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ASPECTS REGARDING THE ASEPTIC PACKAGING OF FOOD PRODUCTS

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Abstract: Aseptic packaging of food products is necessary to prolong their validity and to preserve their original qualities, but also for obtaining higher quality products. Aseptization must be done both for the product to be packaged and for packaging, but also for the enclosure where packaging takes place (the packing machine). There are many ways to sterilize package, but the sterilization procedure usually begins with the packaging material which must be maintained under sterile conditions until the package is made, but also during filling and closing. For the product to be packaged, the most used sterilization methods are thermal treatments, while for packing machines both thermal treatments are used (with steam and hot air) but also combined treatments (thermal and chemical). For packaging material, the most commonly used sterilization procedure is spraying with hydrogen peroxide or peracetic acid solution.
Keywords: food products, aseptic packaging, sterilization

INTRODUCTION

Aseptic packaging is defined as the filling of a sterile food product intended for marketing in sterile containers, under sterile conditions and closing the containers so that reinfection is prevented (hermetic closure). It is obtained, therefore, high quality products with a high shelf life.

Aseptic packaging involves both sterilization of the product and of the materials and package used. Sterilization of products for aseptic packaging is carried out, in general, by HTST or UHT procedures which allow both the destruction of microorganisms and the inactivation of enzymes *(Turtoi M., 2003; Ramos et al. 2015; Tran et al. 2008; Nema & Ludwig, 2010))*.

Aseptic term implies absence or removal of any unwanted micro-organism from the package, product or other characteristic areas, while the term hermetic is used to indicate mechanical properties corresponding to the exclusion of penetration phenomenon of microorganisms into a package, but also of water vapor or gas in / out of the packaging.

Aseptic packaging is used for many reasons:

- the use of unsuitable packages for sterilization in the package;
- thermal treatments used allow achieving of a high temperature for a relatively short time, thus increasing the efficiency of treatment in comparison to lower temperature but long-term treatments;
- prolonging the shelf life of food products stored at normal temperatures.

At aseptic packaging, the product is transported to the packaging machine in a closed system, presterilized and then aseptically dosed in packages that is formed inside the machine. Filling takes place in the aseptic area of the machine, packages sterilization being performed with sterile air under pressure. The aseptic area of the machine in which is realized the filling is small with few moving elements. This is a very important factor which contributes to the integrity of the entire system. The packages are closed under the liquid level, filling is thus complete and, in this way, the content is completely protected against oxidation and at the same time the package is used with maximum efficiency. For products that require agitation, filling may be incomplete.

MATERIAL AND METHODS – ASEPTIC PACKAGING PRINCIPLES

The food products are altered depending on the speed at which the micro-organisms multiply. Multiplication of micro-organisms occurs rapidly in a warm environment and slows at low temperatures. It results that, when the food product is frozen, micro-organisms cannot multiply at all, being completely destroyed when a very high temperature is applied (*Okawara. 2008*; *Office of Compliance, 2004*).

By controlling and destroying micro-organisms, the food products are kept longer. Sterilization methods used in aseptic processing of food are HTST (high temperature - short time) or UHT (ultra-high temperature).

The HTST process is defined as being sterilization by heating the product at an elevated temperature between a few seconds and a few minutes depending on the temperature value. The UHT process is a thermal sterilization treatment in continuous flow to a temperature that may vary between 130-150°C with a maintenance time of 2-8 seconds. The maximum temperature is used for products with low viscosity, (for example milk) and the minimum value is used for products with high viscosity. Thermal treatment must reach 135°C for a period of one or more seconds (*Ramos et al. 2015; Tran et al. 2008)*.

Milk products and fruit juices must be packaged under aseptic conditions to preserve the microbiological qualities conferred by the thermal treatment applied.

When sterilizing food products through processes HTST or UHT problems with inadequate enzyme inactivation may occur. This is specific especially to vegetal enzymes (ex. peroxidases), namely proteases and bacterial lipases.

It is noteworthy that, bacterial enzymes have a much higher resistance to temperature as compared to spores of *Bacillus stearothermophilu,* which are reference spores in thermal treatment.

