Paper No.: 02

Paper Title: The Principles of the Food Processing & Preservation

Module No. : 11

Module Title: Aseptic Processing & Packaging

11.0 Introduction

Aseptic processing is a high-temperature, short-time (HTST) process which results in products with improved texture, color, flavor, and nutritional value, compared to conventional canning. Aseptic processing is the process in which a sterile (aseptic) product (typically food or pharmaceutical) is packaged in a sterile container in a way that maintains sterility. Sterility is achieved with a flash-heating process (temperature between 195 and 295 °F (91 to 146 °C)), which retains more nutrients and uses less energy than conventional sterilization techniques such as retort or hot-fill canning. Aseptic food preservation methods allow processed food to keep for long periods of time without preservatives, as long as they are not opened. The aseptic packages are typically a mix of paper (70%), polyethylene (LDPE) (24%), and aluminum (6%), with a tight polyethylene inside layer. Together these materials form a tight seal against microbiological organisms, contaminants, and degradation, eliminating the need for refrigeration.

The first aseptic filling plant for milk was presented in Switzerland in 1961. The Tetra Pak company later became one of the leading suppliers of processing and packaging equipment for dairies. Aseptic techniques were common in Europe and Asia before they were introduced in the United States in the 1980s. Aseptic processing makes worldwide export and import of new, economical and safe food products possible. Bag-In-Box technology is commonly used because it provides strong containers that are lightweight and easy to handle prior to being filled. Other common package types are drink boxes and pouches.

High Temperature Short Time (HTST) processes are possible if the product is sterilised before it is filled into pre-sterilised containers in a sterile atmosphere. This forms the basis of aseptic processing, also known as ultra-high temperature (UHT) processing. Aseptic processing is used to sterilise a wide range of liquid foods, including milk, fruit juices and concentrates, cream, yoghurt, salad dressings, egg and ice cream mix. A number of systems have been introduced for true HTST treatment, using two or more steps for heating, applying steam injection or infusion for the final split second temperature rise up to some 150ºC, followed by very rapid evaporative and heat exchanger cooling. Heating equipment for aseptic processing includes the following:

- Direct systems:
  - steam injection
  - steam infusion
- Indirect systems:
  - plate heat exchangers (including tube-in-tube)
  - tubular heat exchangers (concentric tube or shell-and-tube)
  - scraped surface heat exchangers.

The main advantages and disadvantages of the of the direct and indirect heating methods are summarized in Table.1 & 2.

Recent developments in the heating system technologies include tube-in-tube heat exchangers, a development of plate heat exchangers, in which the thin-walled plates are formed into a tube and corrugations or twists in the tubes are introduced to promote turbulent flow. One tube is inserted inside another, which may be repeated two or more times and heat transfer takes place across the tube walls. Incoming material is heated by sterilized product to regenerate heat and increase energy efficiency. Steam from hot water is used for the final heating and, after initial cooling by the incoming material, the product is cooled with cold water. This system is relatively low cost and is widely used, although it suffers from some drawbacks such as:

- The equipment is restricted to relatively low viscosity liquids that do not cause
- Significant fouling
- Seal integrity is critical to prevent mixing of incoming material, sterilized
- Product or heating and cooling media
- The seal strength limits the pressure that can be used
- Seals may be difficult to clean.

The process has been widely used for fruit juices, milk and dairy products. The problems encountered in straight tube heat exchangers are largely overcome by forming a single tube into a continuous helix or coil, which has a carefully defined ratio between the diameter of the coil and the diameter of the tube. The coil is contained within an insulating material to minimize heat losses. The design of the coil promotes secondary flow of liquid within the tube, and this causes turbulence at relatively low flow rates, and high rates of heat transfer (between two and four times the rates in tube-in-tube or shell-and-tube heat exchangers. This enables processing of heat-sensitive products (e.g. liquid egg) and products that cause fouling of heat exchanger surfaces. The mixing action in the coil gives a uniform distribution of particles, making the equipment suitable for salad dressings, fruit pure´es and other foods that contain a range of particle sizes, as well as for high viscosity liquids such as cheese sauce. Additionally, the continuous tube has no seals and is easily cleaned in place, and the simple design is virtually maintenance-free.

