UNIT – 1

FOOD PRESERVATION BY PRESERVATIVES

DEFINITION, SCOPE AND IMPORTANCE OF PRESERVATION

Food preservation has been defined "as the science which deals with the process of prevention of decay or spoilage of food thus allowing it to be stored in a fit condition for future use". It has also been described as the state in which any food may be retained over a period of time without (1) being contaminated by pathogenic organisms or chemicals (2) losing optimum qualities of colour, texture, flavor and nutritive value.

Food production and supply does not always tally with the demand or meets of the people. In some places there is surplus production of a food product, whereas in some other place there is inadequate supply. Even foods are perishable and semi-perishable like juicy fruits, vegetables, mangoes, tomato, papaya and many more, which very quickly gets spoilt. It is therefore important to improve and expand facilities for storage and preservation of food. Food preservation helps in:

1. Increasing the self-life of foods thus increasing the supply. So many perishable foods can be preserved for a long time.

2. Making the seasonal food available throughout the year.

3. Adding variety to the diet.

4. Saving time by reducing preparation time and energy, as the food has already been partially processed.

5. Stabilising prices of food, as there is less scope of shortage of supply to demand.

6. Decreasing wastage of food by preventing decay or spoilage of food.

7. Improving the nutrition of the population. Preserved foods help people to bring a variety in the diet, thereby decreasing nutritional inadequacies.

PRINCIPLES OF FOOD PRESERVATION

1. Prevention or delay of microbial decomposition of food

- By keeping out micro-organisms (asepsis)
- By removal of micro-organisms (filtration)
- By hindering the growth or activity of micro-organisms (use of low temperature, drying, creating anaerobic conditions or using chemicals).
- By killing the micro-organisms (using heat or irradiation).

2. Prevention or delay of self decomposition of food

- By destruction or inactivation of food enzymes (blanching or boiling)
- By prevention or delay of purely chemical reactions (use of antioxidants to prevent oxidation).

3. Prevention of damage by insects, animals, mechanical causes etc (use of fumigants, cushioning, packaging etc).

1. Prevention or delay of microbial decomposition

i) **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.

ii) **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 and washing etc can also be used but are not very effective.

iii) **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 (15^0C) like root crops, potato, onion refrigerator or chilling temperatures (0-50^0C) like most fruits and vegetables, meat, poultry, fresh milk and milk products and under freezing temperature (-18^0Cto -40^0C) like frozen peas, mushrooms etc.

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.

d. By use of chemicals: Appropriate quantity of certain chemicals added to the food can hinder the undesirable spoilage in the food by

- Interfering with the cell membrane of the micro-organisms, their enzyme activity or their genetic mechanism
- By acting as an anti-oxidant. The optimum quantity of preservative as per approved regulation need to be used as higher concentrations can be a health hazard.
- Chemical preservatives are benzoic acid and its sodium salt, sorbic acid, potassium meta-bi-sulphite, calcium propionates etc.
- Common antioxidants to check off flavour (rancidity) in edible oils include butyl hydroxy anisole (BHA), butyl hydroxy toluene (BHT), tertiary butyl hydroxy quinone (TBHQ), lecithin etc.
- Addition of organic acids like citric, acetic and lactic acid in the food inhibits the growth of many organisms.

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 100^0C (pasteurization) at 100^0C (boiling) or at temperature above 100^0C (sterilization).

i) Pasteurization (heating below 100^0C): 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 62.2^0C for 30 minutes refers to LTLT process.
- Heating at 72^0C for 15 seconds is termed as HTST process.
- Grape wine is pasteurized at $82\text{-}85^0$C for 1 minute and beer is pasteurized at 60^0C.
- Pasteurization of juices depends upon their acidity and method of packing whether in bulk or in bottle or can.
- Bottled grape juice is pasteurized at 76.7^0C for 30 minutes while in bulk the juice is heated to $80\text{-}85^0$C for few seconds by flash treatment.

- Carbonated juice is heated at 65.6^0C for 30 minutes in bottles and vinegar in bulk is held at 60-65^0C for 30 minutes.

ii) Boiling (heating at 100^0C): Cooking of food including vegetables, meat etc by boiling with water involves a temperature around 100^0C. Boiling of food at 100^0C 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 100^0C.
- Various terms used for heating of food are baking (in bread), simmering (incipient or gentle boiling), roasting (in meat) frying (shallow or deep fat frying) and warming up (small increase in temperature up to 100^0C).

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. The temperature in retort at mean sea level is 100^0C; with 5psi pressure at 109^0C; with 10psi pressure at 115.5^0C and with 1 kg/cm2 (100 Pa) pressure at 121.5^0C.

- 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 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.

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, 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.

FOOD SPOILAGE

Food spoilage is the process of change in the physical and chemical properties of the food so that it becomes unfit for consumption. Food spoilage is any undesirable change in food. Most natural foods have a limited life: for example, fish, meat, milk and bread are perishable foods, which means they have a short storage life and they easily spoil. Other foods also decompose eventually, even though they keep for a considerably longer time. The main cause of food spoilage is invasion by microorganisms such as fungi and bacteria.

Microbial spoilage

Microbial spoilage is caused by microorganisms like fungi (moulds, yeasts) and bacteria. They spoil food by growing in it and producing substances that change the colour, texture and odour of the food. Eventually the food will be unfit for human consumption.

When food is covered with a furry growth and becomes soft and smells bad, the spoilage is caused by the growth of moulds and yeasts. Microbial spoilage by moulds and yeasts includes souring of milk, growth of mould on bread and rotting of fruit and vegetables. These organisms are rarely harmful to humans, but bacterial contamination is often more dangerous because the food does not always look bad, even if it is severely infected. When microorganisms get access to food, they utilise the nutrients found in it and their numbers rapidly increase. They change the food's flavour and synthesise new compounds that can be harmful to humans. Food spoilage directly affects the colour, taste, odour and consistency or texture of food, and it may become dangerous to eat. The presence of a bad odour or smell coming from food is an indication that it may be unsafe. But remember that not all unsafe food smells bad.

Physical spoilage

Physical spoilage is due to physical damage to food during harvesting, processing or distribution. The damage increases the chance of chemical or microbial spoilage and contamination because the protective outer layer of the food is bruised or broken and microorganisms can enter the foodstuff more easily. For example you may have noticed that when an apple skin is damaged, the apple rots more quickly.

Chemical spoilage

Chemical reactions in food are responsible for changes in the colour and flavour of foods during processing and storage. Foods are of best quality when they are fresh, but after fruits and vegetables are harvested, or animals are slaughtered, chemical changes begin automatically within the foods and lead to deterioration in quality. Fats break down and become rancid (smell bad), and naturally-occurring enzymes promote major chemical changes in foods as they age.

Enzymic spoilage (autolysis)

Every living organism uses specialised proteins called **enzymes** to drive the chemical reactions in its cells. After death, enzymes play a role in the decomposition of once-living tissue, in a process called **autolysis** (self-destruction) or **enzymic spoilage**. For example, some enzymes in a tomato help it to ripen, but other enzymes cause it to decay. Once enzymic spoilage is under way, it produces damage to the tomato skin, so moulds can begin to can attack it as well, speeding the process of decay.

Enzymic browning

When the cells of fruits and vegetables such as apples, potatoes, bananas and avocado are cut and exposed to the air, enzymes present in the cells bring about a chemical reaction in which colourless compounds are converted into brown-coloured compounds. This is called **enzymic browning**. If the food is cooked very soon after cutting, the enzymes are destroyed by heat and the browning does not occur. For example, apples are prone to discolouration if cut open when raw, but when cooked they do not go brown.

FACTORS AFFECTING FOOD SPOILAGE

They include its water content, environmental conditions, packaging and storage.

Water content

The amount of water available in a food can be described in terms of the water activity (a_w). The water activity of most fresh foods is 0.99. This means that they have a very high water content and can support a lot of microbial growth.

Environmental conditions

No matter whether food is fresh or processed, the rate of its deterioration or spoilage is influenced by the environment to which it is exposed. The exposure of food to oxygen, light, warmth or even small amounts of moisture can often trigger a series of damaging chemical and/or microbial reactions. Changing the environment can help to delay spoilage. For example, storing foods at low temperatures reduces spoilage because both microbial and enzymic decay is faster at higher temperatures.

Packaging and storage

Packaging is a means of safeguarding food when it is raw, or after it has been processed or prepared. It helps to protect food against harmful contaminants in the environment or conditions that promote food spoilage including light, oxygen and moisture. The type of packaging is a key factor in ensuring that the food is protected. Packaging of foods in cans, jars, cartons, plastics or paper also serves to ensure food safety if it is intact, because it provides protection against the entry of microorganisms, dust, dirt, insects, chemicals and foreign material.

PRESERVATION BY CHEMICALS

Preservative is defined as a substance which when added to food is capable of inhibiting, retarding or arresting the process of fermentation, acidification or other decomposition of food. According to Indian Food Laws, the preservatives are classified into following two classes as Class I and Class II preservatives.

i) Class I preservatives: Class1 preservative broadly include naturally occuring substances and there is no maximum limit specified under law for their use. The common examples of class I preservative are common salt, sugar, dextrose, glucose syrup, spices, vinegar or acetic acid, honey and edible vegetable oils.

ii) Class II preservatives: Class II preservatives are chemical substances added to the food. They include sulphurous acid and salts thereof, benzoic acid and salts thereof, sorbic acid including its Na, K and Ca salts, nitrates or nitrites of Na or K, niacin, sodium and calcium propionates, methyl or propyl parahydroxy-benzoate (parabens), propionic acids including esters or salts and Na, K and Ca salts of lactic acid etc. In fruit and vegetable products generally sulphuric acid and its salts, benzoic acid and its salt and sorbic acid and its salt are used. Class II preservatives being chemical substances have maximum limit beyond which they should not be present in different products. Maximum limit for these substances under FPO (Fruit Products order) in different fruit and vegetable products vary between 40 to 2000 ppm (SO_2), 120 to 750 ppm (benzoic acid) and 50 to 500 ppm (sorbic acid) depending upon the type and category of foods. When two or more preservatives are added to the food, their ratio shall be calculated proportionally to their maximum limit.

Benzoic acid and its salt

Widely used as an antimicrobial agent. Benzoate is more effective against yeasts and bacteria than molds. Antimicrobial activity is achieved by inhibition in enzymatic system of microbial cells, affecting acetic acid metabolism, citric acid cycle and oxidative phosphorylation. Antimicrobial activity is affected by pH of medium. The maximum inhibition occurs at pH value of 2.5 to 4.0 and it decreases when pH rises above 4.5.

The food products preserved with the benzoate include fruit juices and drinks, salads, jams and jellies, pickles, dried fruits and preserves, ketch up and sauce, syrup, carbonated beverages, bakery items, salad dressings, margarine and other fat spreads, spices. 0.1% is the permissible limit.

Parabens

Parabens are esters of p-hydroxybenzoic acid. The Parabens are Methylparaben, Ethylparaben, Propylparaben, utylparaben.

Under FDA regulation, Methylparaben and Propylparaben are generally recognized as safe (GRAS) when used as chemical preservatives in foods, with a use limit of 0.1% for each. They are used in processed vegetables, baked goods, fats and oils, seasonings, sugar substitutes, and frozen dairy products in concentrations up to 0.1%. Parabens are the most commonly used because of their low toxicity to humans and their effective antimicrobial activity, especially against molds and yeasts.

Propionic acid and its salts

Propionic acid & its salts (Ca & Na) are used most extensively in the prevention of mold growth and rope development in baked goods and for mold inhibition in many cheese foods and spreads. They are more effective against molds as compared to yeasts and bacteria. Propionates has an upper pH limit for activity around 5 to 6. The maximum concentration allowed is 0.1 per cent.

Sulphur dioxide and sulfites

Sulphur dioxide (SO2) gas is one of the oldest antimicrobial agents. It is a colourless, nonflammable gaseous compound or liquid under pressure with a suffocating pungent odour. When dissolved in water of foods, it yields sulphurous acid and its ions, owing to its solubility in water.

Sulphite salts such as sodium sulphite, sodium bisulphite, potassium sulphite, potassium bisulphite, sodium metabisulphite, potassium metabisulphite used as preservatives. When dissolved in water, form sulphurous acid, bisulphite and ions. Sulphurous acid formed from these compounds is an active antimicrobial substance. The effectiveness of sulphurous acid is enhanced at low pH values. Antimicrobial activity of sulfites against yeasts, molds and bacteria is selective, with certain species being more sensitive to inhibition them others. Bacteria are generally more sensitive to inhibition than yeasts and molds. In addition to antimicrobial action, they are also used, to prevent enzymatic and non enzymatic changes as well as discoloration in some foods. Sulphur dioxide and sulphites are used in dry fruits, fruit products such as fruit juice concentrate, squashes, pickles and chutneys. Maximum permissible limit is 200-300ppm.

Nitrates

The salts of nitrite and nitrate are commonly used for curing meat and other perishable produce. They are added to food to preserve it and also help hinder the growth of harmful microorganisms, in particular Clostridium botulinum, the bacterium responsible for life-threatening botulism. Nitrites, together with nitrates, are also added to meat to keep it red and give flavour, while nitrates are used to prevent certain cheeses from bloating during fermentation.

Epoxides

Epoxides like ethylene oxides and propylene oxide are used in preserving dry items like nuts and spices. They are cyclic ethers and used in gaseous form. The epoxides destroy all microorganisms including spores and viruses.

Antioxidants

Antioxidants play a vital role in extending the shelf life of food. Some examples of antioxidants are Ascorbic acid (E300) or vitamin C is found in many different fruits.
Butylated hydroxyanisole (E320) is a synthetic antioxidant which works by stabilizing free radicals.
Butylated hydroxytoluene (E321) or BHT is another synthetic antioxidant.
Propyl gallate (E310) is a synthetic antioxidant. Its main food use is in products that contain oils and fats.
Tocopherol(E306) is natural antioxidant which are forms of vit E. The most important sources are palm, corn, sunflower, soyabean oil etc.

