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Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 23: Sterilization of packaging material and food contact surfaces

1 INTRODUCTION:

Packaging plays an important role in the food manufacturing process. It makes food more appropriate and gives the food more safety from microorganisms and biological and chemical changes so that the packed foods can have longer shelf life. To have longer shelf life along with food product the packaging material and all food contact surfaces must be sterilized. Sterilization of packaging material and food contact surfaces is a very important operation to free the surface from microorganisms before filling the product, mainly in aseptic packaging of food products. Packaging material and equipment surface may be sterilized by various methods such as heat, hydrogen peroxide, irradiation, infrared light etc. and combinations of methods.

2 CHARACTERISTICS OF GOOD STERILANT /STERILIZING AGENT:

Sterilization of packaging material is a vital step in the aseptic packaging system. Therefore, the sterilization process should meet the following requirements for sterilization of packaging materials:

1. Rapid sporicidal activity
2. Ease of application and compatibility with packaging machinery.
3. Compatibility with packaging material
4. Ease of removal and minimum residues
5. Not threat to health of consumer
6. No detrimental effects of residues on the package/ product
7. No health hazard to personnel operating and around the packaging equipment
8. Compatible with environment
9. Non-corrosive to surfaces treated
10. Should be economical & Easy to handle

3 METHODS OF STERILIZATION OF PACKAGEING MATERIALS AND EQUIPMENTS:

Many methods for the sterilization of packaging materials are currently used in aseptic packaging systems. The sterilization process employed should be recognized in terms of numbers of log cycle reductions of the most resistant microorganisms. Packaging material is usually sterilized either inside the packaging machine or externally and fed aseptically into the aseptic zone of the packaging machine. Methods of sterilization are briefly discussed here in this module.

3.1 Thermal Processes of Sterilization:

Microorganism inactivation has traditionally been accomplished by heating. Reaction velocity for their destruction depends on how rapidly the heat can be transferred to the cell. When heat is used, the nature and type of the surface must be considered. Plastics or carton packaging with their low conductivity are more difficult to thermally sterilize than the metal packaging materials. Also, plastic materials have a low thermal stability and can be permanently distorted by the time temperature combinations necessary to achieve sterilization by heat. Thermal processes do not deposit any hazardous or undesirable residues on the surface being treated and do not present environmental hazards.

3.1.1 Dry Heat:

In this method the packaging material is heated in a hot air oven for a specified minimum temperature for a stated time. Various combinations of temperature and time are recommended depending on the type of the material being sterilized; for example, the usual recommended minimum holding times and temperatures are 180 °C for 30 minutes for glassware.

Spores show greater thermal resistance when exposed to dry heat than moist heat. Spores of *Bacillus stearothermophilus* are extremely resistant to heat. Spores of *Bacillus subtilis* ATCC 9372 are used as indicators in dry heat and these spores are used commercially in sterility testing of aseptic fillers (e.g. the spore-strip kit developed by North American Science Associates, Northwood, OH, USA). *D*-values (the time required to reduce the number of microorganisms by one log cycle) and *Z*-values (the temperature rise

necessary to reduce the *D*-value by a factor of 10) are significantly higher for dry heat sterilization than for steam sterilization. Dry heat produces microbial death as a result of dehydration followed by protein oxidation. Dry heat sterilization is slow and not suitable for heat-sensitive materials like many plastic packaging materials.

3.1.2 Super Heated Steam Systems:

Metal containers were the first used in aseptic operations and are still in use today. In this system, sterilization of the metal container and its closure is accomplished by the application of heat using super heated steam. The advantage of this system is that it can achieve high temperatures at atmospheric pressure; The Martin–Dole process continuously sterilizes tinplate cans by passage through 220–256 ¯C-superheated steams at normal pressure for 45 sec. However micro organisms are more resistant to superheated steam than saturated steam, thus higher temperatures are required while using superheated steam for sterilization.

3.1.3 Saturated Steam Systems:

Saturated steam is a moist heat form. Sterilization of metal cans and lids by saturated steam was used as early as 1920 in the USA. It is also used today for sterilizing thermo-stable plastic cups. To achieve tolerable destruction in the short time available in high speed packaging machines, the surface temperature of the material must be increased to 135°C. The main problem is to obtain a sufficiently high surface temperature to achieve the required sterility in proper time with consistent high production rates and to avoid softening and deformation of the material. Moulded polystyrene cups and foil lids are exposed to saturated steam at 165°C and 6 bars immediately after deep drawing. At the same time the external cup surface is cooled to limit the effect of the short time heat application on the material. It should be noted that *Bacillus subtilis* is not generally recommended for validation of steam sterilization.

