Sterilizing Equipments

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1. Introduction

Today, the consumer demands more than the production of safe and shelf-stable foods and insist on high quality foods with convenient end use. Heat treatment of products is one of the main techniques in the food industry for food conservation. Heat treatment stops bacterial and enzyme activity; thus preventing a loss of quality and keeping food non-perishable. Sterilization is a controlled heating process used to completely eliminate all living micro-organisms, including thermoresistant spores in milk or other food. It can be achieved by moist heat, dry heat, filtration, irradiation, or by chemical methods. Compared to pasteurisation, a heat treatment of over 100°C is applied for a period long enough to lead to a stable product shelf-life.

Sterilisation is used to treat all types of food products. These include milk, juices, beer and many others. Ultra High temperature (UHT) sterilization is used for low viscosity liquid products (milk, juices, cream, wine, salad dressings), foods with discrete particles (baby foods, tomato products, fruits and vegetables juices, soups) and larger particles (stews).

Generally in sterilization, the product is canned or bottled and then heat-treated in a sterilizer. Sterilizers may be batch or continuous. In heat treatment processes, various time and temperature combinations can be applied, depending on the product properties and shelf-life requirements. There are two types of sterilizing heat are being used such as moist heat and dry heat.

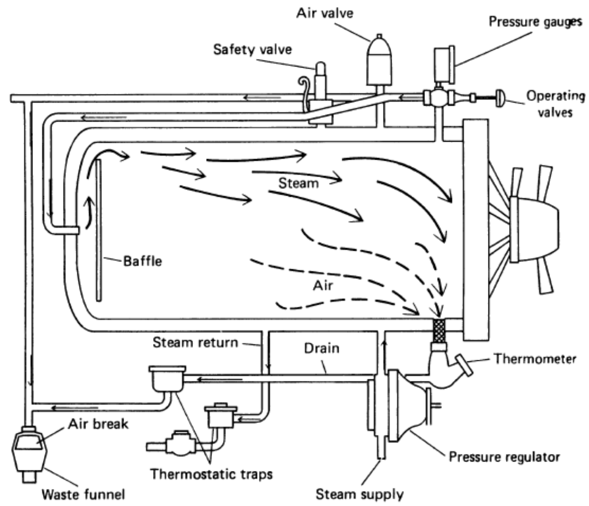
Sterilization with moist heat: In sterilisation with moist heat, temperatures generally range from 110 to 130°C with sterilization times being from 20 - 40min. For example, canned foods are sterilised in an autoclave at about 121°C for 20min. Higher temperatures and shorter times may have similar effects, e.g. 134°C for 3min. However, if conditions do not allow the germination of spores, lower temperatures and shorter times can also be applied. For example, with acid fruit juices, jam, or desserts, heating to 80 – 100°C for 10min is normally sufficient.

Sterilization with dry heat: For killing bacterial endospores by dry heat, longer exposure times (e.g. up to 2 hours) and higher temperatures (e.g. 160 – 180°C) are required than with moist heat.
Sterilization by chemical means: Chemical means may also be applied. Ethylene oxide is used to sterilize food, plastics, glassware, and other equipment.

2. Autoclave (Steam Sterilizing Equipment)

An autoclave is a large pressure cooker; it operates by using steam under pressure as the sterilizing agent. High pressures enable steam to reach high temperatures, thus increasing its heat content and killing power. Most of the heating power of steam comes from its latent heat of vaporization. This is the amount of heat required to convert boiling water to steam. This amount of heat is large compared to that required to make water hot. For example, it takes 80 calories to make 1 liter of water to boil, but 540 calories to convert that boiling water to steam. Therefore, steam at 100 ºC has almost seven times more heat than boiling water. Steam is able to penetrate objects with cooler temperatures because once the steam contacts a cooler surface, it immediately condenses to water, producing a concomitant 1,870 fold decrease in steam volume. This creates negative pressure at the point of condensation and draws more steam to the area. Condensation continues so long as the temperature of the condensing surface is less than that of steam; once temperature equilibrate, a saturated steam environment is formed. Achieving high and even moisture content in the steam-air environment is important for effective autoclaving. The ability of air to carry heat is directly related to the amount of moisture present in the air. The more moisture present, the more heat can be carried, so steam is one of the most effective carriers of heat. Steam therefore also results in the efficient killing of cells, and the coagulation of proteins. Moist heat is thought to kill microorganisms by causing coagulation of essential proteins. Another way to explain this is that when heat is used as a sterilizing agent, the vibratory motion of every molecule of a microorganism is increased to levels that induce the cleavage of intramolecular hydrogen bonds between proteins. Death is therefore caused by an accumulation of irreversible damage to all metabolic functions of the organism.