Acidulants

Acidulants are chemical compounds that give a tart, sour, or acidic flavor to foods or enhance the perceived sweetness of foods. Acidulants can also function as leavening agents and emulsifiers in some kinds of processed foods. Though acidulants can lower pH they do differ from acidity regulators, which are food additives specifically intended to modify the stability of food or enzymes within it. Typical acidulants are acetic acid (e.g. in pickles) and citric acid. Many beverages, such as colas, contain phosphoric acid. Sour candies often are formulated with malic acid. Other acidulants used in food production include: fumaric acid, tartaric acid, lactic acid and gluconic acid.

Antibiotics

Antibiotics are secondary metabolites produced by microorganism such as fungi (Penicillium) and bacteria (Streptomyces, Actionmycetes). These inhibit/kill wide spectrum of microorganisms. Use of antibiotics in foods to control spoilage organism started in 1950 with the use of tetracyclines in poultry. However, antibiotic use in food is not very popular because of risks involved. Some of the antibiotics used in food are;
Tetracyclines
Subtlin

Tylosin
Nisin
Natamycin

Tetracyclines:
Among several antibiotics, chlorotetracycline (CTC) and oxytetracycline (OTC) are well suited to use in fresh foods. Tetracyclines are effective against microorganisms because they inhibit protein synthesis. CTC and OTC were approved as food preservatives in 1955 and 1956, respectively. These are heat sensitive and storage labile. Also used in human and animals to treat disease. These are used for extending shelf life of refrigerated fish and other seafoods, red meat, vegetables, raw milk and other foods. CTC is generally more effective than OTC in controlling spoilage flora. A dose of 7-10 ppm level is known to extend shelf life of refrigerated meat by 3-5 days. Use of CTC with sorbates extends shelf life of fish for up to 14 days. Antibiotics are used as feed supplement. Their use is restricted because the risks outweigh the benefits.

Subtilin:
Subtilin is produced by Bacillus subtilis and is effective against Gram positive bacteria. This is stable to acid treatment and heat resistant (stable at 121^0C for 30-60 min). Subtilin is effective in canned foods at 5-20 ppm level in preventing germinating endospores. It is not used in human medicine and animal feed. The inhibitory effect of subtilin is because of its effect on membrane transport systems.

Tylosin:
Tylosin is effective against Gram positive bacteria. It inhibits protein synthesis by combining with 50S ribosomal subunit. Used mainly in animal feeds, and also to treat some diseases in poultry.

Nisin:
Nisin is a bacteriocin (not antibiotic) produced by some strains of Lactobacillus lactis, and is widely used in food preservation. Bacteriocins are small proteins which inhibit only closely released strains /species of Gram positive bacteria. Nisin is effective against Gram positive bacteria and ineffective against fungi and Gram negative bacteria. The inhibitory effect is due to disruption of cytoplasmic membrane leading to pore formation, thus affecting membrane transport system. Nisin is used in processed dairy foods. Use of nisin in low acid foods (vegetables) allows reduction in processing time and temperature. Used at 1% level in foods. Nisin is desired in food as preservative because it is non toxic, produced naturally by lactic acid bacteria, heat stable, excellent storage stability, destroyed by digestive enzymes, does not contribute for off flavour/odour, and has narrow spectrum of antimicrobial activity. Natamycin This antibiotic is isolated from Strptomyces natalensis and is effective against yeast and molds (antifungal). It is effective in controlling yeasts and molds at much lower concentration (1-25 ppm) than sorbates. These bind to sterols in cell membrane and disrupt selective membrane permeability.

Compounds	Effective against	Application in food	Maximum tolerance
Acetic acid, acetates, diacetates (E260)	Yeasts, bacteria	Baked goods, condiments, confections, dairy products, fats/oils, meats, sauces	0.32%
Benzoic acid, benzoates (E210-E213)	Yeasts, molds	Beverages, fruit products, margarine, flavoured soft drinks (soft drinks or syrups),	0.1%
Dimethyl dicarbonate, Lactic acid, lactates (E270)	Yeasts, bacteria	fermented foods, beverages Meats	
Lactoferrin	Bacteria	Meats	
Lysozyme	Clostridium botulinum, other bacteria	Cheese, cooked meat, and poultry products	
Natamycin (E235)	Molds	Cheese	
Nisin (E234)	Clostridium botulinum, other bacteria	Cheese, cooked meat, and poultry products	1%
Nitrite, nitrate (E249- E252)	Clostridium botulinum	Cured meat	120 ppm
Parabens (alkyl esters (propyl, methyl, heptyl) of p-hydroxy benzoic acid	Yeasts, molds, bacteria (Gram-positive)	Beverages, baked goods, syrups, dry sausage	0.1%
Propionic acid, propionates (E280-E283)	Mold	Bakery products, dairy products	0.32%
Sorbic acid, sorbate (E200-E203)	Yeasts, molds, bacteria	Most foods, beverages, wines beverages (fruit juices, wine and cider), pastries and partially cooked bakery,	0.2%
Sulûte (E221-E226) Sulphur dioxide (E220)	Yeasts, molds	Fruits, fruit products, wines, dry fruits	200-300 ppm

NOTE: GRAS (Generally Recognized As Safe) per Section 201 (32) (s) of the U.S. Federal Food, Drug, and Cosmetic Act.

FERMENTATION

In food processing, fermentation is the conversion of carbohydrates to alcohol or organic acids using microorganisms—yeasts or bacteria—under anaerobic (oxygen-free) conditions. The science of fermentation is known as zymology or zymurgy.

The term "fermentation" sometimes refers specifically to the chemical conversion of sugars into ethanol, producing alcoholic drinks such as wine, beer, and cider. However, similar processes take place in the leavening of bread (CO_2 produced by yeast activity), and in the preservation of sour foods with the production of lactic acid, such as in sauerkraut and yogurt.

Other widely consumed fermented foods include vinegar, olives, and cheese. More localised foods prepared by fermentation may also be based on beans, grain, vegetables, fruit, honey, dairy products, and fish.

Application in the food industry

- Production of fermented foods as cheese, wine, beer, and bread to high-value products
- Food grade bio preservatives
- Functional foods/Neutraceuticals

Some Fermentation in food industries

Dairy Fermentation

Fermented dairy products are made from milk and include, cheese, yogurt, and kefir. The *Lactobacillus delbrueckii ssp. bulgaricus* and *ssp. lactis* are commonly used in freeze-dried yogurt starter cultures. These bacteria, along with *Bifidobacterium*, produce conjugated linoleic acids, vitamins, and bioactive peptides. Yogurt milk contains sucrose and/or glucose or a non-calorie sweetener and a stabilizer such as pectin, starch, or agar. The milk is generally standardized, deaerated, homogenized, and pasteurized prior to inoculation and fermentation.

Kefir has traditionally been produced using kefir grains, which consist of a mixture of lactic acid bacteria, yeasts, and acetic acid bacteria in a polysaccharide and protein matrix. Most kefir produced today is made with a freeze-dried starter culture that contains a similar microbial composition to kefir grains. The diversity in bacteria and the presence of yeast provide a unique flavor different than yogurt, with a small percentage of ethanol.

Meat Fermentation

Examples of fermented meats include pepperoni, summer sausage, and salami. These products can last for months, if not years, due to culturing with *Micrococcus*, *Lactobacillus*, and/or *Leuconostoc*, which are used to bring the pH of the meat to approximately 5.0 over time so that the pH is at the approximate isoelectric of the salt-soluble proteins, myosin and actin. This causes moisture loss such that the water activity and salt content make the product shelf stable. This is a relatively short process of 2–3 days for semidry sausages, like summer sausage. But for dry sausages, like pepperoni and hard salami, it can take 30 days or longer, and more than 90 days for genoa, in which the green room, or fermentation room, has specific temperatures, relative humidity, and air flow to dry the meat and optimize quality.

Vegetable Fermentation

Two fermentation products produced from cabbage include sauerkraut and kimchi. Sauerkraut can be made through natural fermentation or through the addition of a starter culture, while kimchi is made through spontaneous fermentation from vegetables, including cabbage, chives, radishes, and leeks.

UNIT – 2

FOOD PRESERVATION BY LOW TEMPERATURE

REFRIGERATION

Food refrigeration is a preservation process based on the reduction or maintenance of a controlled temperature for a given time and space, usually in cold rooms. This process is based on the extraction of energy from bodies with high thermal energy, thus reducing their energy, and consequently bacterial activity, in this case, in the preservation of foodstuffs. This consists of keeping food at a temperature, between **0 °C and 8 °C**, close to freezing point. It is usually used for fresh food to slow down microbial growth.

When we talk about thermal energy, we refer to the temperature of a given body, since the more thermal energy, the higher the temperature of the body. Conversely, the lower the thermal energy, the lower the temperature.

In addition, to better understand the importance of food refrigeration, it is important to know the cold chain. If we were to analyse our daily food consumption, we would see that the vast majority of them are perishable and therefore need to be refrigerated in order to be consumed in the desired time and form without altering their optimal conditions of consumption.

FREEZING

Freezing preservation is one of the most beneficial preservation methods. It involves, conversion of liquid content of food into ice crystals, which lowers down water activity and microbial growth is arrested due to cold shock. Pure water is frozen at 0^0C but since fruits and vegetables contain number of dissolved solids like sugars, acids, they freeze at below 0^0C.

PROCESS OF FREEZING OR FREEZING CURVE

During freezing the commodity cools down below their freezing point but don′t freeze this phenomenon is called as ***super cooling***. It is shown by AB phase of curve in Fig. Here the temperature of water will be lower than 0 ^{0}C but it will remain in liquid form. At super cooled storage nuclei formation (***nucleation***) which is the first and most important step in ice-crystal formation in freezing process takes place. The second step is called ***crystal growth stage***. The release of heat of crystallization further enhances temperature (BC). Various water molecules gathers around nuclei and due to subsequent addition, crystal growth occurs. Nucleation may be either due to chance orientation of molecule or due to induction of nuclei from outside, but in fruits & vegetable mostly chance nucleation occur. So, time taken by freezing curve from initial cooling to E point of curve is known as ***thermal arrest time***. It determines how quick or slow freezing process is.

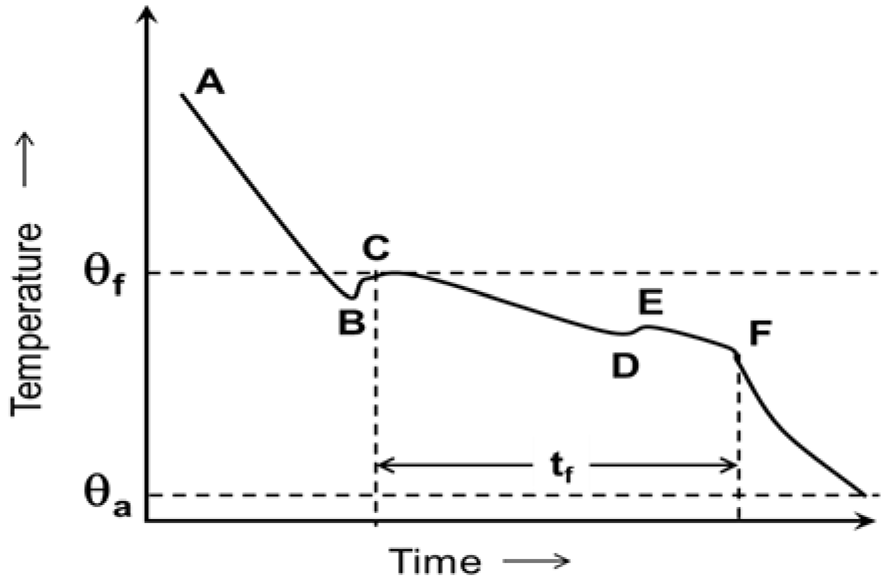


Fig. Schematic diagram of freezing process

Advantages of Freezing

- No nutrient loss
- Retain freshness of commodity.
- Retain colour and flavor constituents.
- No microbial contamination.
- No respiration, hence longer shelf-life.

CHANGES OCCURING DURING FREEZING

As most of the foods have 80% or more water content which gets converted to ice and ice being a solid form of water though chemically same (H2O), it gets hardened. Hardening is attributed to the formation of ice crystals that are interwoven with each other very strongly and provide strength and hardness to ice and the product.

There is an expansion on volume by 6 to 8% when water is converted into ice. This expansion is due to crystal formation and size of ice crystals is directly related to freezing temperature and rate of freezing. When the temperature is very low, rate of freezing or the rate of heat exchange is much faster, the ice crystals formed are smaller in size and fitted more compactly, therefore less expansion in the tissue cells and the reverse happens when the freezing temperature is high. Ice crystals formed during slow freezing are big and hence expansion in the product is much higher.

This expansion may damage tissue cells and distort and deform the product sometimes. Damage in the tissues due to expansion results in higher drip loss or loss of biological exudates, nutrients and weight loss. Freezing makes a product lighter density of ice (0.9) is lesser than pure water hence on freezing ice and the product becomes lighter. This is the reason ice floats in the water.

TYPES OF FREEZING

1. **Slow freezing**: When thermal arrest time is more than 30 min it is called sharp freezing. The temperature may vary from -15 to -29 ^{0}C and freezing may take from 3 to 72 hours. In slow freezing, less number of nuclei is formed and as a result of slow freezing more concentrated solution is left in inter-cellular spaces which causes osmotic effect and liquid comes out from cells. This affects turgidity of cell and they collapse and on thawing cannot regain their original shape. Also, crystals formed are larger in size and pierce the cell membrane, puncture it and damage the cells.
2. **Quick freezing**: Thermal arrest time is less than 30 min. In quick freezing large number of nuclei are formed, hence having large numbers of crystals of smaller size evenly distributed within the cell and in the intercellular space. Since process is very quick, no concentration effect occur and commodities retain their original shape.