Aseptic packaging is used for food products such as:

- whole milk / partially skimmed / dietetic milk pasteurized or sterilized (UHT);
- milk based drinks (milk with flavours, milk with cocoa, milk with chocolate);
- milk enriched with vitamin and mineral salts for children, athletes and future mothers;
- consumer cream, sweet or fermented;
- acid dairy products, such as yoghurt, beaten milk, etc.;
- natural mineral water with flavours or purified water;
- specific beverages for athletes;
- simple or mixed fruit juices;
- beverages based on fruit juice;
- alcoholic beverages;
- cold tea;
- coffee and coffee based drinks with added milk;
- soups, flavoured sauces;
- vegetable oil and oil based products (creams, mayonnaise, liquid margarine, dessert sauces).

Tetra Pack aseptic packaging consists of successive cardboard layers, aluminium foil and polyethylene. This combination provides safety and convenience in the use of the product. Each type of packaging material has its specific function in protecting the food. Combination of cardboard, polyethylene and aluminium foil varies according to the product to be packaged; in all cases, however, the only material that comes in direct contact with the food is polyethylene for food use.

Thus, for a product packaged in Tetra Brik Aseptic, there is the following combination of materials:

- 75% paper from renewable sources that gives firm packages and stability;
- 25% polyethylene to prevent reinfection of the product with micro-organisms, which confers resistance to the aggression of external factors;
- 5% aluminium, which is a barrier to air and light, helping to preserve the taste and nutritional qualities of the food product.

Aseptic packages have different shapes and are accessible to any type of consumer. It is necessary, however, that everything is sterile in the manufacturing process, food products, packaging material, equipment and environment in which packaging is carried out. Aseptic packaging is UHT sterilized before heat-treated food product is introduced, resulting in a food with a life span of over 3 months.

As a method of sterilization, the passage of the packaging material can be used through a hydrogen peroxide bath, in concentration of 30%, heated to 70°C for 5-6 seconds. Hydrogen peroxide is then removed from the packaging by pressing rollers or hot air. The environment in which foods are thermally processed and sealed must be, also, lacking bacteria, which means that packaging machines must be sterile as before and after the packaging process is completed.

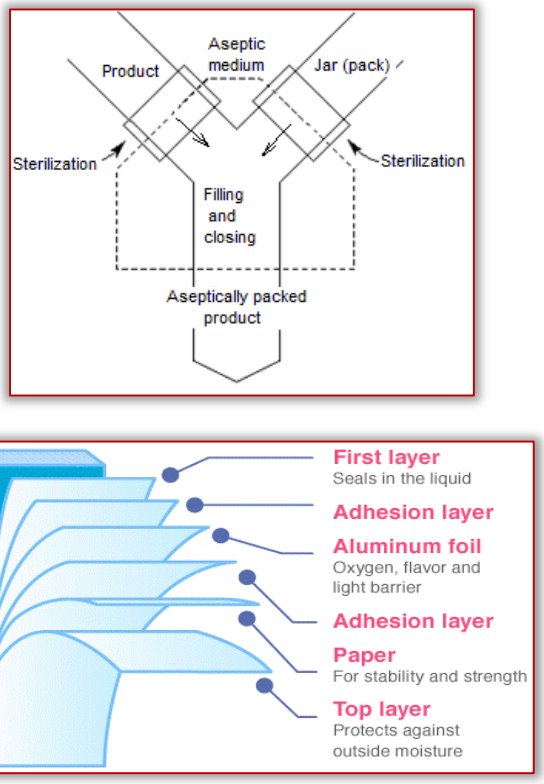

Figure 1 – Principle of aseptic packaging (a) *(Turtoi. 2003)* and complex material for aseptic packaging (b)

RESULTS

— Sterilization of the surface of packaging material in contact with food products

For the sterilization of packaging material used in aseptic packaging three methods can be used, singular or in combination: thermal treatment, chemical treatment and irradiation.