Table.1 Advantages & Disadvantages of Direct Heating Systems

Steam injection		**Steam infusion**	
Advantages	**Limitations**	**Advantages**	**Limitations**
• One of the fastest methods of heating and the fastest method of cooling and is Therefore suitable for more heat sensitive foods	• The method is only suitable for low viscosity products	• Almost instantaneous heating of the food to the temperature of the steam, and very rapid cooling which results in high retention of sensory characteristics and nutritional properties	• The method is only suitable for low viscosity products
• Volatile removal is an advantage with some foods (for example milk)	• There is relatively poor control over processing conditions	• Greater control over processing conditions than steam injection	• There is relatively poor control over processing conditions
	• A requirement for potable steam which is more expensive to produce than normal processing steam	• Lower risk of localized overheating of the product	• There is a requirement for potable steam which is more expensive to produce than normal processing steam
	• Regeneration of energy is less than 50% compared with more than 90% in indirect systems	• The method is more suitable for higher viscosity foods compared to steam injection	• Regeneration of energy is less than 50% compared with more than 90% in indirect systems
	• Flexibility for changing to different types of product is		• Flexibility for changing to different types of product is low

	low		• Blockage of the spray nozzles • Separation of components in some foods

Table.2 Advantages & Disadvantages of Indirect Heating Systems

Steam injection		Steam infusion	
Advantages	**Limitations**	**Advantages**	**Limitations**
• Relatively inexpensive	• Limited to low viscosity liquids (up to 1.5Nsm^{-2})	• Few seals and easier cleaning and maintenance of aseptic conditions	• Limited to relatively low viscosity foods (up to 1.5Nsm^{-2})
• Economical in floor space and water consumption	• Operating pressures limited by the plate gaskets to approximately 700kPa	• Operation at higher pressures (7,000-10,000 kPa) and higher liquid flow rates (6ms^{-1}) than plate heat exchangers	• Lower flexibility to changes in production capacity
• Efficient in energy use (>90% energy regeneration)	• Liquid velocities at relatively low pressure also low (1.5-2ms^{-1})	• Turbulent flow at tube walls due to higher flow rates hence more uniform heat transfer and less product deposition	• Larger diameter tubes cannot be used because higher pressures needed to maintain the liquid velocity and large diameter pipes have a lower resistance to pressure
• Flexible changes to production rate, by varying the number of plates	• Low flow rates can cause uneven heating and solids deposits on the plates which require more frequent cleaning		• Any increase in production rate requires duplication of the equipment
• Easily inspected by opening the plate stack	• Gaskets susceptible to high temperatures and caustic cleaning fluids and are replaced more regularly than in pasteurisation • Careful initial sterilisation of the large mass of metal in the plate stack is necessary for uniform expansion to prevent distortion and damage to plates or seals • Liable to fouling		• Difficulty in inspecting heat transfer surfaces for food deposits

A major challenge lies in aseptic processing of particulate-containing foods, especially at particle sizes of 5ï 10mm or more. The major problem is that of ensuring sterility of the fastest moving particle without heat damage to the slower moving ones. To reduce this problem, processes have been designed where liquid and particles are processed separately and mixed again before the aseptic packaging stage, or where liquid and particles are moved through the heating zone at different rates. The ôTwinthermô system is a semi-continuous process in which particulate food is heated by direct steam injection in a pressurised, horizontal, cylindrical vessel that rotates slowly. Once the particles have been held for the required time, they are cooled evaporatively, and liquid that has been sterilised in conventional UHT heat exchangers is used to carry the treatment of particles compared to continuous processes. The single flow fraction specific thermal processing (FSTP) system employs a separate holding section which is a cylindrical vessel containing slowly rotating fork blades on a central shaft. These blades form cages which hold the particles as they are rotated around the cylinder from the inlet to discharge pipes. Liquid moves freely through the cages, giving rapid heat transfer. This method of aseptic processing is now used for foods such as soups, baby foods, fruit and vegetables.