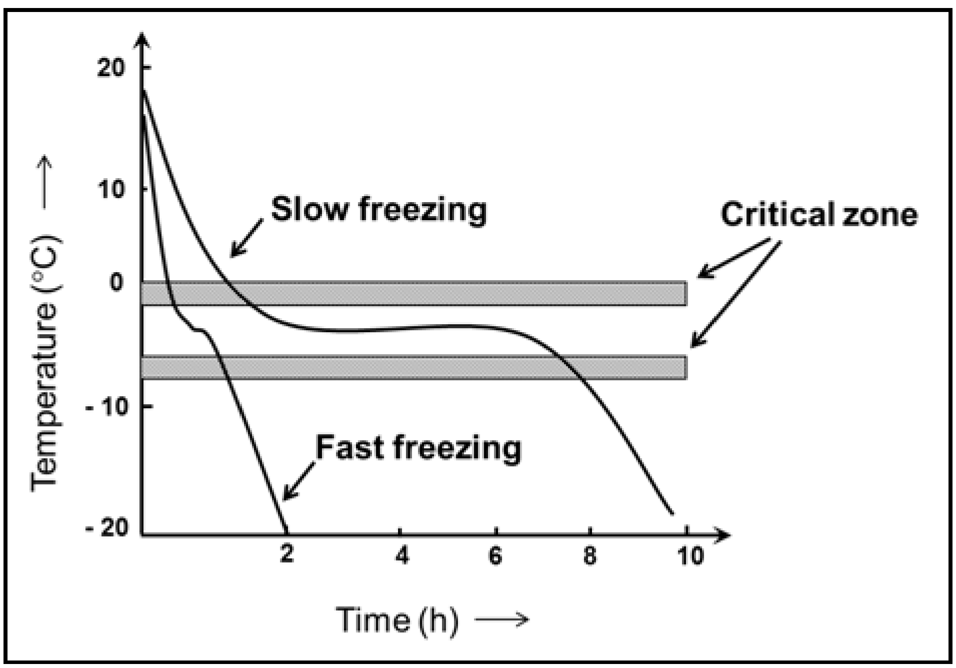
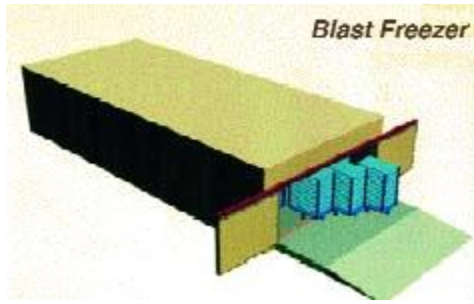


Fig. Schematic diagram of temperature changes of food through the critical zone during freezing process

A. Air-blast freezers

This refers to vigorous circulation of cold air in order to freeze the product. Freezing is done by placing the food stuffs on trays or on a belt which are then passed slowly through an insulated tunnel containing air in it. Hence the air temperature is approximately -18 to -34°C or even lower. This process is economical and a variety of sizes and shapes can be accommodated.

Air blast freezer.

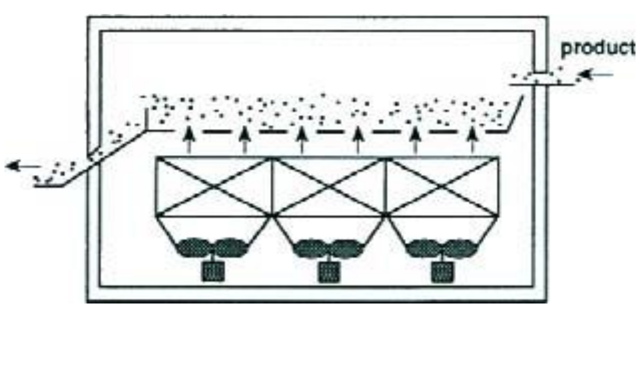


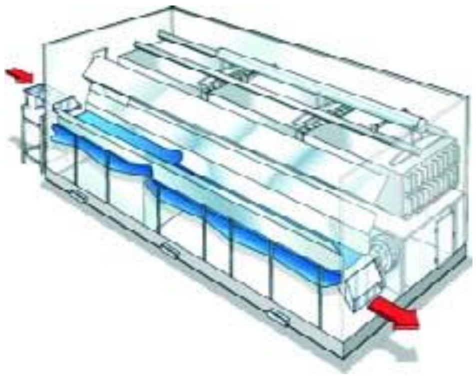
a. **Fluidized bed freezing**

This is a modification of air blast freezing. The food stuff is fluidized to form a bed of particles and then frozen. Air is forced upward through the belt to partially lift or suspend the particles. If the air is appropriately cooled, drying can be done quite speedily. The depth of the bed of particles varies with the product. Solid food particles of the size of peas up to strawberries can be frozen with the depth of 1 to 5 inches. Peas and whole kernel corn are easily fluidized particles and the bed depth used is slightly more than 1 inch. Green beans French beans are partially fluidizable products and the depth is 8 to 10 inches. Fluidized bed freezing has certain advantages

- it gives more sufficient heat transfer and more rapid rates of freezing
- extent to which the product gets dehydrated is less and
- defrosting of equipment is required less frequently

Fluidized bed freezer





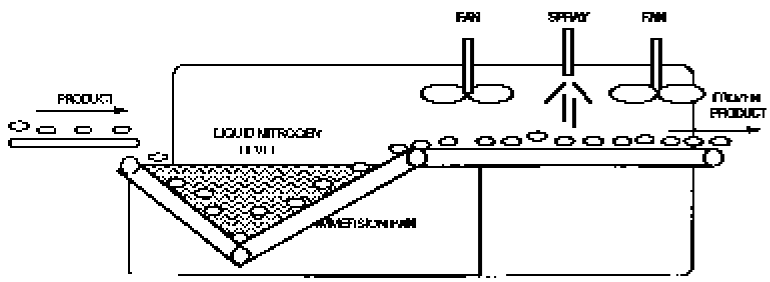
b. **Plate freezing**

In this method food products are placed in contact with a cold surface. The cooling temperature of the metal surface is accomplished by using cold brine or vaporizing refrigerants. This process is suitable for packaged food products which may rest on slide against or be pressed between cold metal plates. The process is also suitable for unpacked food stuffs, example shrimps which can be frozen by freeze adhesion to a slowly rotating cold drum. Fruit juices can also be frozen in cylindrical scraped surface heat exchangers. Contact plate freezing is quite economical. It minimizes problem of dehydration, defrosting of equipment and packet bulging.

B. **Immersion freezers**

The immersion freezer consists of a tank with a cooled freezing media, such as glycol, glycerol, sodium chloride, calcium chloride, and mixtures of salt and sugar. The product is immersed in this solution or sprayed while being conveyed through the freezer, resulting in fast temperature reduction through direct heat exchange. Direct immersion of a product into a liquid refrigerant is the most rapid way of freezing since liquids have better heat conducting properties than air. The solute used in the freezing system should be safe without taste, odour, colour, or flavour, and for successful freezing, products should be greater in density than the solution. Immersion freezing systems have been commonly used for shell freezing of large particles due to the reducing ability of product dehydration when the outer layer is frozen quickly. A commonly seen problem in these freezing systems is the dilution of solution with the product, which can change the concentration and process parameters. Thus, in order to avoid product contact with the liquid refrigerant, flexible membranes can be used.

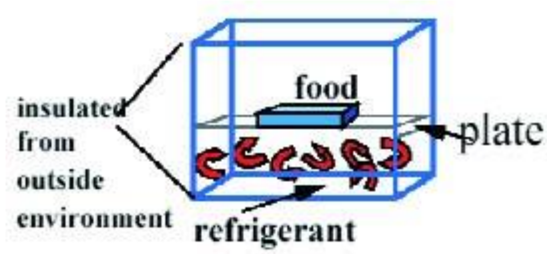
Simple illustration of a typical immersion freezer



C. **Indirect contact freezers**

In this type of freezer, materials being frozen are separated from the refrigerant by a conducting material, usually a steel plate. The mechanism of indirect contact freezer is shown in Figure. Indirect contact freezers generally provide an efficient medium for heat transfer, although the system has some limitations, especially when used for packaged foods due to resistance of package to heat transfer. Additionally, corrosive effects may occur due to interaction of metal packages with heat transfer surfaces.

Indirect contact freezer.



3. **Cryogenic freezing**

Cryogenic freezing is a relatively new method of freezing in which the food is exposed to an atmosphere below -60 °C through direct contact with liquefied gases such as nitrogen or carbon dioxide. The cryogen is in intimate contact with the food and rapidly removes heat from all surfaces to produce high heat transfer coefficients and rapid freezing. The main advantages of cryogenic freezing are as follows:

- Short freezing time due to high heat transfer
- Reduction in flavor loss
- Reduction in drip loss
- Reduction in oxidative changes
- Improved texture of the product
- Suitable for freeze sensitive products

The main disadvantage of cryogenic freezing is relatively high cost of cryogens.

4. **Dehydro-freezing**

It is a process where freezing is preceded by partial dehydration. In case of some fruits and vegetables about 50% of the moisture is removed by dehydration prior to freezing. This has been found to improve the quality of the food. Dehydration does not cause deterioration and dehydro-frozen foods are relatively more stable.

5. **Freeze Drying**

In this process food is first frozen at -18°C on trays in the lower chamber of a freeze dryer and the frozen material dried (initially at 30°C for 24 hours and then at 20°C) under high vacuum (0.1mm Hg) in the upper chamber. Direct sublimation of the ice takes place without passing through the intermediate liquid stage. The product is highly hygroscopic, excellent in taste and flavor and can be reconstituted readily. Mango pulp, orange juice concentrate passion fruit juice and guava pulp are dehydrated by this method.

EFFECT OF FREEZING ON FOODS

The effect of freezing on the food components is diverse, and some components are affected more than others. For example, protein can be irreversibly denatured by freezing, whereas carbohydrates are generally more stable. Other common chemical changes that can proceed during freezing and frozen storage are lipid oxidation, enzymatic browning, flavour deterioration, and the degradation of pigments and vitamins. The main goal of the freezing process is to extend the shelf life of a raw material or product beyond that achievable at temperatures above the initial freezing point of the material. Therefore, it is important to understand the modifications that can occur during freezing in food components and that can further lead to quality degradation. Changes that occur in foods during freezing, storage and thawing can be both chemical and physical in nature. Various chemical, enzymatic and physical changes are promoted as a result of the concentration of components (concentration effects) in the unfrozen water phase within the frozen foods. For example:

- Chemical changes such as oxidative rancidity or oxidation of flavour components, pigments and vitamins.
- Enzymatic reactions such as enzymatic browning or lipolytic rancidity.
- Meats become tougher due to protein denaturation by chemical effects and cell breakage by ice crystals

In freezing foods, the objective is to promote the formation of tiny ice crystals rather than the formation of fewer but larger ice crystals that cause cellular damage. Ice crystal damage can lead to loss of water from the food product once it is thawed. The drip that is found in thawed strawberries or beef is due in part to ice crystal damage to the cells, leading to leakage of cellular fluids into extracellular spaces, and to the loss of water-holding capacity of food components as a result of concentration effects.

Other undesirable changes include formation of package ice and freeze dehydration which is popularly called freezer burn and can produce unsightly food surfaces and loss of nutrients. "Freezer burn" is a misnomer since the food does not "burn" in the freezer but rather takes on an appearance of having been burned because of the moisture loss that occurs during this freeze dehydration.

THAWING

Thawing is the process of taking a frozen product from frozen to a temperature (usually above 0°C) where there is no residual ice, i.e. “defrosting”. Thawing is often considered as simply the reversal of the freezing process. However, inherent in thawing is a major problem that does not occur in the freezing operation. The majority of the bacteria that cause spoilage or food poisoning are found on the surfaces of many foods. During the freezing operation, surface temperatures are reduced rapidly and bacterial multiplication is severely limited, with bacteria becoming completely dormant below -10°C. In the thawing operation these same surface areas are the first to rise in temperature and bacterial multiplication can recommence. On large objects subjected to long uncontrolled thawing cycles, surface spoilage can occur before the centre regions have fully thawed.

Most thawing systems supply heat to the surface and then rely on conduction to transfer that heat into the centre of the food. A few use electromagnetic radiation to generate heat within the food. In selecting a thawing system for industrial use, a balance must be struck between thawing time, appearance, end microbiological condition of product, processing problems such as effluent disposal and the capital and operating costs of the respective systems. Of these factors, thawing time is the principal criterion that governs selection of the system. Appearance, microbiological condition and weight loss are important if the material is to be retailed in the thawed condition but are less important if the food is to be used for further processing.

UNIT – 3

FOOD PRESERVATION BY HIGH TEMPERATURE

BLANCHING

Blanching is used to destroy enzymatic activity in vegetable and some fruits prior to other processing like freezing or dehydration or canning or thermal processing. It is a pretreatment by mild heat for a specific time followed by rapid cooling or passing immediately to the next processing stage. The time and temperature combination varies from product to product, the condition and size of product. Generally the temperature varies from 88 to 99 º C. In some of the fruits and vegetables poly phenol oxydase enzyme is responsible for discoloration in presence of oxygen, hence it needs to be inactivated by blanching pretreatment, before futher processing of fruits and vegetables to maintain its original colour after processing.

Mechanism of Blanching

Plant cells are discrete membrane-bound structures contained within semirigid cell walls. The outer or cytoplasmic membrane acts as a skin, maintaining turgor pressure within the cell. Loss of turgor pressure leads to softening of the tissue. Within the cell are a number of organelles, including the nucleus, vacuole, chloroplasts, chromoplasts and mitochondria. This compartmentalisation is essential to the various biochemical and physical functions. Blanching causes cell death and physical and metabolic chaos within the cells. The heating effect leads to enzyme destruction as well as damage to the cytoplasmic and other membranes, which become permeable to water and solutes. An immediate effect is the loss of turgor pressure. Water and solutes may pass into and out of the cells, a major consequence being nutrient loss from the tissue. Also cell constituents, which had previously been compartmentalized in sub cellular organelles, become free to move and interact within the cell.

The following factors are affecting blanching time:

1. The type of fruit or vegetable.
2. The size of the pieces of food.
3. The blanching temperature and
4. The method of heating

Purpose and Objective of Blanching

The purpose of blanching is to achieve several objectives.