Polypropylene cups that have higher thermal tolerance, thus they can be treated on surfaces at lower temperatures and longer times, 140–147°C for 4–6 sec, in a pressure chamber. Lid foil can be treated continuously by passage through a pressure lock. Wet heat could cause blistering or delamination of paper-based packaging materials and

weaken the heat-sealing characteristics of plastics. Atmospheric steam can only be used on non-paper based pre-formed containers. Saturated steam is a preferred treatment method for sterilizing metal food contact surfaces downstream from the hold tube, including sterile hold tank, homogenizers, fillers and the aseptic packaging area. Equipment sterilization can be attained by exposure of the surfaces to an appropriate time temperature combination (e.g. 30 min at a surface temperature of at least 121°C) by superheated water, saturated steam, superheated steam or other appropriate treatments.

3.2 Chemical Methods of Sterilization:

Thermal destruction is by far the most common and efficient mode of sterilization. Dry or moist heat for sterilization is also not always feasible. Chemical methods use a wide variety of chemicals in the form of liquids and gases to disinfect and sterilize equipment and packaging materials.

3.2.1 Hydrogen Peroxide Systems:

Hydrogen peroxide is one of the most widely used sterilants used for sterilizing packaging materials. The first successful aseptic filling system for cartoning the aseptic Tetra Pak of 1961 used a combination of hydrogen peroxide and heat for the sterilization of the surface of container material (Burton, 1988). Many aseptic packaging systems use hydrogen peroxide at concentrations from 30 to 35% as a sterilant for packaging materials and other food contact surfaces followed by hot air (60–125°C) to enhance the sterilizing effect and to dissipate residual hydrogen peroxide. Sterilizing performance increases with both temperature and peroxide concentration. At ambient environmental temperatures, the activity of hydrogen peroxide is relatively low; however, it can be increased considerably by raising the temperature to 85–90°C and/or increasing concentration.

A number of systems are utilizing hydrogen peroxide in combination with heat and / or other adjuncts. In this system, the packaging material is not metal and it comes in rolls rather than in preformed containers. The rolls are continuously fed into a vertical machine which sterilizes, forms, fills, and seals the package. Sterilization is accomplished with a combination of hydrogen peroxide and heat.

A second system is similar to the one just discussed. The main difference is in how the heat is applied to the package surface. This system provides the heat necessary for sterilization by means of a heated stainless steel drum. A thin film of peroxide is applied to the product contact surface. This surface is then rolled over the heated drum. Contact with the drum heats the peroxide and the nascent oxygen thus produced due to breakdown of peroxide reacts with the oxidizable cell components of the microorganisms and causes bactericidal effect.

A third system also uses packaging material which comes in rolls. The rolls are continuously fed into the machine which forms, fills, and seals the package. Sterilization is accomplished with a combination of hydrogen peroxide and heat. The packaging material travels through a bath of hot hydrogen peroxide which softens the material for forming. Cups are then formed, filled and sealed with a lid which also travels through a hydrogen peroxide bath.

A fourth system utilizes preformed cups to which a lid foil is heat-sealed after filling. The cups are fed into the machine where they are sterilized by applying a spray of peroxide followed by heating. The lid material is sterilized by being passed through a bath of hydrogen peroxide.

Another system which can utilize preformed carton sprays low concentration hydrogen peroxide solution on the inside of the carton. This sprayed carton then passes under a UV light source which acts synergistically with the hydrogen peroxide in destroying micro organisms.

3.2.2 Low-Temperature Hydrogen Peroxide Gas Plasma (LTHPGP) Sterilization:

Low-temperature hydrogen peroxide gas plasma (LTHPGP) sterilization is a relatively new technology, marketed under the trade name Sterrad by ASP is used mainly for rapid sterilization of medical instruments without leaving toxic residues.

3.2.3 Exposure to Gaseous Ethylene Oxide:

Use of ethylene oxide sterilization has made possible the use of sterile, low-cost, disposable thermoplastic devices for industrial application. It has been used to pre-sterilize paperboard cartons and plastic packaging materials. However, no commercial

system uses ethylene oxide as a sterilizing agent in aseptic packaging of low acid foods for ambient temperature storage and distribution. The vapour form is flammable and explosive and hence employed as a mixture with an inert gas such as dichlorodifluoromethane. An important consideration in bulk sterilization of preformed packaging materials is ethylene oxide's ability to permeate and contact all surfaces that need to be sterilized.