A. Sterilization of the surface of the packaging by thermal treatments

a. Sterilization with saturated steam

The safest thermal agent for sterilization is saturated steam. When using it, the following problems may occur:

- an enclosure is required in which the packaging must be kept under pressure in order to reach sufficiently high temperatures at which sterilization can take place in a few seconds;
- avoid the penetration of fake air into the sterilization space as far as possible otherwise it can influence heat transfer from the steam to the surface of the packaging;
- steam condensation may remain on the surface of the packaging by diluting the food product.

b. Steam sterilization with superheated steam

Overheated steam can be used for sterilization of aluminium metal cans and tin plate.

It has the advantage that it can be used for sterilization of packaging, as well as packaging materials under normal pressure conditions, reaching temperatures of 220-225°C, for

35–45 s depending on the material from which they are made.

c. Hot air sterilization

As with overheated steam, hot air sterilization has the advantage that the necessary temperatures can be obtained at atmospheric pressure. This simplifies the problems of mechanical design of the sterilization system.

This process is used for the sterilization of complex aseptic cartons made from cardboard / aluminium foil / plastic material. At the surface of the material, the temperature 145°C can be reached for 180 s. under the conditions in which the hot air used for sterilization has a temperature of 315°C. Even if the working temperature is high, hot air treatment can only be used for packaging where acidic food is packaged.

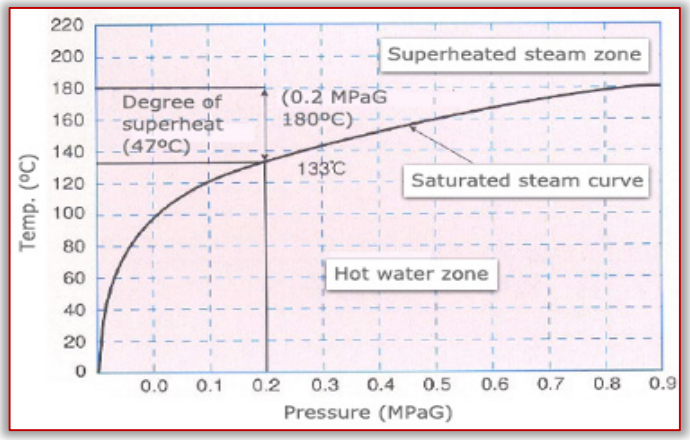

Figure 2 – State Diagram of Water (Pressure - Temperature) *(Okawara. 2008)*

d. Sterilization with hot air and steam

It is a combined process that is used to sterilize packages from stable materials to lower temperatures (about 160°C),, such as the sterilization of the inner surfaces of glasses and caps made from polypropylene, in which case the hot air blows inside the glasses through a nozzle that evenly heats both the bottom and the walls of the glass (*Akers. 2010*).

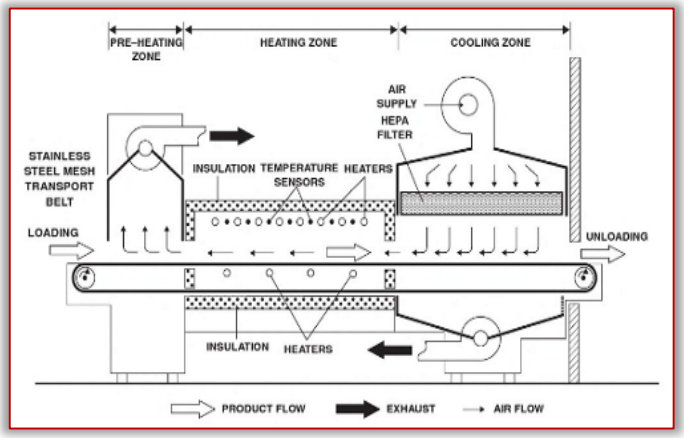

Figure 3 – Dry heat sterilization / depyrogenation tunnel. Schematic *(Akers. 2010)*

e. Sterilization by extrusion in the manufacture of packaging

In the process of extruding preforms for obtaining plastic containers (polyethylene, polyethylene terephthalate, polypropylene etc.) can be reached temperatures of 180-230°C, which are kept for up to 3 minutes so that the packaging is sterilized. Variations in retention time of the granules inside the extruder and uneven temperature distribution cannot guarantee, however, the sterility of all the particles.