1. To soften the tissue to facilitate packaging.
2. To avoid damage to the product.
3. To eliminate air form the product.
4. To preserve the natural colour.
5. To destroy or retard certain undesirable enzymes.
6. To help preserve natural flavour.

The major purpose of blanching is frequently to inactivate enzymes, which would otherwise lead to quality reduction in the processed product. For example, with frozen foods, deterioration could take place during any delay prior to processing, during freezing, during frozen storage or during subsequent thawing. Similar considerations apply to the processing, storage and rehydration of dehydrated foods. Enzyme inactivation prior to heat sterilization is less important as the severe processing will destroy any enzyme activity, but there may be an appreciable time before the food is heated to sufficient temperature, so quality may be better maintained if enzymes are destroyed prior to heat sterilisation processes such as canning.

It is important to inactivate quality-changing enzymes, that is enzymes which will give rise to loss of colour or texture, production of off odours and flavours or breakdown of nutrients. Many such enzymes have been studied, including a range of peroxidases, catalases and lipoxygenases. Peroxidase and to a lesser extent catalase are frequently used as indicator enzymes to determine the effectiveness of blanching. Although other enzymes may be more important in terms of their quality-changing effect, peroxidase is chosen because it is extremely easy to measure and it is the most heat resistant of the enzymes in question. More recent work indicates that complete inactivation of peroxidase may not be necessary and retention of a small percentage of the enzyme following blanching of some vegetables may be acceptable.

Blanching causes the removal of gases from plant tissues, especially intercellular gas. This is especially useful prior to canning where blanching helps achieve vacuum in the containers, preventing expansion of air during processing and hence reducing strain on the containers and the risk of misshapen cans and/or faulty seams. In addition, removing oxygen is useful in avoiding oxidation of the product and corrosion of the can. Removal of gases, along with the removal of surface dust, has a further effect in brightening the colour of some products, especially green vegetables.

Shrinking and softening of the tissue is a further consequence of blanching. This is of benefit in terms of achieving filled weight into containers, so for example it may be possible to reduce the tin plate requirement in canning. It may also facilitate the filling of containers. It is important to control the time/temperature conditions to avoid over processing, leading to excessive loss of texture in some processed products. Calcium chloride addition to blanching water helps to maintain the texture of plant tissue through the formation of calcium pectate complexes. Some weight loss from the tissue is inevitable as both water and solutes are lost from the cells.

A further benefit is that blanching acts as a final cleaning and decontamination process. It also removes pesticide residues or radionuclides from the surface of vegetables, while toxic constituents naturally present (such as nitrites, nitrates and oxalate) are reduced by leaching. Very significant reductions in microorganism content can be achieved, which is useful in frozen or dried foods where surviving organisms can multiply on thawing or rehydration. It is also useful before heat sterilization if large numbers of microorganisms are present before processing.

Principles of Blanching

Blanching is achieved in hot water for a short period of time or in an atmosphere of steam. In water blanching, the product is moved through water usually maintained at a temperature between 88 and 99 ^{o}C. In steam blanching the product is carried on a belt through a steam chamber into which live steam is constantly injected. The steam chamber is hooded and equipped with exhaust and also a drain for the condensate. The time temperatures are regulated for each specific product to achieve the desired enzyme inactivation, colour preservation and other characteristics. As a guide, the operator utilizes either the catalase or the peroxidase tests to determine the adequacy of blanching. Currently the peroxide test is commonly used in industry. For the most part, a negative peroxidase test is necessary to prevent the development of undesirable characteristics in the finished product. Immediately after blanching, vegetables are quickly cooled, usually in cold water, which often serves as means to convey the product to the next operation. A rod type cylindrical reel connected to the discharge of blancher and equipped with water sprays also serves as an excellent cooling system.

Processing Conditions for Blanching

It is essential to control the processing conditions accurately to avoid loss of texture, weight, colour and nutrients. All water-soluble materials, including minerals, sugars, proteins and vitamins, can leach out of the tissue, leading to nutrient loss. In addition, some nutrient loss (especially ascorbic acid) occurs through thermal liability and, to a lesser extent, oxidation.

Ascorbic acid is the most commonly measured nutrient with respect to blanching, as it covers all eventualities, being water soluble and hence prone to leaching from cells, thermally labile, as well as being subject to enzymatic breakdown by ascorbic acid oxidase during storage. Wide ranges of vitamin C breakdown are observed, depending on the raw material and the method and precise conditions of processing.

The aim is to minimize leaching and thermal breakdown while completely eliminating ascorbic acid oxidase activity, such that vitamin C losses in the product are restricted to a few percent. Generally steam blanching systems give rise to lower losses of nutrients than immersion systems, presumably because leaching effects are less important.

Blanching is an example of unsteady state heat transfer involving convective heat transfer from the blanching medium and conduction within the food piece. Mass transfer of material into and out of the tissue is also important. The precise blanching conditions (time and temperature) must be evaluated for the raw material and usually represent a balance between retaining the quality characteristics of the raw material and avoiding over-processing.

The following factors must be considered for deciding processing conditions of blanching:

1. Fruit or vegetable properties, especially thermal conductivity, which will be determined by type, cultivar, degree of maturity etc

2. Overall blanching effect required for the processed product, which could be expressed in many ways including: achieving a specified central temperature, achieving a specified level of peroxidase inactivation, retaining a specified proportion of vitamin C.

3. Size and shape of food pieces

4. Method of heating and temperature of blanching medium

Time/temperature combinations vary very widely for different foods and different processes and must be determined specifically for any situation. Holding times of 1–15 minutes at 70–100 ºC are normal

Methods of Blanching

The two most widespread commercial methods of blanching involve passing food through an atmosphere of saturated steam or a bath of hot water. Both types of equipment are relatively simple and inexpensive. Microwave blanching is not yet used commercially on a large scale. There have been substantial developments to blanchers in recent years to reduce the energy consumption and also to reduce the loss of soluble components of foods, which reduces the volume and polluting potential of effluents and increases the yield of product.

Conventional steam blanching consists of conveying the material through an atmosphere of steam in a tunnel on a mesh belt. Uniformity of heating is often poor where food is unevenly distributed; and the cleaning effect on the food is limited.

However, the volumes of waste water are much lower than for water blanching. Fluidised bed designs and ‘individual quick blanching’ (a three-stage process in which vegetable pieces are heated rapidly in thin layers by steam), held in a deep bed to allow temperature equilibration, (followed by cooling in chilled air) may overcome the problems of non uniform heating and lead to more efficient systems.

The two main conventional designs of hot water blancher are *reel* and *pipe* designs. In reel blanchers, the food enters a slowly rotating mesh drum which is partly submerged in hot water. The heating time is determined by the speed of rotation. In pipe blanchers, the food is in contact with hot water recirculating through a pipe. The residence time is determined by the length of the pipe and the velocity of the water. There is much scope for improving energy efficiency and recycling water in either steam or hot water systems. Blanching may be combined with peeling and cleaning operations to reduce costs.

Following the microwave heating, the vegetable material is subjected to blanching comprising heat treating in a current of hot air at temperature 100 to 150ºC. The heating is conducted in an environment which prevents loss of water from the vegetable material and this may readily achieved by introducing steam in to the oven.

Equipment for Blanching

a) Steam Blanchers

At its simplest a steam blancher consists of a mesh conveyor belt that carries food through a steam atmosphere. The residence time of the food is controlled by the speed of the conveyor. In conventional steam blanching, there is often poor uniformity of heating in the multiple layers of food. To overcome this Individual Quick Blanching (IQB) was introduced which involves blanching in two stages. In the first stage food is heated in single layer to a sufficiently high temperature. In the second stage a deep bed of food is held for sufficient time to allow the temperature at the center of each piece to increase to that needed for enzyme inactivation.

b) Hot Water Blanchers

There are a number of different designs of blanchers each of which retains the food in hot water at 70 – 100 ºC for a specific time and thus removes it to a dewatering-cooling section. It has three sections: a pre-heating stage, a launching stage and a cooling stage. The food is preheated with water that is circulated through a heat exchanger. After blanching a second re-circulation system cools the food. The two systems pass water through the heat exchanger and this heats the pre-heat water and simultaneously cools the cooling water. A re-circulated water-steam mixture is used to blanch the food and final cooling is done by cold air.

CANNING

The process of sealing fruits and vegetables or any other foodstuffs hermetically (air tight) in containers and sterilizing them by heat for long storage is known as canning. In 1809, Nicholas Appert of France invented this process and he is called as Father of Canning. The process of canning is also known as Appertization. Fruits and vegetables are canned in the season when the raw material is available in plenty. The canned products are sold in off-season and give better returns to the grower.

Sorting and grading

Sorting and grading are terms which are frequently used interchangeably in the food processing industry, but strictly speaking they are distinct operations. Sorting is a separation based on an individual physical property of raw materials such as weight, size, shape, density, photometric property, etc. while grading is classification on the basis of quality incorporating commercial value, end use and official standards. The selection of fruits and vegetables is important from processing point of view for the manufacture a particular end product. The fruit should be ripe, but firm and evenly matured while vegetable should be tender and reasonably free from soil, dirt, etc. They should be free from blemishes, insect damage and malformation. Over ripe fruit is generally infected with microorganisms and would yield a poor-quality finished product. After this preliminary sorting, the fruits and vegetables are graded. This is necessary to obtain a pack of uniform quality as regards size, colour, etc. It is done manually or with the help of grading machines.

Washing

The graded fruits and vegetables are washed with water in different ways, such as soaking and subsequent washing in running water or sprayed with water or dry air to remove surface adhering material. A thorough wash is very essential for improved microbiological quality of final product. Vegetables may preferably be soaked in a dilute solution (0.1%) of potassium permanganate or sodium hypochlorite solution to disinfect them. Agitation of the washing water is effected generally by means of compressed air or a force pump or propeller-type equipment. Among all, spray washing is the most efficient method.

Size reduction

Fruits and vegetables are processed either as whole or into small pieces by size reduction. Size reduction involves peeling, coring and sizing. Peeling is done to remove unwanted or inedible material and to improve the appearance of the final product using a peeler while coring is done to remove central inedible portion using a corer. There are five main methods of peeling. They are flash peeling (e.g. for root crops), knife peeling (e.g. for citrus fruits), abrasion peeling (e.g. for potato), caustic peeling (e.g. for guava, orange segments) and flame peeling (e.g. onion and garlic). Some of these are given below:

a. Hand peeling

Many of the fruits and vegetables are peeled and cut by hand with the help of special knives.

b. Peeling by heat

Some fruits and vegetables, particularly certain varieties of peaches and potatoes, are scalded in steam or boiling water to soften and loosen the skin, which is subsequently removed easily by hand. It usually involves exposing the fruit or vegetable to a temperature of 40^{o}C for 10-60 seconds where by the skin bursts and retracts facilitating its easy removal by means of pressure sprays. To achieve good results, the fruits and vegetables should be of uniform size and maturity. Using this method, there is practically no loss of flavour and the product is of uniform colour, free from any blemishes.

c. Lye peeling

Fruits and vegetables such as peaches, apricots, sweet orange, carrots, sweet potatoes, etc. are generally peeled by dipping them in boiling caustic soda or lye solution of 1 to 2 percent strength, for short periods, ranging from 0.5 to 2 minutes depending on the maturity of the fruit or vegetable. The hot lye loosens the skin from the flesh underneath. The peel is then removed easily by hand. Any traces of alkali is removed by washing the fruit or vegetable thoroughly in running cold water or preferably by dipping it for a few seconds in a very weak solution of hydrochloric or citric acid.

d. Flame peeling

It is used only for garlic and onion which have a papery outer covering. This is just burnt off.

Fig. Pineapple corer

Blanching

Blanching refers to the mild heat treatment given to fresh produce such as vegetables to inactivate enzymes. Polyphenol oxidase (PPO) is most important groups of enzymes causing browning, off-flavour development in fruits and vegetables. PPO cause oxidation of phenolic compound namely Catechin, Gallic acid, Chlorogenic acid and Caffeic acids. Besides PPO certain peroxidase and pectic enzymes also require inactivation. Pectic enzymes such as Pectin methyl esterase (PME) and Polygalacturonase (PG) are highly heat resistant and if failed to inactivate may lead to loss of cloud in citrus juices and serum separation in fruits and vegetables products, respectively. Their inactivation is the index of blanching. Blanching also improves colour, flavour and nutritional quality. Usually it is done with boiling water or steam for short periods, followed by cooling. In small scale industries, the fruit or vegetable to be blanched is placed in a wire of perforated basket, which is first dipped in hot water (88-99ºC) for about 2-5 minutes. Microwave treatment is also used for blanching. Blanching requirement varies with different fruit or vegetable and depends upon relative enzyme concentration and maturity of commodity.

