Post-Harvest Operations and Processing of Fruits, Vegetables, Spices and Plantation Crop Products

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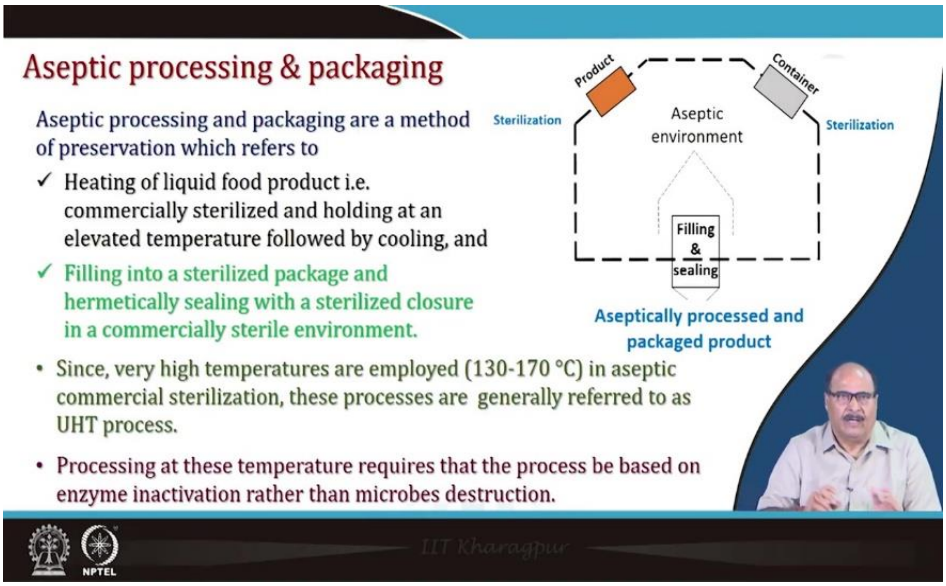
Lecture 28
Aseptic processing and packaging

In this lecture a very important aspect of processing and preservation of fruits and vegetable products, particularly juices, paste, concentrates, beverages etc. is covered i.e., Aseptic Processing and Packaging.

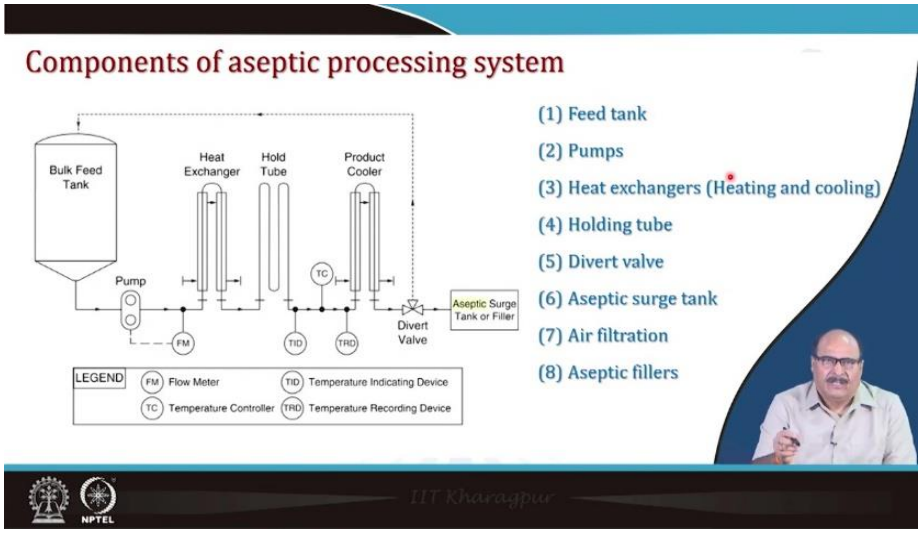
Aseptically processed and packaged products, fruits, and vegetable products, have gained popularity in the market as well as in the consumer mind in the recent past. In this lecture, the

topics covered are aseptic processing, components of aseptic processing systems, and finally the sterilization of the aseptic packaging materials and equipment are discussed.



Aseptic processing & packaging

Aseptic processing and packaging are methods of preservation, which refers to heating of the liquid food product i.e., commercially sterilized and holding at an elevated temperature followed by cooling and filling it into a sterilized package and hermetically sealing with a sterilized closure in a commercially sterile environment. It can be seen from the figure that there are two lines, one is the product line and another is the packaging material line. So, both the products and packaging material are the specific systems. The product and the packaging material are sterilized separately. After that, they are brought to the filling room and packaging room, which are maintained under a sterile environment or in an aseptic environment. So, processing and packaging and then finally, filling and sealing are all performed in the aseptic environment. Since, in aseptic processing and packaging, very high temperatures are employed (130 or 170 °C), these processes are generally referred to as ultra-high temperature processes i.e., UHT processes. Processing at these temperatures require that the product sterilization process be based upon the enzyme inactivation, because under these high temperature ranges, it had been seen that enzymes give a higher resistance than the micro-organisms. So, most of these processes are generally based upon the enzyme inactivation kinetics.

