Preservation of foods by physical methods – low and high temperature

(Theory and Self-learning)

Production of Courseware e-Content for Postgraduate Subjects

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Component-I (A) - Module Structure:

Structure of Module/Syllabus of a module (Define Topic of module and its subtopic)	
Preservation of foods by physical methods – low and high temperature	Introduction, Physical methods of food preservation: Low Temperature Methods (Refrigeration and Freezing); High Temperature Methods (Pasteurization, Sterilization, Ultra-Heat Treatment (UHT), Cooking, Ohmic Heating and Canning).

Component-II - Description of Module

	Description of Module
Subject Name	Food Technology
Paper Name and no.	P 3 : Food Microbiology
Module Name and no.	M 10 : Preservation of foods by physical methods – low and high temperatures
Module Id	FT/FM/10
Pre-requisites	Types of food preservation methods, Biological and chemical nature of food and types of food.
Objectives	To study about types low and high temerpratures methods for preservation of food.
Keywords	Physical methods, Milk, Pasteurization, Ohmic Heating, UHT, Canning, Shelf-life.

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1. Introduction

In order to slow down the spoilage process and increase the shelf life of fods for a longer period, a wide range of preservation methods are applied to foods like pasteurization, boiling, refrigeration, freezing, vacuum treatment, addition of antimicrobial agents. In general, most methods involve the removal or control of factors which affect bacterial growth such as the use of low or high temperatures, moisture control, dehydration and use of certain chemicals as preservatives. In practice, there are two important methods used to control or kill the microorganism:

1. Physical methods: Mostly temperature control methods like low or high temperatures.
2. Chemical methods: It included certain antimicrobial chemicals such as sorbate, benzoates, nitrates

2.1 Physical methods of food preservation

Physical preservation methods are mostly aimed at extending the stability of foods by slowing down or suppressing the spoilage mechanisms by the changing of relevant parameters. Microbial growth and multiplication can be influenced by temperature, water activity and high-energy radiation. Generally, microorganisms are killed by the application of high temperatures in combination with the treatment times required in a given case.

Comparatively mild treatments affect only the vegetative forms (pasteurization), while more destructive treatments are required to kill spores as well (sterilization). The pasteurized foods need additional cold storage to prevent further germination of the spores. Use of low temperatures processing, reduces and inhibits the growth of microbes (in refrigeration) or prevent any microbial activity at deep-freezing.

High temperature methods such as canning, sterilization and cooking are capable in complete destruction of all forms of microbes and their toxins. Hence, providing more safe food for consumption. Application of ionising radiation on certain food can be used to reduce a potential risk to hygiene, to influence physiological processes, to control insects populations and to increase the shelf-life of of fresh food within in the short time. However, at the end the optimum product quality can be retained by linking various preservation process. Few important and most widely accepted as well as used low and high temperature based methods for food preservation are discussed below.

2.1 Low Temperature Methods

Storage at low temperatures extends the shelf life of many foods. Because, low temperatures reduce the growth rates of microorganisms, slows down the speed of enzyme reaction and slow many of the physical and chemical reactions that happen in foods. Hence, the use of low temperatures can prevent the growth of most food borne pathogens and food spoilage causing microorganisms. Preservation methods using low temperatures include:

2.1.1 Refrigeration

It is a modern food preservation method based on the fact that dangerous foodborne illness bacteria do not grow (or grow very slowly) at refrigeration temperatures (0-5°C or below). In general, refrigeration is considered as a temporary food preservation method because it will slow down the growth of microbes (food spoilage microbes: bacteria and fungi) but doesn't stop it completely as freezing does. Hence. refrigeration only keeps food for days rather than the months that freezing does.

Practically, the life of many foods may be extended by storage at temperatures below 4°C. Refrigeration cannot improve the quality of decayed food as it can only retard microbial deterioration. Most commonly refrigerated foods like fresh fruits and vegetables, eggs, fish, dairy products, meats etc. Certain foods like bananas cannot be refrigerated because it is damaged if exposed to low temperatures.

Limitation: There is one issue of modern mechanical refrigeration that is dehydration of stored foods because of moisture condensation and though, It has been overcome through humidity control mechanisms within the storage chamber and by selecting suitable packaging techniques.