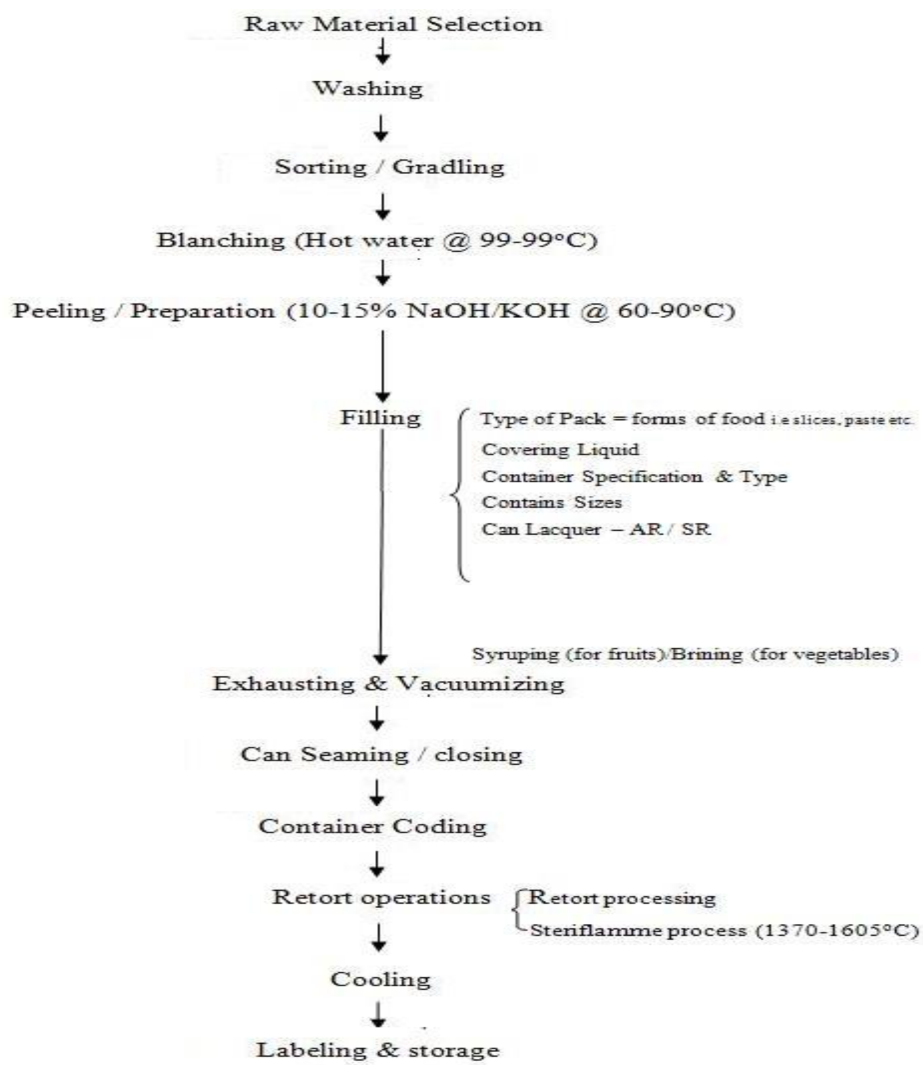


Fig. Flow diagram for the canning process of fruits and vegetables

Can filling

Can filling is the process of aseptically filling whole or sized fruit or vegetables into the containers. The cans are washed with water or subjected to steam jet to remove any adhering dust or foreign matter. Tin cans made of thin steel plate of low carbon content, lightly coated on either side with tin metal to a thickness of about 0.25 mm are usually used in canning. The thickness of coating varies from 0.31 mm to 1.54 mm. The following are the different types of base plates used for can manufacture:

A) Type L: It is a high purity steel with low metalloid and residual content. This kind of base plate is used for highly acidic foods.
B) Type MR: It is a low metalloid steel with no severe restriction on residual content. It is used for moderate acid foods.
C) Type MC: It is similar to MR type but has high phosphorus content to give mechanical strength or stiffness. It is usually used for low acid foods.

Lacquering

It is difficult to coat steel plate uniformly with tin during the process of manufacture. Small microscopic spaces are always left uncoated, although the coating may appear perfect to the naked eye. The content of the can may react with the exposed parts of container and cause discolouration of the product or corrosion of the tin plate. When the corrosion is severe, the steel is attacked and black stains of iron sulphide are produced. Hence, it is necessary to coat the inside of the can with some material like lacquer, which would prevent discolouration, but would not impart its own flavor or injure the wholesomeness of the contents. The process of coating of inner side of the can to prevent discolouration of the product is called as lacquering. Lacquers include oleo-resinous material, synthetic resins, phenolic resins, epoxy resins and vinyl resins. There are two types of lacquers: (a) acid resistant and (b) sulphur resistant. The acid-resistant lacquer is ordinary gold coloured enamel and the cans treated with it are called as A.R-enamel cans. The sulphur-resistant lacquer is also of golden colour and the cans coated with it are called C-enamel cans or S.R. cans. Acid-resistant cans are used for packing of fruits of the acid group with soluble colouring matter such as raspberry, strawberry, red plum, coloured grapes, etc. Sulphur-resistant cans are used for non-acid products like peas, corn, beans, etc.

Syruping and brining

In canning, syrups are added to fruits whereas brine (salt solution) is added to the vegetables. Purpose of adding syrups or brine is to improve the flavor, fill the space between the pieces of canned product and aid in the heat transfer during sterilization. Cane sugar, glucose syrup, invert sugar and high fructose corn syrups are used for canning. Brine containing 1 to 2 percent of common salt is generally used for vegetables. Strength of syrup is measured by using hydrometer or a refractometer while strength of brine is measured by salometer or salinometer. The syrup or brine should be added to the can at a temperature of about 90^0C, leaving suitable headspace in the can.

Exhausting

Exhausting usually means heating the can and can contents before sealing. Sometimes it may also refer to the treatment of the container under a mechanically produced vacuum. But in either case it is done to remove air from the can interior and prevent corrosion. It also prevents undue strains upon the can during sterilization and prevents overfilling of can contents. Removing of air also helps in better retention of vitamins especially of vitamin C. The other advantages of the exhaust process are prevention of bulging of the can when stored at high altitudes or in hot climates. In heat exhaust method, the cans are generally passed through a tank of hot water at about 92-97ºC or on a moving belt through a covered steam box. The time of exhaust varies between 5 to 25 minutes. After exhausting cans are immediately sealed with the help of double rolling operation of seamer.

Processing of the cans

The term processing as used in canning technology, means heating of canned foods (fruits, vegetables and other food stuffs) to inactivate bacteria. This is also called as retorting. Processing consists of determining just the temperature and the extent of cooking that would suffice to eliminate all possibilities of bacterial growth. In retort, saturated steam is supplied to heat the product. Time-temperature combination of processing depends upon the type and physical state of the product, the heat resistance of microorganisms or enzymes likely to be present in the food, the heating conditions, pH of the food, and size of the can to get complete sterility. In low acid foods (pH > 4.5), *Clostridium botulinum* is the most dangerous heat resistant spore forming pathogen likely to be present. Under anaerobic conditions inside a sealed can it can grow to produce a powerful exotoxin, botulin, which is sufficiently potent to be 65% fatal to humans. Because of the extreme hazard from botulin, the destruction of this microorganism is therefore a minimum requirement of heat processing (i.e. in canning and sterilization). Normally foods receive more than this minimum treatment as other more heat-resistant spoilage bacteria may also be present. In more acidic foods (pH 4.5 - 3.7), other microorganisms (e.g. yeast and fungi) or heat-resistant enzymes are used to establish processing times and temperatures. In acidic foods (pH < 3.7), enzyme inactivation is the main reason for processing and hence, heating conditions are less severe. The preservative effect of heat processing is due to the denaturation of proteins, which destroys enzyme activity and enzyme-controlled metabolism in microorganisms.

The rate of destruction is a first-order reaction; that is when food is heated to a temperature that is high enough to destroy contaminating microorganisms, the same percentage die in a given time interval regardless of the number present initially. This is known as the logarithmic order of death and is described by *thermal death rate* curve. The time needed to destroy 90% of the microorganisms (to reduce their numbers by a factor of 10) is referred to as the decimal reduction time or ***D-value***. D-values differ for different microbial species and a higher D-value indicates greater resistance. The thermal destruction of microorganisms is temperature dependent and cells die more rapidly at higher temperature.

Cooling

Immediately after processing, cans are cooled to room temperature in cold water bath or water tank. Once cooling is carried out, the outer surface is dried and labelled.

CONTAINERS USED IN CANNING

Glass containers: Glass containers are chemically inert, clear, transparent, rigid, resist internal pressure, heat resistant and are cheap in comparison to other packaging materials. Glass containers are the excellent barriers to solid, liquids and gases. They preserve food against odor and flavour contaminations. But when faulty closures are used odour and flavour contamination may occur, hence; the closure should be air tight. Glass does not deteriorate with age in comparison to other packaging material but are light in weight and are fragile (breakable) with thermal shock and impact.

Types of glass containers

1. Bottles: The bottles have narrow neck and small closure over the top. Narrow neck facilitates pouring and reduces the size of closure. Bottles are used for packing liquids and small sized solids.

2. Jars: They do not have any appreciable neck but are wide mouthed bottles. They are easy to clean and easy to take out product from them. They are used for packing jams and powders.

3. Tumblers: They are similar to jars but do not have any neck and no finish. They can be used for packing jams and jellies.

4. Jugs: These are large sized bottles with carrying handlers. Used for packing liquids, foods in large quantities like ½ gallon or more.

5. Vials: These are small glass containers. Vials used for packing pharmaceuticals while ampoules are used for packing small quantity like spices, food colors, aroma, essences etc.

Properties of glass containers

1. Glass containers are chemically inert: Almost all types of chemicals can be packed in the glass containers except hydrofluoric acid (it eats the glass hence packed in plastic container). Oils and fats have no reaction with the glass. Water has little or negligible reaction with the glass at low temperature. The products like drugs and transfusion liquids are packed in specially treated glass containers as at higher temperature (during sterilization) the hydrogen from the water is displaced.

2. Clarity of glass containers: Products packed in glass containers are easily visualized from outside especially useful for the products kept on the shelves. But some nutrients are packed in colored bottles e.g. brown bottles, amber colored bottles. Opal glass is a ground glass, in which visibility is lost.

3. Glass containers are rigid containers: Rigidity helps in filling of containers and make it possible for stacking. It also helps in loading and vacuum filling of containers. It also provides support to the material.

4. Glass containers resist the internal pressure: Glass containers offers resistant against internal pressure brought about by CO2 or other gases in the product e.g. beer, beverages, soft drinks etc.

5. Heat resistant: Glass containers are heat resistant in comparison to other packaging material except cans. A temperature of 1500 ^{0}C is applied during manufacturing of glass. Melting point of alumina is 2000 ^{0}C, which is used for making glass. Viscous hot materials are poured into glass containers while they are still hot.

Disadvantages of glass:

Glass containers are fragile/brittle, hence great care is required to be exercised during handling. Glass containers are heavy in weight. Glass containers are not easy to dispose.

Closures: Closures should prevent loss of contents and must make reseal (crown corks do not make reseal). Closure should not react with the product e.g. in ketchup, formation of black neck takes place. Different types of closures are Crown corks, roll on cap, lug cap, vacuum seal, temper proof, snap fit, press on caps and screw caps.

Procedure for bottling

The bottles are thoroughly washed and sterilized. The fruit slices are filled leaving about 3 cm space at the top of the jar or bottle. The sugar syrup recommended for different fruits is filled boiling hot leaving a head space of 1-1.5 cm.

Exhausting and sterilization:

Separate exhausting of bottles is not required and it is done simultaneously with sterilization by putting a pad of cloth (false bottom) under the bottles. The bottles should not be abruptly immersed in hot water, otherwise they may break because of sudden rise in temperature. The temperature of the water should be about the same as that of the contents and should be raised gradually and the bottles kept in the boiling water for the required time. At the start of sterilization, the lids are left loose and the level of boiling water should come up to the neck of the bottle. When sterilization is over, the mouths of bottles and jars should be immediately closed or corked tightly. Cooling of bottles is done and the bottles are labeled after drying. The products preserved in bottles require more attractive labels.

Store in cool and dry place. Thus, canning and bottling is a well tested acceptable method of preservation of fruit and vegetable for conversion into stable products. For canning no chemical preservative is used. Shelf-life of adequately processed product in cans is around one year. Keeping in view the versatility of the process, canning and bottling of fruit and vegetable can be adopted as a successful enterprise.

SPOILAGE ENCOUNTERED IN CANNED FOODS

Chemical spoilage

The chemical spoilage in most cases is due to production of hydrogen gas produced in can because of action of acid of food on iron of can. This spoilage is termed as Hydrogen swell. It occurs due to following factors:

a) Increased storage temperature.

b) Increased acidity of food

c) Improper exhaust

d) Presence of soluble sulfur and phosphorous compounds

e) Improper timing and lacquering of can at internal surfaces

Biological spoilage

The cause of biological spoilage is microbial activity. In heat treated cans, the growth of microorganisms occur due to:

Leakage of can

It occurs because of manufacturing defects, punctures or rough handling. Bacteria are introduced into can by either in holes or improper seams. In this type, the microorganisms are not usually heat resistant and wide array of organisms had been found to cause spoilage as it is post processing contamination. Microbes may also get entry into can due to cold water, used to cool cans after heat treatment. Leakage may also be responsible for release of vacuum, which can favor the growth of microorganisms. Presence of low heat resistance organisms usually indicates leakage of can.

Under processing

It includes sub-optimal heat treatment, faulty retort operations, excessive microbial load and contamination in product, change in consistency of the product.

Microbial Spoilage of Canned Foods

The microbial spoilage of canned food is classified as caused by thermophilic bacteria and mesophilic organisms. Most common spoilages of microbial origin are known as flat sour spoilage, Thermophilic anaerobic (TA) spoilage and putrefaction. These different types are briefly described here.

Spoilage by thermophilic spore forming bacteria

Spoilage by these types of bacteria is most prevalent in under processed heat treated canned foods. Their spores survive the heat treatment and undergo vegetative cell formation and subsequent growth in canned conditions. Major spoilages by these organisms are:

Flat sour spoilage

This is caused by souring bacteria. One characteristic of this spoilage is that ends of can remain flat during souring. Because of this condition, the detection of spoilage from outside is not possible thereby culturing of contents become necessary to detect the type of organisms. Main organisms involved are *Bacillus,* while it occurs more frequently in low acid foods. *Bacillus* spp. has ability to produce acid without gas formation.

TA spoilage

This type of spoilage is caused by thermophilic anaerobe not producing hydrogen sulfide. *Clostridium thermosaccharolyticum* is the main organism involved. It produces acid and gas in foods. Spoiled food produces sour or cheesy smell.

Sulfur stinker spoilage

This type of spoilage occurs in low acid foods and primarily *Desulfotomaculum nigricans* is involved. The spores of these organisms are destroyed at optimal heat treatment, thus presence of this organism usually indicates under processing in terms of heat treatment. It produces hydrogen sulfide which produce typical odour.

Spoilage by Mesophillic Spore formers

Bacillus and Clostridium are involved in this type of spoilage which is usually indicative of under spoilage.