The method can be carried out at low temperatures and damages relatively few materials. It is however difficult to control and use of ethylene oxide. Compared to other methods of sterilization, the bactericidal efficiency of ethylene oxide is also low. Extensive aeration of the sterilized materials is necessary to remove residual Ethylene Oxide because it is toxic in nature.

3.2.4 Peracetic acid:

It is a peroxide of acetic acid and on decomposition it is converted in to acetic acid and water. The low pH and oxidizing properties make it an excellent sporicidal agent. It has all the advantages of hydrogen peroxide and is not hydrolysed by catalase and peroxidases. It is a liquid sterilant which is effective against spores of aerobic and anaerobic bacteria and is effective at lower temperatures than hydrogen peroxide. In practice, it is used in form of a solution along with hydrogen peroxide. The solution containing peracetic acid and hydrogen peroxide is effective against resistant bacterial spores even at 20°C, for example a 1% solution will eliminate 10^7–10^8 of resistant spores in 5 min at 20°C. The maximum usable temperature is 40°C when the sterilization times are about 5 times shorter. In spite of its sporicidal properties, peracetic acid is not an approved sterilant for use on aseptic packaging materials. Its vapour is very pungent and irritating. Therefore, the system which utilizes this compound must be airtight to prevent environmental release. No tolerance is allowed for peracetic acid and vapours in the headspace of package, because they can cause disagreeable vinegar like off-favour in some food products. In spite of these problems, this compound deserves attention as a possible sterilant for aseptic packaging materials because of its effectiveness as a sporicidal agent. The presence of small amounts of acetic acid may not be considered off-favours.

3.2.5 Ethyl alcohol:

At 80% concentration, ethyl alcohol is effective in sterilization of packaging materials. Its mechanism of action appears to involve protein denaturation and membrane lipids dissolution. However, ethanol is effective only against vegetative cells and not against fungal conidia or bacterial spores therefore its use in packaging of foods is limited to extension of shelf life of packaged foods normally stored under refrigeration.

3.3 Sterilization by Irradiation:

When neither heat nor chemicals can be used to sterilize a given material, radiation is considered as an option. Electromagnetic radiation characterized by a frequency, a wavelength, penetrating power and an energy range are infrared, ultraviolet, γ rays, etc. The dosage and type of radiation sterilization is a function of the type and amount of the microbial load that has to be removed from a given packaging materials and equipment. Irradiation does neither leave any residue on the treated surface nor affect the immediate environment, The products used for packaging in radiation sterilization recommended by the International Atomic Energy Agency (IAEA) are polyethylene, polyester, polypropylene, nylon, PVC, etc.

Advantages:

1. Irradiation sterilization is a single process.
2. Irradiation sterilization is a clean process – No residual chemicals
3. Irradiation sterilization is a reliable process
4. Irradiation sterilization is a cold process and hence less damage to packaging materials occurs.
5. Irradiation sterilization is an energy saving process.
6. Irradiation sterilization is a cost effective and economic process

3.3.1 Irradiation with Ultra - Violet Rays:

They are generally recommended for use with sterilization of contaminated surfaces and disinfection of aseptic handling rooms or boxes. The disinfection capacity of UV rays in air is affected by moisture, dust concentration etc. Despite this limitation, UV radiation is a powerful disinfectant. Its sterilizing power arises from its capacity to get selectively or

reasonably absorbed at 228 nm and 265 nm wavelength by the peptide bonds of nucleic acid in the cells of microbial organisms. Both vegetative cells and spores are sensitive to UV radiation. Microbial resistance to UV radiation increases in the order: vegetative bacterial cells<<yeasts < bacterial spores < mould spores. Gram-positive bacteria require twice the dosage of Gram negative bacteria, and 5–10 times for bacterial spores. Mould spores, particularly those that have dark colours (e.g. *Aspergillus niger*) are especially resistant and require dosage levels 20–100 times higher. Covered, shaded or shielded organisms will not be affected. Dust particles present on the surfaces reduce the effectiveness of UV irradiation for sterilization of aseptic packaging materials. The penetration ability of UV rays is very limited.

UV rays are produced by mercury discharge tubes fitted with quartz windows for transmission of UV rays with minimum absorption. These units are relatively inexpensive. UV radiation is harmful to man particularly to the skin. Direct exposure to UV rays must be avoided. Combination of UV rays with organic acid or hydrogen peroxide is found to be more lethal.