The diagram of an autoclave depicts the simplicity of its operation. Basically, steam enters the chamber jacket, passes through an *operating valve* and enters the rear of the chamber behind a *baffle* plate. It flows forward and down through the chamber and the load, exiting at the front bottom. A *pressure regulator* maintains jacket and chamber pressure at a minimum of 15 psi, the
pressure required for steam to reach 121 ºC (250 ºF). Overpressure protection is provided by a *safety valve*. The conditions inside are thermostatically controlled so that heat (more steam) is applied until 121ºC is achieved, at which time the timer starts, and the temperature is maintained for the selected time.



Points to achieve complete autoclaving

Guidelines for autoclaving

Time/Volume/Mass/Insulation/Microbe concentration/Etc. You must think about all of these variables! There is no simple formula for how long a certain item needs to be autoclaved to achieve sterility.

Secondary Containers. Plastic or steel containers (trays) are commonly used to contain material during autoclaving, since it is important to contain spills. But don't forget that such containers alter the nature of the autoclave run! Polypropylene plastic pans with 6 inch sides are favored over polyethylene and polystyrene because it can withstand autoclaving without melting. (Don't ever autoclave a plastic item -- like a tray-- if you are not sure it can handle the heat. It is no fun to pry out a melted tray!).

Indicators. These are tools used to validate the autoclaving process. However, use this with caution. Stick-on tape indicators can only be used to verify that the autoclave has reached normal
operating temperatures for decontamination and not that the run was long enough. Biological indicators can be used in the efficacy testing of

the autoclave process to effectively sterilize the contents being treated, however this is tedious and we don't routinely do this.

Be cautious of packages wrapped too tightly. Air and steam do not mix readily. Air, being heavier than steam, normally is displaced to the bottom of the sterilizer and is then forced out through the drain. If your dry items are wrapped too tightly, however, air is trapped and cannot escape. It forms cool air pockets at the center of the packages, preventing the items from reaching temperatures sufficient to kill all microorganisms.

Some general guidelines. Here are some recommended times for autoclaving liquids of the following volume per container:

- ≅ 75 to 200 ml for 20 minutes
- ≅ 200 to 500 ml for 25 minutes
- ≅ 500 to 1000 ml for 30 minutes
- ≅ 1000 to1500 ml for 35 minutes
- ≅ 1500 to 2000 ml for 40 minutes

Remember to modify these times as needed! For example, more time is required if the flasks in a plastic tray (which is the standard method); if many bottles are close to each other in the tray; if the chamber is full of several trays; if the liquid contains microbes; if you are using plastic instead of glass containers; etc. Therefore, you probably need to go longer than the times indicated above.

JUST TO BE SAFE, when running the autoclave make sure that it reaches the desired pressure and temperature. Also, before using the autoclave, check the drain screen at the bottom of the chamber and clean if blocked. If the sieve is blocked with debris, a layer of air may form at the bottom of the autoclave, preventing efficient operation.

3. UHT Sterilizer (Ultra High Temperature Sterilizing equipment)

The equipment is designed to sterilize puree/pulp concentrates, fibrous liquids to ensure long period shelf life. UHT sterilizer is generally used for a very short heat treatment at temperature of approximately 140°C (135 - 150°C) for only a few seconds. This results in a sterilized product with minimal heat damage to the product properties. UHT treatment is only possible in flow-through equipment. The product is thus sterilized before it is transferred to pre-sterilized containers in a sterile atmosphere. It is designed through digital heat quantity calculation which controls the precise sterilization temperature and cooling time, thus reducing flavour/aroma/nutrition loss and ensuring ascepticity of the product. This requires aseptic processing.

There are two principal methods of UHT treatment:
Direct heating: The product is heated by direct contact with steam of potable or culinary quality. The main advantage of direct heating is that the product is held at the elevated temperature for a shorter period of time. For a heat-sensitive product (for example milk), this means less damage. There are two methods of direct heating: (a) injection and (b) infusion.