Spoilage by Non-Spore Formers

Presence of non spore formers in cans indicate post processing contamination. The organisms whose vegetative cells are heat resistant are more readily found. Following organisms are more prominent:

Enterococcus	*Streptococcus thermophilus*
Micrococcus	*Lactobacillus*
Leuconostoc	*Microbacterium*

Presence of these organisms indicates leakage of container. Cooling water is one of the important source of contamination, thus coilforms also gain entry into the can through leakage.

Spoilage by Fungi

Yeasts

Yeasts and their spores are not thermo tolerant, thus they are not found in suitably heat treated cans. Their presence indicates under processing or post pasteurization contamination through leakage. Fermentative yeasts are more prominent and they produce carbon dioxide, thus causing swelling of cans. Film yeasts too can grow on the surface of the food products.

Molds

Among molds, *Aspergilus* and *Penicillium* are most spoiling organisms. These can grow at high sugar concentration. Acidification is considered method of preventing growth of molds. Some of the molds are resistant to heat. Molds are more common in home canned foods where heating as well as sealing is not under total aseptic conditions.

PASTEURIZATION

It is the process of heating a food-usually a liquid-to or below its boiling point for a defined period of time. The purpose is to destroy all pathogens, reduce the number of bacteria, inactivate enzymes and extend the shelf life of a food product. Pasteurization treatment is able to kill most heat resistant non spore forming organisms like *Mycobacterium tuberculosis* and *Coxiella burnetti*. Foods with a pH of less than 12.6, such as milk and spaghetti sauce, can be pasteurized. Permanent stability that is, shelf life of about two years is obtained with foods that can withstand prolonged heating, such as bottled juices. There is a greater loss of flavour from foods that are exposed to a longer time-temperature relationship. Therefore, temporary stability (that is, limited shelf life) is only obtained with some foods where prolonged heating would destroy its quality. These foods, such as milk, usually require subsequent refrigeration. "High Temperature Short Time" (HTST) and "Ultra High Temperature" (UHT) processes have been developed to retain a food's texture and flavour quality parameters. Pasteurization is not intended to kill all microorganisms in the food. Instead pasteurization aims to reduce the number of viable pathogens so that they are unlikely to cause disease. Pasteurization involves a comparatively low order of heat treatment, generally at temperature below the boiling point of water. Heating may be done by means of steam, hot water, dry heat or electric currents. Products are immediately cooled. Desired pasteurization can be achieved by a combination of time and temperature such as heating food to a low temperature and maintain for a long time i.e. LTLT - 62.8°C for 30 minutes or by heating food to a high temp and maintain for a short time - HTST - 71.7°C for 15 second.

Pasteurization is used when more rigorous heat treatment might harm the quality of the food product, as the market milk and for the main spoilage organisms which are not heat resistant, such as yeast in fruit juice. It also kills the pathogens.

Ultra heat pasteurization

In this process milk is heated to 120-138°C for 2-4 seconds and followed by rapid cooling. This treatment kills all the spoilage microorganisms. UHT pasteurized milk is packaged aseptically.

The word pasteurization is derived from the name of an eminent French scientist Louis Pasteur (1860), who found that heating certain liquids specially wines to a high temperature improved their keeping quality. Pasteurization came into use on a commercial scale in the dairy industry shortly after 1880 in Germany and Denmark. This process is widely employed in all branches of dairy industry. Heat treatment destroys microorganisms present in milk. Further, a more or less complete inactivation of enzymes occurs, depending on temperature and treatment time. In order to retain as many sensory and nutritive properties of the raw materials as possible, different heating methods have been developed to destroy pathogenic organisms (pasteurization) or destroy all microorganisms and inactivate enzymes (sterilization).

Definition

According to International Dairy Federation (IDF), pasteurization can be defined as ‘a process applied to a product with the object of minimizing possible health hazards arising from pathogenic microorganisms associated with milk by heat treatment, which is consistent with minimal chemical, physical and sensory changes in the product’.

In general, the term pasteurization as applied to market milk refers to the process of heating every particle of milk to at least 63°C for 30 min or 72°C for 15s or to any temperature-time combination which is equally efficient, in a properly operated equipment. After pasteurization, the milk is immediately cooled to 5°C or below.

Importance of Pasteurization

• To render milk safe for human consumption by destroying all the pathogenic microorganisms.

• To improve the keeping quality of milk by killing almost all spoilage organisms (88-99%).

Drawbacks of Pasteurization

• It may encourage slackening of efforts for hygienic milk production and may mask low quality milk.

• It diminishes the cream line or cream volume.

• Pasteurized milk may increase the renneting time.

• It fails to destroy bacterial toxins

• In India, pasteurization is not necessary as milk is invariably boiled on receipt by the consumer

Methods of Pasteurization

Low-temperature long-time (LTLT)/Batch pasteurization

Milk is heated, held and cooled in the inner vessel. The space between vessel and the outer casing forms a jacket, through which the heating or cooling medium is circulated. To heat the milk, hot water or low-pressure steam is circulated through the jacket and milk is continuously agitated for rapid and uniform heating. The heating process could be manually or automatically controlled. The milk is heated to a minimum of 62.7°C and held at this temperature for minimum 30 min. It is then cooled as rapidly as possible to 4°C. A cooling medium is circulated in the jacket for chilling the milk, but more often the heated milk is discharged to a surface cooler where a film of milk flows down the corrugated metal plates or series of interlocked tubes. A cooling medium such as brine or chilled water is circulated on the other side of the plates or through the tubes.

The LTLT pasteurizer may be of three types

Water – jacketed vat

This is double-walled around the sides and bottom of the vat in which hot water or steam under partial vacuum circulates for heating, and cold water for cooling. The outer wall (lining) is usually insulated to reduce heat loss. The heat-exchange takes place through the wall of the inner lining. The difference between temperature of the hot water and the milk is kept to a minimum. The milk is agitated by slowly revolving paddles/propellers. When heating, the vat cover is left open for escape of off-flavors; and when holding, the cover is closed. During the holding period, an air space/foam heater (steam or electrically heated) prevents surface cooling of milk.

Advantage: Flexibility in usage - multipurpose vat.

Water–spray type

A film of water is sprayed from a perforated pipe over the surface of the tank holding the product which is continuously agitated. A rapidly moving continuous film of water provides rapid heat transfer.

Coil-vat type

The heating/cooling medium is pumped through a coil placed in either a horizontal or vertical position, while the coil is turned through the product. The turning coil agitates the product (but additional agitation may be necessary).
Disadvantage: Coils are difficult to clean.

High-Temperature Short-Time (HTST) Pasteurization

This was first developed by A.P.V. Co. in the United Kingdom in 1922. It is the modern method of pasteurizing milk and is invariably used where large volumes of milk are handled. The HTST pasteurizer gives a continuous flow of milk which is heated to 72°C for 15s and then promptly cooled to 5°C or below.

Advantages

1. Capacity to heat treat milk quickly and adequately, while maintaining rigid quality control over both the raw and finished product

2. Less floor space required

3. Lower initial cost

4. Milk packaging can start as soon as milk is pasteurized

5. Easily cleaned and sanitized (system adapts itself to CIP)

6. Lower operating cost (due to regeneration system)

7. Reduced milk losses

8. Development of thermophiles is not a problem

9. Automatic precision controls ensure proper pasteurization.

Disadvantages

1. The system is not well-adapted to handling small quantities of liquid milk products

2. Gaskets require constant attention for possible damage and lack of sanitation

3. Complete drainage is not possible (without losses exceeding those from the holder system)

4. Margin of safety in product sanitary control are so narrow that automatic control precision instruments are required in its operation

5. Lethal effect on high-thermoduric bacteria in raw milk is not as great as compared to LTLT system

6. Accumulation of milk-stone in the heating section.

Equipment used in HTST pasteurization

The following steps or stages are involved as milk passes through the HTST pasteurizer:

1. Balance tank

2. Pump

3. Regenerative heating

4. Heating

5. Holding

6. Flow diversion valve (FDV)

7. Regenerative cooling

8. Cooling by chilled water or brine

Functions of specific parts

Float-controlled balance tank (FCBT)

Maintains a constant head of the milk for feeding the raw milk pump; also receives milk diverted by FDV (if at all diverted).

Pump

Either a rotary positive pump between the regeneration and heating sections (USA), or a centrifugal pump with a flow control device to ensure constant output, after FCBT (UK and Europe) is used.

Plates

The Plate Heat Exchanger (PHE) (also called Paraflow) is commonly used in the HTST system. The PHE is a compact, easily cleaned unit. Its plates may be used for heating, cooling and regeneration. These plates are supported in a press between a terminal block in each heating and cooling sections. The heat moves from a hot to a cold medium through stainless steel plates. A space of approximately 3 mm is maintained between the plates by a non-absorbent rubber gasket or seal which can be vulcanized to them. The plates are numbered and must be properly assembled. They are tightened into place, and designed to provide a uniform, but somewhat turbulent flow for rapid heat transfer. Raised sections (corrugations) on the plates in the form of knobs, diamonds and channels, help provide the turbulent action. Greater capacity is secured by adding more plates. Ports are provided in appropriate places, both at the top and bottom of the plates, to permit both the product and the heating/cooling medium to flow without mixing.

Filter

Filter units are connected directly to the HTST system, placed after the pre-heater or regenerative (heating) section. These units, using 40-90 nylon mesh cloth are usually cylindrical in shape. Usually two filters are attached; when one is being used, other can be subjected to cleaning. This permits continuous operation.

Regeneration

The raw chilled incoming milk is partially and indirectly heated by the heated outgoing milk (milk-to-milk regeneration). This adds to the economy of the HTST process, as the incoming milk requires less heating by hot water to raise its temperature to pasteurization temperature in the heating section.

Heating

The preheated milk from regeneration section passes through heating section of HTST, where it is heated to 72°C or more with the help of hot water from hot well. Thereafter, the heated milk enters into the holding section (plates/tube).

Holding

The holding tube ensures that the milk is held for a specified time, not less than 15s., at the pasteurization temperature of 72°C or more.

STERILIZATION (RETORTING)

Sterilization refers to complete destruction of microorganisms. It requires heat treatment of 121°C for 15 minutes which destroys all spores. But it has severe effect on heat sensitive nutrients and proteins through maillard reaction. The temperature and time required to sterilize the food varies with the type of food. Such high temperatures can be created by steam under pressure in steam pressure boilers/ sterilizers. Temperature at sea level is 100°C at atmospheric pressure but with 15psi temperature of 121.5°C can be achieved.

Sterilization destroys all pathogenic and spoilage microorganisms in foods and inactivates enzymes by heating. All canned foods are sterilized in a retort (a large pressure cooker) and called commercial sterilization which indicates that no viable organisms are present. This process enables food to have a shelf life of more than two years. Foods that have a pH of more than 4.6, such as meat and most vegetables must undergo severe heating conditions to destroy all pathogens. These foods are heated under pressure to 121°C for varying times. Severe conditions are applied primarily to ensure that *Clostridium botulinum* spores are destroyed during processing. These spores produce the deadly botulinum toxin under anaerobic conditions (that is, where there's no oxygen). The spores are destroyed by heat or are inhibited at pH values of less than 4.6. Therefore, a food with a pH of less than 4.6 that is packaged anaerobically, such as spaghetti sauce, doesn't need to undergo such a severe heat treatment. The destruction of vegetative and spore forming organism and pathogens is secondary objective of commercially sterilized foods.

Commercial sterilization

Commercial sterility is achieved when all pathogenic and toxin forming microorganisms have been destroyed along with the spoilage microorganisms. Usually target organism is a heat resistant microorganism, most often a spore or schlerotia forming organism rather than a vegetative one (e.g. spore forming anaerobic bacteria – Clostridium botulinum). Such foods may contain viable spores but these are not able to grow under normal conditions. If packaged aseptically, these products can be marketed without refrigeration. These products generally have a shelf life of 2 years or more.

UNIT – 4

FOOD PRESERVATION BY MOISTURE CONTROL

Drying and dehydration of fruits and vegetables is an age old method to preserve these products. Removal of the water (75-90%) present in fresh commodity results in reduction in the water activity and ultimately resistance against most of the deteriorative agents. The removal of water is carried out by the application of heat and this heat is usually supplied in the form of solar energy or artificially generated hot air. Removal of moisture and exposure of heat often results in poor textural attributes, loss in nutritive value (vitamins), discolouration and loss of flavouring components. Although both drying and dehydration are interchangeably used, drying is referred to removal of water to an equilibrium moisture content while dehydration is removal of water to an almost bone dry condition.

A number of processing steps are carefully designed to check all these adverse effects of drying. Some of the new technologies have been introduced in recent years to produce a wholesome and nutritive product. Partial dewatering by osmosis and impregnation soaking process before drying saves energy during drying and improves quality of dried product. Osmotic dehydration is gaining popularity, as the dehydrated product is more stable during storage due to low water activity by solute gain and water loss. The low water activity resulted in fewer rates of chemical reactions avoiding deterioration of the food. Osmotic dehydration in many cases is employed to increase sugar to acid ratio of acidic fruits, thereby to improve the taste, texture and appearance of dried product.

Water activity (aw) defines the proportion of water in a food that is in the free, unbound form.

Microbial activity, enzymatic activity and chemical reactions can occur **only in the free water phase** of foods

- Water activity of foods ranges from 0 to 1.0
- Water activity of **dehydrated** foods is in the range of **0.2** to **0.6**
- Microorganisms **cannot grow** at aw below **0.6**
- Chemical reactions (e.g. Maillard browning) can begin to occur at aw of **0.3**

Water content in foods

Water is present in food as free or unbound and bound water. **Free water or unbound water** is defined as water within a food that behaves as pure water. Unbound water is removed during the constant rate period of drying, when the nature of food does not have a great effect on the drying process.

Bound water can be defined as water that exhibits a lower vapour pressure, lower mobility and greatly reduced freezing point. So, bound water molecules have different kinetic and thermodynamic properties than ordinary water molecules. The a_w as affected by the extent of bound water is given in Table.