For this reason no reduction in microbial spores greater than 3-4 D can be achieved and the packaging thus obtained can only be used for acidic food products with a pH below 4.5. If after the extrusion a sterilization with hydrogen peroxide is made of the packages, they can also be used for products with a pH> 4.5.

B. Sterilization of the packaging surface through chemical treatments

a. Sterilization with hydrogen peroxide

Hydrogen peroxide (H_2O_2) is used for a long time in treating the surface of the packaging to destroy the micro-organisms in combination with the effect of heat, because at the ambient temperature neither the concentrated solutions have a fatal effect. For the short-term destruction of the most resistant spores on the packaging material, the minimum temperature must be at least 80 ° C. and the concentration is at least 30%. There is also the danger that hydrogen peroxide used to sterilize packaging and packaging material will reach the food.

The packaging material is sterilized, mostly, by immersion in hydrogen peroxide with concentration 30-33% or by spraying on the surface of the packaging, followed by hot air drying in both cases.

To reduce the amount of oxygenated water used and increase the efficiency of treatment, we can use a series of combinations of heat and / or radiant or irradiated energy. Thus, for lethal effects of 3-5 D. the hydrogen peroxide concentration drops below 5% for which the possibility of hydrogen peroxide in the packaged product decreases.

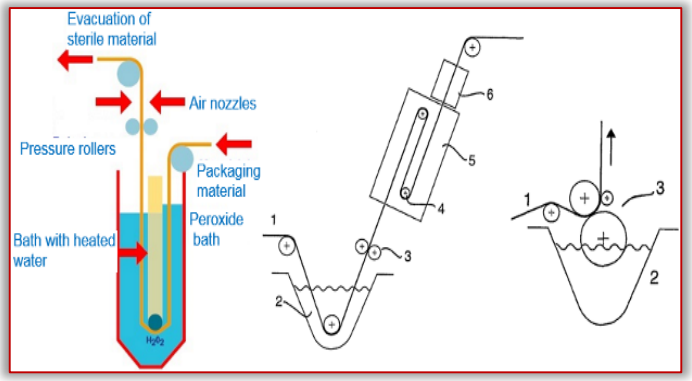

Figure 4 – Sterilization of the packaging material by immersion (chemical treatments)

b. Sterilization with peracetic acid

Peracetic acid has increased destructive efficiency in combination with hydrogen peroxide, even at 20°C. a 1% solution removing over 100 species of resistant spores in just 5 minutes. The duration of sterilization is reduced, in this case about 5 times, and the maximum working temperature is 40°C.

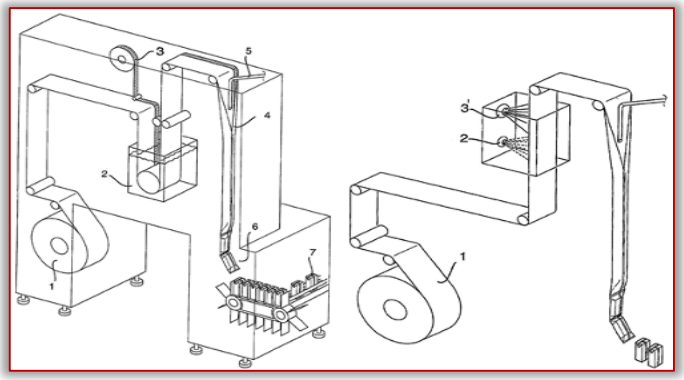

Figure 5 – Chemical treatments applied to packaging materials for forming, filling and closing
1 – roll with packaging material; 2 – immersion area in sterilizing solution; 3 – packaging accessory; 4 – packaging formation; 5 – filling the packaging; 6 – packaged product; 7 – full packaging disposal; 2' – splash area; 3' – hot air drying area

C. Sterilization of the packaging surface by irradiation

Surface of packaging or packaging materials used in aseptic packaging can be sterilized by irradiation with ultraviolet radiation, infrared, ionizing or pulsed light (*Bhavya and Umesh-Hebbar. 2017; Falguera et al. 2011; Reineke et al. 2015; Tanino et al. 2007*).

a. Irradiation with ultraviolet radiation

Ultraviolet radiation with a wavelength of 200-280 nm has the effect of destroying microorganisms, the optimal value being 253.7 nm. To inactivate microorganisms, the energy density of the radiation treatment must be at least 400 J/cm^2 *(Falguera et al. 2011)*.