11.1 Semi-aseptic processes

There are a number of other similar processes to aseptic processing which may be labelled minimal processing compared to conventional canning, in that heat treatment is done in direct contact between heating medium and food. One example is the old Flash-18 process, in which people actually worked inside a pressure vessel in which food was heat sterilised in open cookers and packed hot inside the vessel. A modern, automated version of this is the Pressure-Pac system. In the Vatech system, food is packed and autoclaved in only partially sealed cans, so that steam penetrates into the food and drains all liquid from the can, after which the can is sealed under pressure and cooled.

For bulk pasteurisation of vegetables in combination with semi-aseptic modified atmosphere packaging, two interesting methods are claimed to be in commercial use. One applies vacuum steam followed by vacuum cooling, and the other applies heat below 60ºC under CO2 overpressure. It appears that pasteurisation by heat or other means in combination with packaging under clean room conditions (semi-aseptic) is attracting increasing interest today. Interesting new process equipment that can be used in such applications are spiral steam heaters and coolers, also using impingement steam jets, and microwave and short-wave infrared tunnels.

In the APV high heat infusion system, the very heat-resistant *Bacillus sporotherm durance* is inactivated by a heating step from 125º to 150ºC in 0.2 seconds in a steam infusion chamber, followed by a very precise 2.0 seconds holding time. Upstream, the product is preheated to 70ºC followed by vacuum cooling, after which the product is again preheated, now to 125ºC, prior to the steam infusion. Compared to other UHT systems this is claimed to avoid any fouling, and energy regeneration is claimed to be up to 75% higher. The advantages and disadvantages of high heat infusion are summarised in Table.3. High heat infusion is used mainly for dairy products such as UHT milk, lactosereduced milk, flavoured milks, various sauces and dressings.

Table 3. Advantages and Disadvantages of High Heat Infusion

Advantages	Disadvantages
• Its capacity to kill heat-resistant spores	• Products undergo more severe chemical damage compared to the normal infusion process
• Longer operating times, due to reduced fouling	• In milk production the process also requires downstream homogenisation for the longest possible shelf-life to be obtained
• Increased safety, because the flash chamber (and in some cases the	

homogeniser) is placed prior to UHT treatment

- Increased cost efficiency, especially in energy costs and the cost of maintenance, inspection, etc.
- The possibility of aseptic flavour addition, giving the technology an advantage in the production of flavoured milk or ice cream mixes, for example
- The capacity to manufacture a wider range of products

11.2 Aseptic Packaging

UHT-treated products have to be packaged under conditions which prevent microbiological contamination, i.e. aseptically packaged. With some high-acid foods ($pH<4.5$), it may be sufficient to cool the product after UHT treatment to just below 100°C, fill it into a clean container, seal the container and hold it at that temperature for some minutes before cooling it. This procedure will inactivate microorganisms that may have been in the container or entered during the filling operation and which might grow in the product. The filled container may need to be inverted for some or all of the holding period. However, in the case of low-acid foods ($pH>4.5$) this procedure would not be adequate to ensure the sterility of the product. Consequently for such products, aseptic filling must involve sterilising the empty container or the material from which the container is made, filling it with the UHT-treated product and sealing it without it being contaminated with microorganisms.

In the case of rigid metal containers, superheated steam may be used to sterilize the empty containers and maintain a sterile atmosphere during the filling and sealing operations. Empty cans are carried on a stainless steel conveyor through a stainless steel tunnel. Superheated steam, at a temperature of approximately 260°C, is introduced into the tunnel to sterilise the cans. They then move into an enclosed filling section, maintained sterile by superheated steam. They are sprayed on the outside with cool sterile water before being filled with the cooled UHT product. The filled cans move into an enclosed seaming section, which is also maintained in a sterile condition with superheated steam. The can ends are also sterilised with superheated steam and double-seamed onto the filled cans in the sterile seaming section. The filled and seamed cans then exit from the tunnel. The whole system has to be presterilised and the temperatures adjusted to the appropriate levels before filling commences. This aseptic filling procedure is known as the *Dole process*. Glass containers and some plastic and composite containers may be aseptically filled by this method. Cartons made from a laminate of paper/aluminium foil/polyethylene are widely used for UHT products such as liquid milk and fruit juices. This type of packaging material cannot be sterilised by heat alone. A combination of heat and chemical sterilant is used. Treatments with hydrogen peroxide, peracetic acid, ethylene oxide, ionising radiation, ultraviolet radiation and sterile air have all been investigated. Hydrogen peroxide at a concentration of 35% in water and 90°C is very effective against heat-resistant, spore forming microorganisms and is widely used commercially as a sterilant in aseptic packaging in laminates. Form-fill-seal systems are available as shown in the figure.1.