Water activity as affected by the extent of bound water

Extent of bound water	**Water activity (a_w)**
Tightly bound water	< 0.3
Moderately bound water	0.3 to 0.7
Loosely bound water	> 0.7
Free water	~ 1.0

Reasons for Drying of food

- Reduction in water activity (a_w) so control/check over chemical and microbiological changes (deterioration).
- Reduction in weight, size and volume of the food material. Hence bulk transportation becomes easier and cheaper.
- Packaging requirements are simple and cheap.
- Facilitate further processing. Example: grain drying for flour.

Factors affecting dehydration

1. Initial moisture content of the raw material
2. Composition of raw material
3. Initial load of the food kept in drier
4. Size, shape and arrangement of stacking of the raw material
5. Temperature, relative humidity and velocity of air used for drying
6. Rate of heat transfer on the surface of the food
7. Pre-treatment of the raw material prior to drying (peeling, blanching, sulphuring etc.)

Phases of drying or Normal Drying Curve

1. Initial warm up period
2. Constant drying rate period
3. Falling drying rate period

The first phase, or initial warm up period, is where sensible heat is transferred to the product. This is the heating up of the product. The rate of evaporation increases dramatically during this period with mostly free moisture being removed.

During the second phase, or constant rate period, free moisture persists on the surfaces and the rate of evaporation alters very little as the moisture content reduces. During this period, drying rates are high and there is a gradual and relatively small increase in the product temperature during this period.

The third phase, or falling rate period, is the phase during which migration of moisture from the inner interstices of each particle to the outer surface becomes the limiting factor that reduces the drying rate.

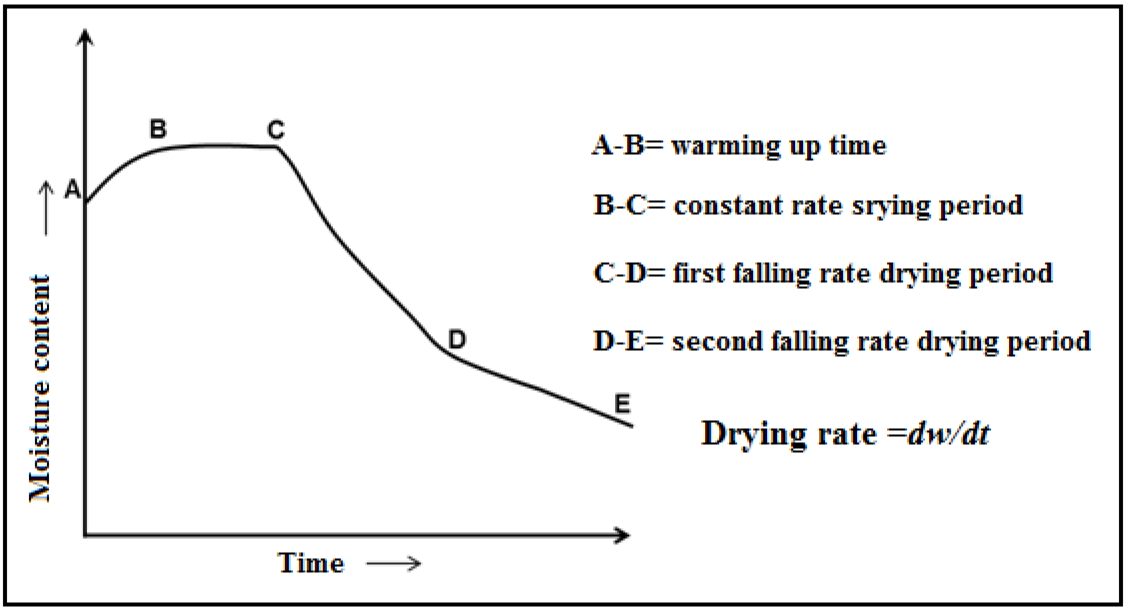


Fig Schematic diagram of change in moisture content with time (drying rate)

Factors Affecting Drying Rate

The factors that affect drying rate are external and internal factors.

The external factors are:

- Dry bulb temperature
- Relative humidity
- Air velocity
- Surface heat transfer coefficient

The Internal factors are:

- Surface to volume ratio
- Surface temperature
- Rate of moisture loss
- Composition i.e. moisture, fat

Effects of Drying on Foods

Shrinkage

During drying as moisture is removed the food material becomes smaller in size. This also affects bulk density (weight per unit volume) of food material. Slow drying results in development of internal stress. These rupture compress and permanently distort the relatively rigid cells, to give the food a shrink / shrivelled appearance. Such food material on rehydration absorbs water more slowly. Gelatinization of starch, denaturation of proteins, and crystallization of cellulose also affect rehydration characteristics. Rapid drying improves textural characteristics such as wettability, sinkability, dispersibility and solubility.

Case hardening

Formation of impervious layer over the surface of a dried food product characterized by inner soft and outer hard layer resulting in inadequate drying. It always occurs in food products rich in solutes and when initial drying temperature is very high. During the initial high temperature solute particles comes out and deposit at the surface resulting of building up of an impermeable layer which prevents further moisture removal. It can be prevented by using lower drying temperature.

Browning

Browning refers to change in the colour of food material to light to dark brown colour. This change in colour may occur by any of the three methods given below.

- **Residual enzymatic browning:** the residual enzymes especially in vegetables such as polyphenol oxidases cause oxidation that result in the change of colour.
- **Maillard reaction:** it is the reaction between the amino group of proteins and reducing sugars of carbohydrates in presence of heat. This type of browning is most common in dried foods.
- **Caramelization:** it is the conversion of sugars only into dark coloured compounds in presence of heat.

During drying process the control of air temperature and its circulation in the system is important. If temperature is too low and humidity is too high, the food will dry more slowly and microbial growth may occur. Conversely, if the temperature is too high in the beginning, a hard shell will develop on the surface of the food which will prevent the removal of moisture from the interior portion of the fruit and moisture will trap inside the food material. This condition is known as case hardening. Further, the temperature that is too high at the end of drying period causes the food to scorch. Temperature between 49^{o}C to 60^{o}C is recommended for drying of fruits and vegetables. Temperature up to 65^{o}C may be used at the beginning, but should be lowered as food begins to dry. While, during the last hour of drying period, the temperature should not exceed 55^{o}C.

DRYING METHODS

a) Sun Drying: It consists of spreading fruit/vegetable either on roof tops or floor for drying in open sun. This method is limited to certain fruits such as raisins, figs, apricots, dates, peaches and salted fish. After 10-12 days of drying the product is packaged in gunny bags/wooden boxes and sent to market for local or distant sale. The moisture content is generally not lowered below 15% which is too high for storage. The quality of product is inferior, characterized by brownish outer appearance and contaminated with insect dirt/dust particles. The quality can be improved by spreading the produce on black polythene sheet and covering it with thin muslin cloth to avoid entry of insects, dust or dirt particles on to the product.

b) Solar drier: Solar drier is an inclined rectangular box of 1.8 x 0.9 x 0.3 cubic meters. The internal dimensions made up of wood and lined internally with thermocol and tin sheets. Its top is covered with a glass sheet and inner sides are painted black. The air inlets and outlets (dampeners) are provided at the lower and upper ends to help in regulation of air flow and temperature. On an average 20-30^{o}C higher temperature can be attained inside the dehydrator as compared to ambient temperature. The loading capacity in solar drier of this size is 25-30 kg fresh fruit/vegetable spread on the trays each measuring 0.9 m× 0.45 m in size.

c) Polytunnel solar drier/ polyhouse solar drier: The basic principle is similar to solar drier. Polyhouse solar drier developed at Acharya N G Ranga Agriculture University, Baptla has a capacity to dry about 22-24 quintals of ripe chilies. It consists of 12×7.8×2.4 m (40'x26'x8') size arch type polyhouse with 1600 sq ft as tray area. Thirty two trays of size 10'×5'×3 (L×B×H) each are used to load 22-24 quintals of ripe chillies. Whole frame structure is covered with a UV stabilized 150 Gsm cross laminated transparent polyethylene sheet with well crow type ventilators at bottom and top of all three sides except on one side (north side) and two chimney ventilators on the roof cover to facilitate removal of moist air. Two chimney ventilators are placed on the top of the roof at a spacing of 4 meters. The height and diameter of each chimney ventilator are 0.6 and 0.25 meters respectively. Generally, temperature of about 15-17^{0}C higher than the ambient temperature can be obtained inside the drier.
Solar radiation is predominantly short wave radiation. The transmitted radiation through polyethylene sheet becomes long wave radiation after absorption and cannot escape from the polyethylene sheet thus leading to increase in temperature inside the drier. Covering of floor with black polyethylene sheet helps to retain better heat. Drying takes place due to convective movement of air caused by the difference in density of air inside the drier. The cold air enters through bottom 'well crow' ventilators and gets heated due to higher temperature inside the drier. The hot air moves through the bed of commodity being dried due to natural convection and transports moisture through the top well crow ventilators and chimney ventilators. The cost of drier is approximately Rs 1.20 lakh.

4. Dehydration equipment
A. Hot air Driers: In hot air driers the food is in contact with a moving stream of hot air. Heat is supplied to the product mainly by convection. Kiln drier, cabinet tray drier, tunnel drier, conveyor drier, bin drier, fluidized bed drier, pneumatic drier, rotary drier and spray drier use hot air for drying of fruits and vegetables.

1) Kiln drier: These are mainly used for hops, apple rings and slices and malt drying. It consists of two storeys with a furnace or burner located on the ground floor and wet material placed on the top floor. The heated air from the furnace rises by natural or forced convection and passes through the slotted floor of the second storey, on which the wet material is spread in an even layer of 10-20 cm. The humidified air is exhausted through a flue in the upper story. However, in kiln drier there is limited control over drying condition and drying time is longer. Besides, regular turning of product is necessary.

2) Cabinet (tray) drier: In tray driers the wet food is spread evenly/thinly on trays in which drying takes place. These consist of an insulated cabinet fitted with shallow mesh or perforated trays, each of which contains a thin (2-6 cm deep) layer of food. Hot air is circulated through the cabinet at 0.5- 5 m/s per square meter tray area. Ducts or baffles are used to direct hot air through each tray, to promote uniform air distribution. Heating is by conduction from heated trays or by radiation from heated surface. The heated air also removes the vapours. Tray driers are used for small scale production (1-20 t/day) or for pilot scale work. They have low capital and maintenance costs but have poor control and more variable product quality.

3) Conveyor drier (Belt drier): These are similar to tunnel drier, but the wet material is conveyed on moving belts rather than trucks. Continuous conveyer driers are up to 20 m long and 3 m wide. Food is dried on the belt in beds of 5-15 cm deep. The air flow is initially upward through the bed of food and then downwards in later stages to prevent dried food from blowing out of the bed. There can be 2 or 3 stage driers in which the food is mixed, repiled into deeper beds (15-25 cm in two stages and up to 250-900 cm in third stage). Major factors of conveyor driers are:

1. It improves uniformity of drying and saves floor space.
2. Food is dried up to 10-15 % moisture contents and finished in bin driers.
3. This equipment has good control over drying conditions and offers high production rates.
4. Can be used for large scale drying of foods (fruit and vegetable dried in 2.0-3.5 hours with a capacity up to 5.5 t/h).
5. Reduces labour costs, since it has independently controlled drying zones and is automatically loaded and unloaded.
6. Offers good replacement for tunnel driers.

4) Tunnel drier: It is the improvement of tray drier, in which trays move through a tunnel where heat is applied and vapours are removed. In most cases, air is used in tunnel drying and the material can move through the drier either parallel or counter current to the air flow. Typically a 24 m long tunnel contains 12-15 racks with total capacity of 5000 kg of food. The time taken for drying is 5-16 hrs.

5) Foam mat drying: In this the liquid foods (fruit juices) are formed into stable foam by the addition of a stabilizer and aeration with nitrogen or air. For drying of lemon juice, carboxy methyl cellulose (CMC) can be mixed with juice to convert into foam. The foam is spread on a perforated belt to a depth of 2-3 mm and dried rapidly in two stages by parallel and thin counter current air flows. Foam mat drying is about three times faster than drying a similar thickness of liquid owing to thin surface area. The thin foam mat of dried food is ground to a free flowing powder which has good rehydration properties. The rapid drying and low product temperature give rise to high quality product.

Limitation: Large surface area is required for high production rates and capital costs are high.

6) Bin drier (Deep bed drier): Bin driers are used for final drying of dried food material. They are provided with cylindrical or rectangular containers fitted with mesh (false bottom). Hot air passes up through a bed of food at relatively low speed 0.5 ms-1 per square meter of bin area. In bin drier, the food stuff is contained in a bin with perforated bottom through which warm air is blown vertically upwards, passing through the material and drying it. Bin driers are also used for equalization of moisture content within the bulk of dried food material.

Advantages

- These driers have a high capacity and low capital and running costs.
- Bin driers improve the operating capacity of initial driers by taking the food when it is in falling rate period, when moisture removed is most time consuming.
- The deep bed permits equalization of varied moisture content in different layers of food.

7) Fluidized bed drier: Heated air is forced up through a bed of solids under such conditions that the solids are suspended in to the air. The heated air acts both a fluidizing and drying medium. Some units have vibrating bases to assist movement of the product. The drier may be batch or continuous type. The drier is used successfully for drying of peas, beans, carrots, cocoa, coffee etc. In some cases, dust separators (cyclones) are included in the exhaust air line to remove fumes.

Advantages

- Fluidized bed driers are compact and have good control over drying conditions.
- They provide high thermal efficiencies and high drying rates.
- Since product is mixed by fluidization, it leads to uniform drying.
- Fluidized bed driers are limited to small particulate foods that are capable of being fluidized without excessive mechanical damage.

8) Pneumatic drier: It is the extension of fluidized bed drier where higher air velocities are used. In this, the solid food particles are conveyed rapidly in an air steam, the velocity and turbulence of the air maintain the particles in suspension. Heated air accomplishes the drying and often classifying device is included in the equipment. The dry matter passes out as product and the moist product is recirculated for further drying.

In pneumatic driers, powders or particulate foods are continuously dried in vertical or horizontal metal ducts. A cyclone separator is used to remove the dried product. The moist food (less than 40% moisture content) is placed into the ducting and suspended in hot air. In vertical driers, the air flow is adjusted to classify the particles; lighter and smaller particles, which dry more rapidly, are carried to a cyclone more rapidly than are heavier and wetter particles which remain suspended to receive additional drying required.