2.1.2 Freezing

It is one of the easiest, least time-consuming and most convenient methods of food preservation. Freezing is very good at retaining the nutritional value and their natural color, flavor and texture better than when other methods of food preservation are used for example fruits, meats, breads, cakes etc. It is suggested that before freezing the fresh vegetables, must be blanched first to stop the enzymatic activity (that can cause alterations in their nutritional values). For blanching, vegetables dropped into a pot of boiling water. Allow them for 1-2 minutes and then immediately stop the cooking process by removing them from the boiling water and dropping them into ice water. When cooled they are ready to put into freezer bags, pressing as much air out of the bag as possible and then into freezer. As freezing one of the most commonly used processes commercially and domestically for preserving a very wide range of food including prepared food stuffs that would not have required freezing in their unprepared state, such as potato waffles are stored in the freezer, but potatoes themselves need only a cool dark place to ensure several days storage. At commercial level, cold stores provide large-volume, long-term storage for strategic food stocks held in case of national or international emergency in many countries.

In general, freezing does not destroy spoilage or contamination microorganisms but it stops their growth as long as the food is kept at -18^0C. Any microorganism present will become active as the food thaws. Properly Proper packaging of food in freezer paper or freezer containers can prevents any deterioration in its quality and damage occurs once food comes in contact with the dry air of a freezer. Following important point should be taken into consideration to avoid freezer burn:

- ✓ Avoid fluctuating temperatures: Maintain the freezer closed as much as possible.

- ✓ Don't overfill freezer: Too full freezer reduces air circulation and speed up freezer damage.
- ✓ Reduce exposure to air: Wrap food tightly and know what you want to remove before opening the freezer door.

Disadvantages of freezing:

1. The initial investment (cost of purchase and maintenance) of the freezer.
2. The size of the freezer: It limits the amount of storage space and
3. Sometimes, the freezing process may gives certain foods an undesirable texture.

2.2 High Temperature Methods

Heat is one of the oldest methods of destroying microorganisms and their spores in food processing and preservation. Development of several high temperature based methods like boiling, roasting, baking and other heat treatments are the greatest advance in food hygiene because such methods kills all the forms of microorganisms (vegetative and spore) and make the food safe. Most commonly used methods of heat treatment used for food preservation are discussed below.

2.2.1 Pasteurization

It is named after its inventor French chemist, Louis Pasteur (1822-1895). He used the application of heat to destroy human pathogens in foods. The Purpose of pasteurization is to increase milk safety for the consumer by destroying disease causing pathogenic microorganisms that may be present in milk and to increase keeping the quality of milk products by destroying spoilage microorganisms and inactivating enzymes that contribute to the poor quality and shelf life of milk. In general, pasteurization is a process of heat treatment of milk and other beverages, requires adequate holding time to assure the thermal destruction of pathogens and microbes accountable for food spoilage, without any changing in the nutritional qualities. Milk is a food product that is pasteurized worldwide, but some other foods are normally pasteurized in certain parts of the world:

- Canned foods: Such as meats, vegetables and fruits that are generally heated in the can or container itself to kill the microbes effectively.
- Juices: Most of the Tetra Pak and bottled juices are pasteurized first before.
- Low-alcoholic beverages: Such as juices, these beverages are also heated and cooled before filling.
- Water: the bottled water is usually pasteurized and in places where polluted water is available.

Practically, pasterurisaton involves heating the food to a specific temperature for a definite time and then cooling quickly. Usually, the temperature applied and the holding time of pasteurization vary with the equipment available and the type of milk or food product (Table 10.1). For pasteurization of milk, the time-temperature combination is carefully selected on the basis of the thermal death time of the most resistant

pathogens (such as *Mycobacterium tuberculosis*) that may be present in raw milk and keeping the maximum temperature and time at which the nutrintional and other qualities of milk (like taste and palatability) are retained. At dairy industries, routinely milk is pasteurised at 62.8°C for at least 30 minutes or at 71.7°C for at least 15 seconds or if using ultra-high temperature (UHT) at 135°C for 1–2 seconds. UHT processed milk is sterilized (all forms of life are killed) and this lengthens its storage time but does affect the taste and other values (Table 10.1).

Table 10.1: Minimum pasteurization requirements for milk and milk products.

