus coagulans, B. stearothermophilus, Deinococcus radiodurans occurs by ethylene and propylene oxide gases.

Salt and Sugar:

NaCl: At high concentration salt exerts drying effect on food and microorganisms. Levels used are 5 to 20%; results in plasmolysis and used to cure meats and fresh meats.

Sucrose: Mode of action same as salt (water diffuses out of cell); used for fruit preservation, condensed milk, candies etc. Osmophiles and osmodurics (yeast like *Zygosaccharomyces rouxii)* can survive in high sugar foods.

Antibiotics:

They are secondary metabolites produced by microorganisms. They inhibit and kill wide spectrum of other microorganisms. Molds and filamentous bacteria (Genus *Streptomyces*) are main producers. Two antibiotics approved for use in food: Nisin and Natamycin. Former is producedby *Lactococcus lactis*. It is a bacteriocin (antibiotic like) and latter is produced by *Streptomyces natalensis.*

Nisin:

It is a polypeptide. It was first used in cheese to prevent spoilage by *Clostridium butyricum. It is h*eat stable and storage stable. No off flavors are imparted but has narrow spectrum of antimicrobial activity. It is used as heat adjunct in canned foods and typical levels incorporated in foods are 2.5 to 100 ppm. It s mode of action is prevention of germination of spores and act on cell membrane lipids. It inhibits gram positive bacteria.

Natamycin:

This antibiotic is a polyene produced by *Streptomyces natalensis.* It is effective against yeasts and molds at 1 to 25 ppm levels and control growth of fungi in strawberries and raspberries. Mode of action is it binds membrane sterols and induces distortion of selective membrane permeability. Bacteria are insensitive to natamycin due to lack of membrane sterols.

Other antibiotics tried for food applications include tetracyclines: chlor- and oxytetracyclines as approved by FDA at 1 to 7ppm level in uncooked refrigerated poultry to control bacterial spoilage.

Antifungal Agents for Fruits:

Compound	Fruits
Thiabendazole	Apples, pears, pineapples
Biphenyl	Citrus fruits

They are applied to fresh fruits after harvest on surface at 0.5 to 1 g/L levels.

References (if any)

1. Food Microbiology by William C Frazier and Dennis C Westhoff,1998, Fourth Edition, Tata McGraw-Hill Publishing company Ltd.
2. Modern Food Microbiology by J M Jay, 1996, Fourth Edition, CBS Publishers
3. Food Microbiology: Fundamentals and Frontiers by M P Doyle and L R Beuchat, 2007, Third Edition, ASM Press.
4. https://upload.wikimedia.org/wikipedia/en/thumb/0/0c/Radura_international.svg/1024px-Radura_international.svg.png