9) Rotary drier: In rotary drier, slightly inclined rotating cylinder is fitted internally with flights to cause the food to move through a stream of hot air as it moves through the drier. Air flow may be parallel or counter current.

The food stuff is contained in a horizontally inclined cylinder through which it travels. The heating is done either by air flow through the cylinder or by conduction of the heat from the cylinder walls. In some cases, the cylinder rotates and in others the cylinder is stationary and the paddle or screw rotates through the cylinder conveying the material. The drier is used for drying of sugar crystals and cocoa beans.

Advantages

- The agitation of the food and the large area of food exposed to the air produce high drying rates and uniformly dried product.

- The drier is suitable for the products that tend to mat or stick on the belt or tray driers.

Limitations

- It may cause damage to the product by impact or abrasion in the drier.

10) Trough drier (belt-trough drier): Small, uniform pieces of food like peas and other dried vegetable are dried in a mesh conveyor belt which hangs freely between rollers, to form the shape of trough. Hot air is blown through the bed of food, and the movement of conveyor mixes and turns it to bring new surfaces continually into contact with the drying air. The mixing action moves food away from the drying air and then allows time for moisture to move from the interior of the pieces to dry the surface. The moisture is then rapidly evaporated when the food again contacts the hot air. The drier operates in two stages to 50-60 % moisture and then to 15-20 % moisture content. Final finishing of dried product is carried out in bin driers.

Advantages

- These driers have high drying rates (55 minutes for dried vegetable compared to 5 hours in a tunnel drier).
- High energy efficiencies with good control over drying conditions.
- Minimum heat damage to the product.

Limitation: Not suitable for sticky foods.

11) Spray driers: A fine dispersion of pre-concentrated food is first "atomized" (sprayed) to form droplets (10-200 µm in diameter) which are sprayed into the drying chamber at a temperature of 150-300^{0}C of heated air. The feed rate is controlled to produce an outlet air temperature of 90-100^{0}C, which corresponds to a wet-bulb and product temperature of 40-50^{0}C. Very short drying time and relatively low product temperature are the main features of spray driers. The main components of a spray drier include:

- Air heating and circulating system
- A spray forming system comprising of pressure nozzle, centrifugal atomizer and bowl nozzle
- A drying chamber
- Cyclone separator for product recovery (2 cyclones, scrubber with cloth filter)

For successful drying, complete and uniform atomization is necessary. Different types of atomizers are centrifugal atomizer, pressure nozzle atomizer, two fluid nozzle atomizer and ultrasonic atomizer.

Advantages:

- Due to very large surface area of the droplets, the drying is very rapid (1-10 s)
- The temperature of the product remains at the wet bulb temperature of the drying air.
- There is minimum heat damage to the food.

In spray drier, liquid or fine solid material in slurry form is sprayed in the form of fine dispersion into a current of heated air. Drying occurs very rapidly, thus this process is very useful for foods that suffer heat damage on long exposures. Spray driers are mostly used for milk, egg, coffee, cocoa, tea, potato, ground chicken, ice cream mix, butter, cream, yoghurt, cheese powder, coffee whitener, fruit juices, meat, encapsulated flavours, wheat and corn starch products.

B). Heated surface driers: Unlike hot air driers, the heat in heat surface driers is supplied to the food by conduction, thus resulting in higher thermal efficiency.

Advantages:

- It is not necessary to heat large volumes of air before drying commences.
- Drying can be carried out in absence of oxygen to protect foods that are sensitive to oxidation.
- Heat consumption is less than that of hot air driers. Heated surface drier utilize 2000 – 3000 kJ energy per kg of water evaporated while in hot air driers it is about 4000-10,000 kJ energy per kg of water evaporated.

Limitations: Since, foods have low thermal conductivities, which become further lower as the food dries. Therefore, the thin layer of food is required to conduct heat rapidly without causing heat damage.

Concentration of Foods

Concentration process increases the solids content and reduces the weight and volume of a food. Latent heat is transferred from the heating medium (steam) to the food to raise the temperature of its boiling point during evaporation. The vapour pressure rises and bubbles of vapour in the liquid are formed due to latent heat of vaporization supplied by the steam. The vapour is then removed from the surface of the boiling liquid. The more common concentrated foods include evaporated and sweetened condensed milks, fruits and vegetable juices and nectars, sugar syrups and flavoured syrups, jams and jellies, tomato paste etc.

Methods of Concentration

Solar evaporation

Solar evaporation is the simplest method of evaporating water with solar energy. This process was used in earlier times to obtain salt from sea water and still it is practiced. However, the process is very slow and is suitable only for concentrating salt solutions.

Open kettles

Only some foods can be satisfactorily concentrated in open kettle that is heated by steam e.g. in case of jellies and jams and for certain types of soups. However, high temperatures and long concentration times damage most foods. In addition, thickening and burning of product to the kettle wall gradually lowers the efficiency of heat transfer and slows the concentration process. This method is apt for caramelized colour and typical flavour development in foods high in sugar.

Concentration by flash evaporation

Concentration process is markedly speeded when sub sized food material is brought in direct contact with heating medium. This is done in flash evaporators. Clean steam superheated at about 150°C is injected into food and then is pumped into an evaporation tube where boiling occurs. The boiling mixture then enters a separator vessel and the concentrated food is drawn off at the bottom and the steam plus water vapour from the food is evacuated through a separate outlet. Foods lose volatile flavour constituent because of high temperature.

Concentration by thin film evaporation

In thin film evaporators, food is pumped into a vertical cylinder which has a rotating element that spreads the food into a thin layer on a cylinder wall. The cylinder wall of double jacket construction usually is heated by steam. Water is quickly evaporated from the thin food layer and the concentrated food is simultaneously wiped from the cylinder wall. The concentrated food and water vapour are continuously discharged to an external separator from which product is removed at the bottom and water vapour passes to a condenser. Product temperature may reach 85°C or higher but since residence time of the concentrating food in the heated cylinder may be less than a minute, heat damage is minimal.

Concentration by vacuum evaporation

This method is suitable for heat sensitive foods as this method involves low temperature. Evaporation under vacuum can be done by operating thin film evaporators under vacuum by connecting a vacuum pump or steam ejector to the condenser. Several vacuum vessels can be attached in series so that the food product moves from one vacuum chamber to the next and thereby becomes more and more concentrated at each step. The consecutive vessels are maintained at progressively higher degrees of vacuum and hot water vapour arising from first step is used to heat the second vessel and so on. In this way heat energy is efficiently used.

Freeze concentration

Initially formed ice crystals during freezing process are removed with the help of centrifugal force resulting in a concentrated unfrozen food which passes through a fine mesh screen. This process is repeated many times to reach final concentration of food.

Ultrafiltration and reverse osmosis

These are the two methods of concentrating foods employing pressure driven membrane separation process. In ultrafiltration large solute particles are selectively removed whereas in reverse osmosis smaller solutes are separated out.

Intermediate moisture foods (IMF)

Intermediate moisture foods are those in which the moisture content is reduced to a level low enough to prevent spoilage microorganisms from growing but moist enough for the food to have improved palatability characteristics. Intermediate moisture foods or semi-moist foods contain 20-50 per cent. In addition, they contain high concentration of dissolved solutes. These foods do not require refrigeration during storage and can be eaten without rehydration. Honey, jam, jelly, cakes, dates and osmo-dried food products are the examples of intermediate moisture foods.

Advantages of Concentration

- Product can be stored without hermetic sealing
- Concentrated foods are more attractive
- Can be preserved for longer period of time
- Prevents microbial spoilage

UNIT – 5

FOOD PRESERVATION BY IRRADIATION

Food irradiation

Food irradiation is the process of exposing food to controlled levels of ionizing radiation to kill harmful bacteria, pests, or parasites, or to preserve its freshness. It is also called cold pasteurization as it kills harmful bacteria without heat.

Mode of Action

Irradiation can directly impair critical cell functions or components like DNA and indirectly form radiolytic products/ free radicals from water, which are responsible for 90 per cent of DNA damage. Irradiation results in a variety of changes in living cells based on the dosage. For example- high doses kill microbes/ insects; low doses destroy some of the enzymes that lead to fruit ripening, thereby, delaying it and it also interfere with cell division, thereby limiting/ preventing the reproduction of microbes, insects, parasites, etc.

Radiation In Food Preservation

Ionizing radiation is the radiation with enough energy to remove electron(s) from atoms and molecules and to convert them to electrically-charged particles called ions. But, at dose levels approved for food irradiation, these radiations cannot penetrate nuclei and thus, food can never become radioactive. Other types of radiation energy i.e. infrared and microwaves are non-ionizing radiations with longer wavelengths. Infrared radiation is used in conventional cooking. Microwaves, due to their relatively longer wavelength, have lower energy levels but are strong enough to move molecules and generate heat through friction. Three types of ionizing radiations are approved to be used for food irradiation.

- Electron beams generated from machine sources operate at a maximum energy of 10 million electron volts (MeV).
- X-rays generated from machine sources operate at a maximum energy of 5 MeV.
- Gamma rays are emitted from Co-60 or Ce-137 with respective energies of 1.33 and 0.67 MeV.

Electron beams

Electron beams are the streams of very fast moving electrons produced in electron accelerators. Electron beams have a selective application in food irradiation as they can penetrate only one and one half inches deep into the food commodity. Due to poor penetration, shipping cartons (pre-packed bulk food commodities) are not irradiated with electron beams. Electron beams can be switched on or off at will and require shielding as they are generated through machine sources.

X-rays

Just like electron beams, X-rays are also generated through machine sources. X-rays are photons and have much better penetration and are able to penetrate through whole cartons of food products. X-rays also can be switched on or off at will and therefore, require shielding.

Gamma rays

Gamma rays are produced from radioisotopes either Cobalt-60 (Co-60) or Cesium-137 (Ce-137). Contrary to electron beams and X-rays, radioisotopes cannot be switched off or on at will and they keep on emitting gamma rays, therefore radioisotopes require shielding. Co-60 source is kept immersed under water when it is not in use and Ce-137 is shielded in lead. Due to their continuous operation, radioisotopes need to be replenished from time to time. Gamma rays are photons and have deep penetration ability.

Units of irradiation

Radiation dose is the quantity of radiation energy absorbed by the food as it passes through the radiation field during processing. The gray (Gy) is the unit used to measure absorbed dose of radiation and is equal to one joule of energy absorbed per kg of matter being irradiated.

1 Gy (Gray) = 100 rad (radiation absorbed dose)
1 Kilogray (kGy) = 1000 Gy

International health and safety authorities have endorsed the safety of irradiation for all foods up to a dose level of 10 kGy. Recent evaluation of an international expert study group appointed by Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA) showed that food treated according to good manufacturing practices (GMPs) at any dose above 10 kGy is also safe for consumption, making irradiation parallel to heat treatment of food.
In India, the Ministry of Health and Family Welfare amended the Prevention of Food Adulteration Rules (1954) through a Gazette notification dated August 9, 1994, permitting irradiation of onion, potato and spices for internal marketing and consumption. In 1998 a number of other food items were permitted for radiation processing . Approval for additional items like fresh, frozen and dried sea foods and pulses have been given under FSSA regulations (2011).

Food items approved for radiation preservation under PFA Rules, 1955 and FSSA regulations, 2011

Name of food	**Purpose**	**Dose (kGy)**	
		Minimum	**Maximum**
Onion	Sprout inhibition	0.03	0.09
Potato		0.06	0.15
Ginger, garlic and shallots (Small onion)		0.03	0.15
Mango	Disinfestation	0.25	0.75
Rice		0.25	1.00

Semolina (sooji, rawa), wheat atta and maida		0.25	1.0
Raisin, figs and dried dates		0.25	0.75
Meat and meat products including chicken	Shelf-life extension and pathogen control	2.5	4
Spices	Microbial decontamination	6	14
Fresh sea foods	Shelf-life extension and pathogen control	1.0	3.0
Frozen sea foods		4.0	6.0
Dried sea foods	Disinfestation	0.25	1.0
Pulses			

Nutritional Quality of Irradiated Foods

Irradiation does not considerably raise the temperature of the food and nutrient losses are small and often significant as compared to other methods of preservation such as canning, drying and heat pasteurization.

Macronutrients like carbohydrates, proteins, and fats, undergo little change during irradiation even at doses over 10 kGy. Similarly, the essential amino acids, minerals, trace elements and most vitamins do not suffer significant losses.

Different types of vitamins have varied sensitivity to irradiation and it depends on the complexity of the food system and the solubility of the vitamins in water or fat. Vitamin losses can be minimized by irradiating the food in frozen form or by packaging it in an inert atmosphere such as under nitrogen. Four vitamins are recognized as being highly sensitive to irradiation: B1, C (ascorbic acid), A (retinol) and E (alpha-tocopherol). However, B1 is even more sensitive to heat than to irradiation.

Advantages and Disadvantages of Food Irradiation

Benefits	Limitations
Radiation processing does not change texture and freshness of food, unlike heat. In fact, it is difficult to distinguish between irradiated and non-irradiated food on the basis of colour, flavour, taste, aroma or appearance.	Radiation processing cannot be applied to all kinds of foods.
Radiation processing does not affect significantly nutritional value, flavour, texture and appearance of food.	Radiation processing cannot make a bad or spoiled food look good i.e. it is not a magic wand.
Radiation cannot induce any radioactivity in food and does not leave any harmful or toxic radioactive residues on foods as is the case with chemical fumigants.	It cannot destroy already present pesticides and toxins in foods.
It is a very effective method due to its highly penetrating nature of the radiation energy and can be used on packed food commodities.	Compliance of a particular food commodity to radiation processing has to be tested first in a laboratory.
Prepackaged foods can be made sterile thus improving shelf-life.	Only those foods for which specific benefits are achieved by applying appropriate doses and those duly permitted under the PFA Rules, (1955) and now FSSA regulations (2011) can be processed by radiation.
The radiation processing facilities are environment friendly and are safe to workers and public around.	--