Pasteurization Type	**Specific Temerature**	**Holding Time**	**Example of Product**	**Storage Condition**
Batch (vat) Pasteurization	62.8°C	30 minutes	Milk	Refrigerated
	65.6°C		Viscous products or with more than 10% fat or added sweetener	
	68.3°C		Egg nog, frozen dessert mixes etc.	
High temperature short time Pasteurization (HTST)	71.7°C	15 seconds	Milk	
	74.4°C		Viscous products or with more than 10% fat or added sweetener	
	79.4°C	25 seconds	Egg nog, frozen dessert mixes etc.	
	82.2°C	15 seconds		
Higher-Heat Shorter Time (HHST)	88.3°C	1.0 second	Milk	
	90°C	0.5 second		
	96.2°C	0.05 Second		
	100°C	0.01 Seconds		
Ultra Pasteurization (UP)	137.8°C	2 Seconds	Milk and cream	Refrigerated for extended storage
Ultra High Temperature (UHT)	135-150°C	4-10 seconds	Milk	Room temperature
Sterilization	115.6°C	20 minutes	Canned products	

It has been observerd that the temperature and time requirements of the pasteurization process are significantly influenced by the pH of the food (Table 10.2).

Table 10.2: Effect of pH of food on the temperature - time requirements of the pasteurization process.

pH	Explanations	Food
Below 4.5	The spoilage microorganisms and inactivating certain enzymes such as pectinesterase and polygalacturonase are the main targets of pasteurization. • The typical processing conditions for the pasteurization of fruit juices include heating to 77°C and holding time for 1 minute, followed by rapid cooling to 7°C. • For inactivating enzymes, these conditions destroy any yeasts or molds that may lead to food spoilage. Comparable conditions capable of reducing spoilage microorganisms involve heating to 65°C and holding for 30 minutes or heating to 88°C and holding for 15 seconds.	Fruit juices
Above 4.5	The heat treatment must be severe enough to destroy pathogenic bacteria. For the milk pasteurization, the time and temperature conditions target the pathogenic bacteria like TB bacillus (*Mycobacterium tuberculosis), Coxiella burnetti* and *Brucella abortus*. • The typical heat treatment used for pasteurizing milk is 72°C for 15 seconds, followed by quick cooling to 7°C. • Other equivalent heat treatments include heating to 63°C for 30 minutes, 90°C for 0.5 second and 94°C for 0.1 second. As the high-temperature–short-time (HTST) treatments cause less damage to the nutrient composition and sensory qualities of foods. Hence, HTST are preferred over the low-temperature–long-time (LTLT) treatment process.	Milk

Limitations:Though, this method kills the pathogens or bacteria present in the raw milk and makes is safe to consume without any health risk but there are few limitations dissussed below:

- Due to loss of certain enzymes in food during pasteurization process, some people believe that raw milk is a better option to pasteurized milk.
- It is belived that milk pasteurized with HTST method may lose 1/3rd of the thiamine present in the milk and half of vitamin B_{12}.

- Survival of heat resistant pathogens has increased the risk of the presence of bacteria even after pasteurizing the food.

2.2.2 Sterilization

It is a method of destruction of all microorganisms using temperatures above 100°C. For complete sterilization of foods, the time and temperature required are much influenced by a number of factors like the type of microorganisms found on the food, the size of the container, the acidity or pH of the food and the method of heating. In general, the thermal processes of canning are generally designed to destroy the spores of the bacterium *C. botulinum* (can easily grow under anaerobic conditions, producing the deadly toxin that causes botulism). In sterilization process, heating to temperatures greater than 100°C and However, *C. botulinum* is not viable in acidic foods (pH less than 4.6), therefore, such foods can be adequately processed by dipping in water at temperatures just below 100°C. For low-acid foods (pH greater than 4.6), the sterilization is generally carried out in steam vessels called retorts at temperatures ranging from 116° to 129°C and the retorts are controlled by programmed devices and detailed records are kept of the time and temperature treatments for each batch of processed cans. At the end of the heating cycle, the cans are cooled under water sprays or in water baths to about 38°C and then dried to prevent any surface rusting. The cans are then labeled properly, placed in fibreboard cases either by hand or machine and stored in cool and dry storerooms.