The conditions for good efficacy of sterilization of ultraviolet radiation surfaces are:

— the irradiated materials to be smooth, UV-resistant and non-adhering dust to avoid the shading effect of surfaces;
— the irradiation intensity should be uniform and suitable for sterilization of the entire package, even if it has a complex form.

The method is used, in general, commercially available in combination with hydrogen peroxide.

b. Irradiation with infrared radiation

Infrared Radiation (IR) is converted into heat by contact with an absorbent surface resulting in an increase of surface temperature. Like UV irradiation, irradiation with IR is used only for smooth and regular surfaces. IR is used to treat the interior of the aluminium caps on which a plastic lacquer was deposited. Due to the possibility of soaking the lake, maximum temperature should be less than 140°C.

c. Irradiation with ionizing radiation

Radiation techniques using gamma radiation of Co60 or Cs139 are used to sterilize the inside of the packaging, usually made of materials that do not withstand sterilization temperatures or cannot be sterilized efficiently by other means, due to the shape they have, such as laminated plastic bags used in bag-in-box aseptic packaging.

They irradiate with at least doses of 25 kGy (2.5 Mrad), which are sufficient to ensure sterility. The bags are enclosed in microorganism impermeable boxes before irradiation. A dose of 20 kGy ensures the sterilization of a 9 mm polyethylene strap infected with approximately 105 spores *Bacillus stearothemophilus*.

d. Treatment with light pulses

Light pulses (PL) are obtained from the "flash" lamp and their effect is sufficient to destroy the microorganisms on the surface of a package. Light pulses have a duration of 10-1–10-6 s. a spectrum of wavelengths of 170–2600 nm, providing an energy density of 0.01–50 J/cm^2. When sterilizing packaging material, the pulse lamp is inserted into the tube that is formed in packs of complex materials type pillow pack to a packaging machine in the formation - filling - closing system *(Bhavya and Umesh-Hebbar. 2017)*.

— Food sterilization

Sterilization is the process by which all living microorganisms are removed or destroyed on the surface of the packaging and inside the food. The sensitivity of micro-organisms must be taken into account in the choice of sterilization methods used in relation with the action of external environmental factors and the physical and chemical qualities of the product subjected to sterilization.

Sterilization is intended to destroy all microorganisms present in the food, both vegetative forms, as well as those sporulated. When sterilizing, some of the microbial and toxins are also destroyed, likewise, some of the enzymes are inactivated (tissues and microbes) (*Barbosa-Canovas and Juliano. 2008*).

In order to be commercially stable the food, it should be heated for a certain time at a pre-determined temperature, depending on the nature of the food (*Cumings. 2004*).

Liquid products less acidic, like milk, are more likely to develop microorganisms and bacteria than strong acid products (for example, fruit juices).

UHT thermal treatment (Ultra High Temperature) or Ultra Pasteurization takes place before packaging, with optimized heat exchangers (*Ramos et al. 2015; Tran et al. 2008)*

Through this controlled process which allows the action of heat for a very short period of time (between 2 and 4 seconds) – followed by an equally rapid cooling, minimal nutritional losses are minimized.

A combined application of electric pulse treatment (PEF) with heat treatment can lead to an accelerated inactivation of endospore in comparison to a pure thermal inactivation in an identical temperature field. This treatment could be used as an alternative treatment technique at ultra-high temperatures of liquid foods with a high pH value, such as milk, vegetable juices or soups (*Reineke et al. 2015)*. The PEF treatment parameters applied resulted in energy inputs of 60.92-257.14 kJ kg^{-1} and thermal loads of 94.61-136.25°C.