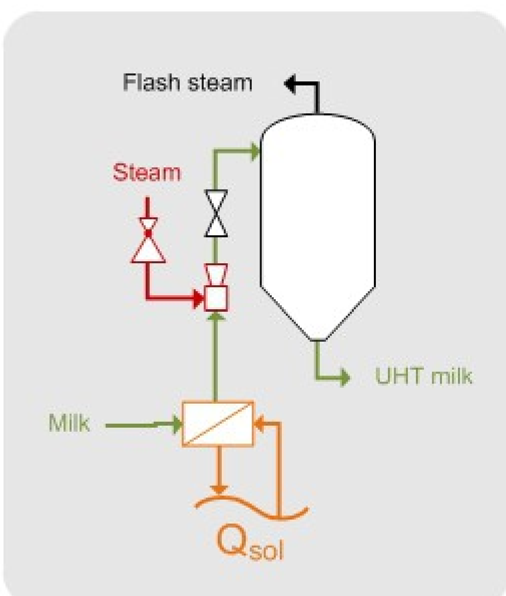


Fig 1. Injection and infusion for direct heating in UHT Sterilizer

(a) Injection: High pressure steam is injected into pre-heated liquid by a steam injector leading to a rapid rise in temperature. After holding, the product is flash-cooled in a vacuum to remove water equivalent to amount of condensed steam used. This method allows fast heating and cooling, and volatile removal, but is only suitable for some products. It is energy intensive and because the product comes in contact with hot equipment, there is potential for flavour damage.
(b) Infusion: The liquid product steam is pumped through a distributing nozzle into a chamber of high pressure steam. This system is characterized by a large steam volume and a small product volume, distributed in a large surface area of product. Product temperature is accurately controlled via pressure. Additional holding time may be accomplished through the use of plate or tubular heat exchangers, followed by flash cooling in vacuum chamber. This method has several advantages: instantaneous heating and rapid cooling, no localized overheating or burn-on and suitable for low and higher viscosity products.
Indirect heating: The heating medium and product are not in direct contact, but separated by equipment contact surfaces. Several types of heat exchangers are applicable:

(a) Plate Heat Exchangers:
Similar to that used in HTST but operating pressures are limited by gaskets. Liquid velocities are low which could lead to uneven heating and burn-on. This method is economical in floor space, easily inspected, and allows for potential regeneration.

(b) Tubular Heat Exchangers:
There are several types: shell and tube, shell and coil, double tube and triple tube. All of these tubular heat exchangers have fewer seals involved than with plates. This allows for higher pressures, thus higher flow rates and higher temperatures. The heating is more uniform but difficult to inspect.

(c) Scraped Surface Heat Exchangers:

The product flows through a jacketed tube, which contains the heating medium, and is scraped from the sides with a rotating knife. This method is suitable for viscous products and particulates (< 1cm) such as fruit sauces, and can be adjusted for different products by changing configuration of rotor. There is a problem with larger particulates; the long process time for particulates would mean long holding sections which are impractical. This may lead to damaged solids and overprocessing of sauce.

(d) Double-cone Heat Exchangers:
Suitable for large particulates because it involves separation of solids/liquids and combines indirect heating in double cone (batch) with direct heating of liquid portion (maybe also scraped surface if too viscous). The solid pieces are fed into a double-cone, rotated slowly on horizontal axis with steam injection and heated surfaces. There is no burn-on because they are the same temperature. The liquid is directly heated with steam separately, then added after pre-cooling. The double cone acts as a blender and coats solids. The product is then discharged to an aseptic filler by overpressure with sterile air. Used for soups, stews, carrots, and vegetables.

4. Continuous sterilizers

Use of continuous sterilizers after filling of cans, bottles and jars.

Continuous sterilizers enable close control over processing conditions and so produce more uniform products. They produce gradual changes in pressure inside the cans, bottles and jars and, therefore, less strain on the seams compared with batch equipment. Continuous sterilizers, e.g. cooker-coolers, can vary slightly in design and size. Some models can accommodate up to 25000 cans, bottles or jars. They carry them on a conveyor through three sections of a tunnel that are maintained at different pressures for preheating, sterilizing and cooling. The food can be cooked during preheating and sterilizing.

The water is re-used continuously and water is added, as required, to replace the minimal evaporation loss, thereby controlling the amount of water and energy consumed. The water is re-used for cleaning when it can no longer be used in sterilization. In this way, the consumption of water and energy is reduced.

The main disadvantages of continuous sterilization include a high in process stock which would be lost if a breakdown occurred, and in some problems, with metal corrosion and contamination by thermophilic bacteria may occur, if adequate preventing measures are not taken.