Limitations: Practically, canning has no major effect on the structure of carbohydrate, protein or fat content of foods and vitamins (A and D) and β-carotene are resistant to the effects of heat but a significant loss of nutrients, mainly heat-sensitive vitamins (Vitamin B1), may occurring the canning process. Likewise, the anaerobic conditions of canned foods have a shielding effect on the stability of vitamin C but it is destroyed during long heat process.

2.2.3 Ultra-Heat Treatment (UHT)

It is also called, ultra pasteurization (UP), the most widely used pasteurization process for milk in Europe and throughout the world (gaining popularity in the United States and Canada too), is a more recently developed process of sterilization of food by heating it for an extremely short period, about 1–2 seconds, at a temperature exceeding 135°C (Table 10.1). Generally, such temperature is required to kill spores in milk. Application of high heat during the UHT process can cause Maillard browning and change the taste and smell of dairy products but not significantly. Although, the most common UHT product is milk, but the process is also used for fruit juices, cream, soy milk, yogurt, wine, soups and honey. When UHT process is coupled with sterile packaging (tetrapak), creates an extended shelf life of milk UHT milk from six to nine months, until opened. At industrial scale, the UHT milk passes through heating and cooling stages in rapid

succession, then is immediately put into a sterile Tetra Pak shelf-safe carton to avoids any re-infection. Such product, lasts up to six months without refrigeration or addition of any preservatives. Specially, the Tetra Pak made of Paperboard, obtained from wood from selectively harvested (regrown trees), is used to make the package more stable and lightweight. Thin layers of polyethylene (a common plastic), are added to seal in the liquid and protect it from external moisture content and a thin layer of aluminum foil protects products from oxygen, flavors and light. For the environment Tetra Pak cartons are biodegradable and more efficient to transport than heavier packages or refrigerated products.

Limitations: Most of people believe that enzymes in raw milk aid digestion and calcium absorption and their specific health benefits are debated within the scientific community. It is true that the UHT and HTST pasteurization processes reduce enzymes in the milk.

2.2.4 Cooking

This method is usually used to improve palatability rather than to improve storage quality of food. It is also called boiling, is the process of using heat to water until the temperature reaches about 100°C. Altough, boiling of foods in water cannot completely destroy all microbes, but the actively growing (vegetative) cells of bacteria and fungi (yeasts and moulds) are generally quickly destroyed at this temperature if maintained for a sufficiently long period of time, helps the heat to completely penetrate the foods and kill the microorganisms. Bacterial spores (extremely resistant to heat) not killed at this temperature, although their growth is prevented such as spores of *Clostridium perfringes* and *Clostridium botulinum* (an organism present in non-acid and semi-acid foods like peas, corn, green beans, meat etc. and produces injurious toxins in food), being highly resistant to heat. Botulin (toxin) is inactivated by boiling foods for at least 10 minutes and the spores of such bacteria are easily destroyed only if food is cooked under pressure and destruction by heat is affected by time and temperature variation. However, some enterotoxins (produced by *Staphylococci*) are not easily inactivated. The thermophilic microrganisms may survive the effects of boiling and improperly handled cooked food are rapidly cause food spoilage whenever environmental conditions are favourable for them.

Limitations: Generally, cooking destroy the spoilage causing microbes and reduces the possible risk of disease transmission but it can damage the food's qualities (i. e. appearance, texture and flavor etc.) and may also destroy some important vitamins.

2.2.5 Ohmic Heating

In most of the used heating techniques for liquid depends on heat transfer from a hot surface and such heat can be generated directly via an electrical heating element or indirectly from a hot medium (like steam). In general, such methods need a temperature gradient to transfer heat to the process liquid and we know that these surfaces are at a higher temperature than the product. Thus, this can cause fouling of the surfaces for

certain products which become burnt onto the hot surfaces reducing heat transfer rates and negatively affecting the quality of product. An another problem with heat transfer is found when heating very viscous fluid and fluids with particulates where effective, even heat transfer is very difficult to achieve without compromising the quality of food product.

To overcome, these issuses, An ohmic heater (also known as a joule heater) can be used in which electrical heating device that uses a liquid's own electrical resistance to generate the heat. In such process, the fluid is heated directly by passing an electrical current (usually AC) through the product and its own electrical resistance causes heating throughout giving a uniform temperature increase without any loss in performance for high viscosity or low flow rates. Hence, the heat is produced directly within the fluid itself by Joule heating as electrical current passes through it and is not transmitted to it by means of temperature gradients or hot surfaces and microbes are destroyed by the use of high-voltage electric current through foods. Practically, Ohmic heaters are very efficient with over 94% of the applied electrical power converted to heat and have been revealed to improve the colour and vitamin retention of foods and provide an extended shelf life for pasteurised products when compared to hot surface heating devices.