Also, food products (in general, vegetables and fruits) can be sterilized with ionizing radiation. Still, conservation with ionizing radiation destroys vitamins, minerals and lack the food from taste and smell. The method has the benefit that the food remain "fresh" for a long time. This treatment

involves exposing the food to a stream of ionizing rays that can be generated by a radioactive source. Foods can be irradiated with gamma or with X ray. Radiation-beam technology uses radioactive substances. ^{60}Co or ^{137}Cs. Here, the processors should however have a great responsibility, because doctors draw attention to the danger of these treatments (*Bogdan et al. 2011*).

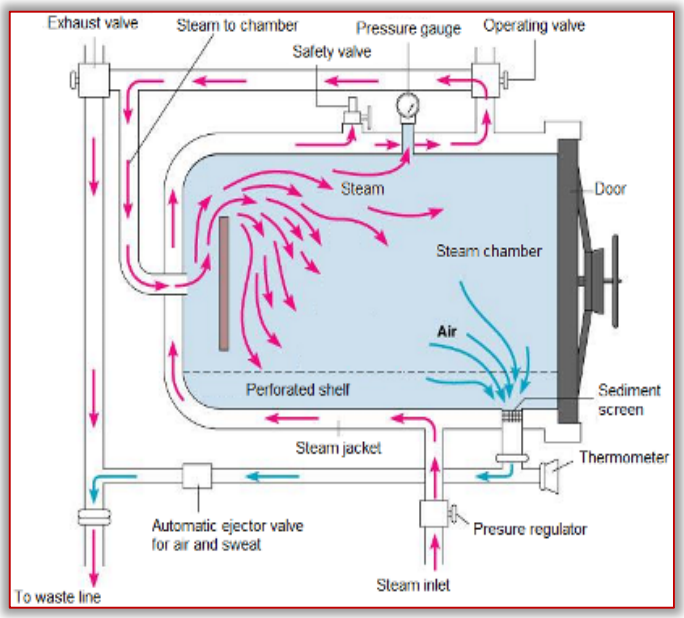

Figure 7 – The principle of sterilizing autoclaves of preserved foods (Cumings. 2004)

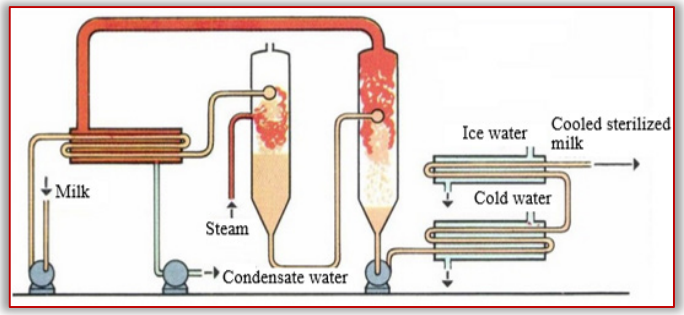

Figure 8 – Sterilization of milk with steam injection

CONCLUSIONS

To ensure high quality food products and preserve its quality for a long time, processors are forced to use aseptic packaging technology lines. It is necessary to sterilize both food product, before filling the packages, as well as sterile packaging, but for aseptic packaging it is also necessary to sterilize the packing machines and the enclosure where filling and closure takes place.

There is an essential difference between hermetic and aseptic. The aseptic term implies the absence or elimination of any unwanted organism in the product, packaging or other specific areas, while the term hermetic is used to indicate mechanical properties corresponding to the exclusion of the microorganism penetration into a packaging and of the gases or water vapours into and out of the packaging. So, it is not sufficient to seal the packing to ensure the quality of packaged products, but also the sterilization of the three elements involved in the packaging process: product, packaging, packaging environment.

Both processors, as well as manufacturers of packaging or packaging materials together with manufacturers of packaging machines must work together to meet the goal of producing aseptic food products with a longer conservation period and improved qualities.

Note

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