3.3.2 Irradiation with Gamma Rays:

Gamma radiation is the most widely used form of ionizing radiation sterilization and in fact, gamma irradiation has become the industry standard for high-energy sterilization due to the convenience, low cost, and good sterilization results. Gamma irradiation involves the bombardment of photons from a ^{60}Co source. Because of the excellent penetrating ability of gamma rays, a wide range of packaging materials may be gamma-sterilized including those composed of multiple resins. Pre-packaged articles may also be gamma-sterilized since many materials such as cellophane, polyethylene, and nylon can be penetrated by gamma rays. Gamma rays have five times the penetration capability than electron beam radiation. Gamma radiation sterilization usually employs ^{60}Co as the radioisotope source with a dosage of generally 2.5 megarads, although higher levels are sometimes used, and maximum temperatures usually are in the range of 30°C–40°C.

3.3.3 Electron beam (E-beam):

Electron beam irradiation is the bombardment of high-energy electrons. Sterilization is

quick but with limited penetration. Less is known about the e-beam sterilization effects on the physical properties and colour stability of thermoplastics compared with gamma sterilization. Doses for e-beam irradiation for the sterilization of medical disposable items are in the 1–6 megarad range. Doses for packaging where the contained food is to be pasteurized are in the 0.1–1 megarad range. There are several differences between e-beam and gamma sterilization. The e-beam process uses no radioactive source and employs lower energy radiation than gamma sterilization. It is claimed that electron beam sterilization causes less material degradation than gamma, thus reducing the risk of product damage. Exposure time for e-beam is shorter than exposure in gamma radiation. Plastic parts sterilized by electron beam are only exposed for minutes versus hours or days with gamma rays. However, the penetration capability of e-beams is poor, resulting in the need for many e-beam sterilized pieces to be irradiated from multiple sides to ensure complete sterilization.

3.3.4 Pulsed Light Sterilization:

The technology of utilizing short pulses of light is a new alternative for sterilizing packaging materials and processing equipment in aseptic packaging. The spectrum of light used for sterilization includes wavelengths in the range of ultraviolet to wavelengths in the near-infrared region.

The material to be sterilized is exposed to at least one pulse of light having an energy density in the range of about 0.01–50 J cm^{-2} at the surface. The duration of pulses ranges from 1 μs to 0.1 s. The packaging materials are exposed to between 1 and 20 pulses of low intensity, short-duration light. A few flashes, applied at a rate of 1–10 per second, provide very high microbial destroyer levels, making the system ideal for continuous in-line sterilization. Comparison of the antimicrobial effects obtained using pulsed light with those obtained using non-pulsed or continuous wave conventional UV sources shows a significantly higher inactivation for pulsed light. More than 7 log cycles of *Aspergillus niger* spore inactivation result with few pulsed light flashes. A variety of microorganisms including *Bacillus subtilis* are inactivated by using between 1 and 35 pulses of light with intensity ranging between about 1 and 12 J cm^{-2}. Spores of *Bacillus subtilis*, *Bacillus*

pumilus, *Bacillus stearothermophilus* and *Aspergillus niger* were inactivated completely from 6–8 logs of colony forming units (CFU) with 1–3 pulses.

Light pulses apparently do not affect the nutrient retention in food, but a detailed study is to be done. Pulsed light treatment costs are very encouraging. Packaging materials compatible with this process will transmit light over the broad spectrum employed. LLDPE, LDPE, nylon, Aclar, HDPE and PP have all been used. Package geometry should not allow any shadowing on the product or the light exposure may not be sufficient.

4. PACKAGING MATERIALS / FORMS STERILIZED BY DIFFERENT METHODS:

Sr. No.	Packaging material/ form	Sterilization method
1	Milk pouch film	UV rays
2	UHT packaging film	Chemical – H_2O_2
3	Metal cans	Heat
4	Plastic bottles, cups	Chemical – H_2O_2

5. CONCLUSION:

Sterilization of packaging materials in-line of processing poses certain difficulties. Based on topics covered it is apparent that hydrogen peroxide sterilization followed by hot air appears to have the most potential for use as in-line sterilant for packaging materials and food contact surfaces. This combination is time tested and no adverse report seems to have put any suspicion over the method's acceptability.

Sterilization of packaging materials using hydrogen peroxide and followed by UV irradiation also has been accepted for industrial application. Dry heat, saturated steam and superheated steam can be effective sterilants, but the degree of heat damages many packaging materials so they have limited application.

Ionizing rays are not accepted as they have harmful effect on persons working in the plant. Light pulses have not been adequately studied so far as their effect on food material is concerned.

Ethylene oxide requires a very long time which precludes its use for in-line applications. Peracetic acid produces an off-flavour in food if residual deposit is enclosed in the container and ethanol is not effective against spores.

Reference:

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