Ohmic heaters are extensively used in food industries for successful heating of conductive and pumpable products like dairy or milk based foods, tomato products, fruit juice, liquid egg, jams, soups, casserolesetc.

2.2.6 Canning

It is one of the most widely used method of preserving food, in which the food contents are processed (using heat to appropriate temperature and for a prescribed time to destroy micro-organisms, including *Clostridium botulinum* spores), and sealed in an airtight container. Canning process was developed by Nicolas Appert. Generally, this practice provides a typical shelf life extending from one year to five years, though under specific circumstances a freeze-dried canned product like canned dried lentils can last as long as 30 years in an edible condition. In the process of canning, there is a careful preparation of food packed into a sealed tin, glass or plastic container which is subjected to defined high temperatures (above 100ºC) for an appropriate period of time and then cooled. During heating there is a removal of oxygen and further hermetic sealing of containers to avoid post-process contamination and boiling the food in the container to kill all the microbes and sealing the can (either before or while the food is in boiling process) to restrict and further prevent any new microorganisms from getting in. After the thermal processing, the sealed container must be cooled immediately to a temperature of about 38ºC to prevent unnecessary adverse effects of heat on the texture, flavour or colour of the food products. Thus, this sterilises the food so it will keep for a long period without any risk of spoilage by unwanted microorganisms. This method involves the following steps:

- Sterilising the food products to be canned
- Aseptic Packing (in sterile, air-tight stainless metal, glass or plastic containers) and

- Hermetically sealing (with a complete, airtight seal)

Nowadays, a several number of canning methods are in practiced but only two (as follows) are approved by the United States Department of Agriculture (USDA):

a) Water-bath canning: It is sometimes referred to as the boiling-water method of canning or as hot water canning, is the simplest and easiest method for preserving high-acid food. Filled jars are submerged in the water and heated to an internal temperature (100^{o}C) for a specific period of time. This method is adequate to kill molds, yeasts, enzymes and some bacteria, making it safe for consumption at a later time. For example, acid foods such as fruit butters and spreads, fruit pie fillings, sauerkraut, pickles and pickled vegetables, jams and jellies can be safely processed by boiling water bath canning, because spoilage causing microorgnisms of foods are usually killed at boiling temperatures. Tomatoes and its products may be processed by this method after little acidification.

   Limitation: As this method never reaches the super-high temperatures required to kill certain bacterial resistant form (spores) and their toxins, which can produce botulism, hence, this method cannot be applied for processing low-acid foods.

b) Pressure canning: In pressure canning, a large kettle used and steam is produced steam in a locked compartment. The filled jars in the kettle reach an internal temperature of 116^{o}C under a specific pressure which is measured with gauge. It is useful for processing vegetables and other low-acid foods (i.e. meat, poultry, seafoods etc.). In such process, *C. botulinum* (the bacterium that causes botulism food poisoning), is destroyed in low-acid foods when they are processed at the correct time and temperature in pressure canners. If *C. botulinum* bacteria survive and grow inside a sealed jar of food, they can produce a deadly toxin and even a tiny taste of food containing this toxin can be deadly.

Before use any canned food we should inspect the physical structure (damage or swollen) of can check because a swollen, bulging can indicates that gas is being produced on the inside and exhibits there is microbial activity in the food, so it would not be safe for consumption. Though, in canning we can keep our food safe but once we open the can, there is a risk because certain microorganism can enter and begin attacking the food. Therefore, it is suggested that we should refrigerate the contents after opening and use within the recommended time.

3. Summary

Most of the Physcical methods (Low and high temperature processing) are a promising and useful approach for milk, fruit juice and beverage preservation under controlled conditions. The products based on these

techniques show many advantages such as the retention of sensorial qualities and nutritional values over chemical preservation methods. More practically, the application of physical methods of food preservation would be the future trends for milk, milk products, fruit juice and beverages preservation with the effective inhibition or destruction of microorganisms and shelf-life extension.

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