5. Hot air sterilizer

Hot air ovens are electrical devices which use dry heat to sterilize. They were originally developed by Louis Pasteur. Generally, they can be operated from 50 to 300 °C, using a thermostat to control the temperature. Their double walled insulation keeps the heat in and conserves energy, the inner layer being a poor conductor and outer layer being metallic. There is also an air filled space in between to aid insulation. An air circulating fan helps in uniform distribution of the heat. These are fitted with the adjustable wire mesh plated trays or aluminium trays and may have an on/off rocker switch, as well as indicators and controls for temperature and holding time. The capacities of these ovens vary. Power supply needs vary from country to country, depending on the voltage and frequency (hertz) used. Temperature sensitive tapes or biological indicators using bacterial spores can be used as controls, to test for the efficacy of the device during use.

They do not require water and there is not much pressure build up within the oven, unlike an autoclave, making them safer to work with. This also makes them more suitable to be used in a laboratory environment. They are much smaller than autoclaves but can still be as effective. They can be more rapid than an autoclave and higher temperatures can be reached compared to other means. As they use dry heat instead of moist heat, some organisms like prions, may not be killed by them every time, based on the principle of thermal inactivation by oxidation.

A complete cycle involves heating the oven to the required temperature, maintaining that temperature for the proper time interval for that temperature, turning the machine off and cooling the articles in the closed oven till they reach room temperature. The standard settings for a hot air oven are: 1.5 to 2 hours at 160 °C (320 °F) or 6 to 12 minutes at 190 °C (374 °F) plus the time required to preheat the chamber before beginning the sterilization cycle. If the door is opened before time, heat escapes and the process becomes incomplete. Thus the cycle must be properly repeated all over.

These are widely used to sterilize articles that can withstand high temperatures and not get burnt, like glassware and powders.

6. Membrane filter apparatus

In the food and beverage industries, the precise separation of particles is increasingly important in the production of beer, apple juice and numerous dairy products. Membrane filtration is a good example of a simple and efficient technology used to enhance food quality with excellent future prospects.

Membrane filtration is a technique that uses a physical barrier, a porous membrane or filter, to separate particles in a fluid. Particles are separated on the basis of their size and shape with the use of pressure and specially designed membranes with different pore sizes. Although there are different membrane filtration methods (reverse osmosis, nanofiltration, ultrafiltration and microfiltration, in order of increasing pore size), all aim to separate or concentrate substances in a liquid.

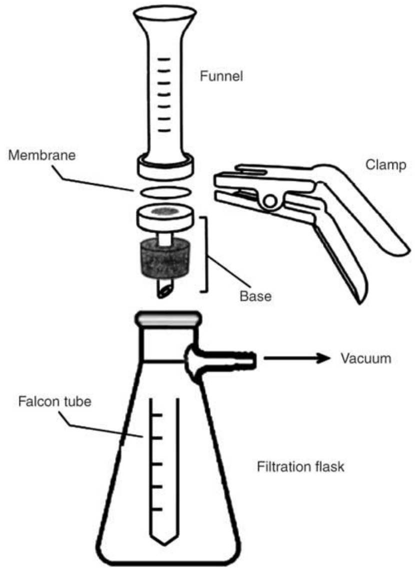


Fig 3. Membrane filter apparatus assembly.

In the food and beverage industries, membrane filtration is state-of-the-art technology for clarification, concentration, fractionation (separation of components), desalting and purification of a variety of beverages. It is also applied to improving the food safety of products while avoiding heat treatment. Some examples of final products using this technique are fruit and vegetable juices, like apple or carrot; cheeses, like ricotta, ice cream, butter or some fermented milks; skimmed or low-lactose dairy products; microfiltered milk; non-alcoholic beers, wines and ciders, etc.

The use of membrane filtration offers a wide range of advantages for the consumer as well as for the producer. On the one hand, filtration technology offers an efficient way to gain superior quality and safety without destroying the fundamental sensory qualities of the product. It removes unwanted ingredients like microorganisms, dregs or sediments that have a negative impact on product quality, making the final product more attractive in texture and increasing its shelf life. On the other hand, it may reduce some production steps and increase yield, has a high degree of selectivity, improves control over the production process and has low energy costs.

Conclusion: Sterilization is one of the most important aspect in the food industry, since microorganisms are to known to contaminate at any point of time such as preparation, processing or packing. Appropriate equipments and procedures must be developed for all the raw materials used for the food preparation and food-product contact surfaces (glasswares, utensils, etc.) and anything which could impact food safety. Sterilizing equipments must be evaluated for adequacy through evaluation and inspection procedures. Adherence to prescribed written procedures should be continuously monitored, and records should be maintained to evaluate long-term compliance.