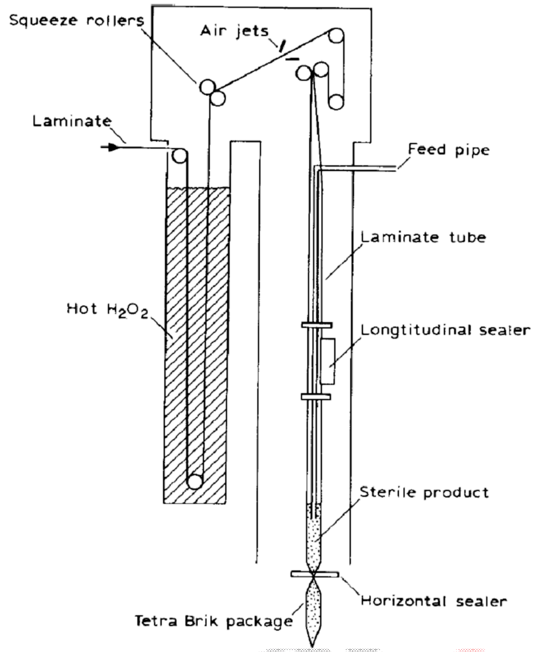

Figure.1: Principle of aseptic packaging system

The packaging material, a polyethylene/paper/polyethylene/foil/polyethylene laminate, is unwound from a reel and a plastic strip is attached to one edge, which will eventually overlap the internal longitudinal seal in the carton. It then passes through a deep bath of hot hydrogen peroxide, which wets the laminate. As it emerges from the bath, the laminate passes between squeeze rollers, which express liquid hydrogen peroxide for return to the bath. Next, a high-velocity jet of hot sterile air is directed onto both sides of the laminate to remove residual hydrogen peroxide, as a vapour. The laminate, which is now sterile and dry, is formed into a tube with a longitudinal seal in an enclosed section which is maintained sterile by means of hot, sterile air under pressure. The product filling tube is located down the centre of the laminate tube. The presterilised product is fed into the sterile zone near the bottom of the tube, which is heatsealed. The air containing the vaporised hydrogen peroxide is collected in a cover and directed to a compressor where it is mixed with water, which washes out the residual hydrogen peroxide. The air is sterilised by heat and returned to the filling zone.

In another system, the laminate is in the form of carton blanks which are erected and then sterilised by a downward spray of hydrogen peroxide followed by hot sterile air. This completes the sterilisation and removes residual hydrogen peroxide. The presterilised product is filled into the cartons and the top sealed within a sterile zone. Similar systems are available to aseptically fill into preformed plastic cups. The lidding material is sterilised with hydrogen peroxide or infrared radiation before being heat-sealed onto the cups within a sterile zone. Thermoform filling systems are available to aseptically fill into polymer laminates. The web of laminate passes through a bath of hydrogen peroxide and then is contacted by hot sterile air which completes the sterilisation, removes residual hydrogen peroxide and softens the laminate. The laminate is then thermoformed into cups and filled with presterilised product within a sterile zone. The sterilised lidding material is applied before the cups leave the sterile zone. Thermoforming systems are usually used to fill small containers e.g. for individual portions of milk, cream and whiteners etc.

11.3 Conclusion

Aseptic processing has been a boon to the food processing sector, enabling both growth and innovation. In aseptic processing, food is stored at ambient temperatures in sterilized containers free of spoilage organisms and pathogens. The results of this food technology come in all shapes and sizes, from the consumer packages of milk on the shelves of the supermarket to the huge containers full of orange juice transported around the world by cargo ships. Over the last couple of decades, aseptic bulk storage and distribution has revolutionized the global food trade. For example, more than 90 percent of the approximately 24 million tons of fresh tomatoes harvested globally each year are aseptically processed and packaged for year-round remanufacture into various food products. The construction of new aseptic facilities continues around the world, and an up-to-date understanding of the technology is essential for a new generation of food scientists and engineers alike.