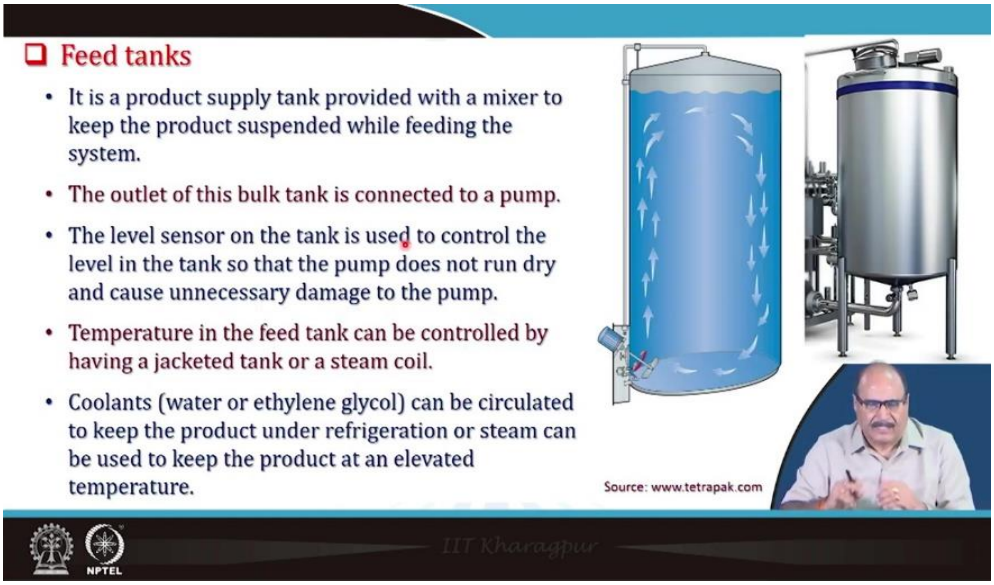


Components of aseptic processing system

The figure shows the components of aseptic processing system. Aseptic processing is normally used for liquid food or even concentrator paste. There is a feed tank. Either pulp or paste or juice, whatever it is, is brought from a manufacturing unit, extraction unit and concentration unit. Any two of these are taken in the feed tank, in the aseptic processing line. From the feed tank, there are suitable pumps, which can feed these materials to the heat exchangers.

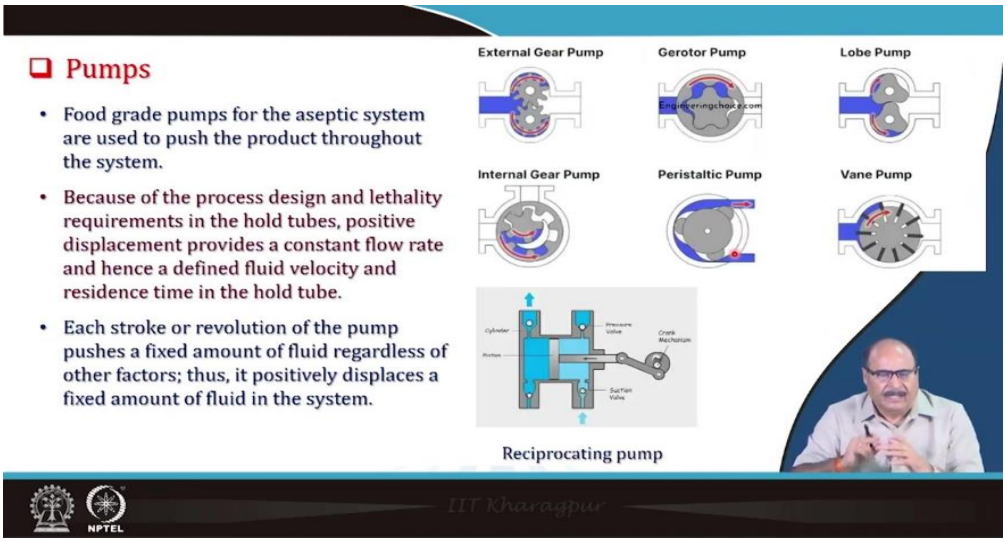
Through the appropriate pumping system, the material from the feed tank, is taken to the heat exchangers, where it is exposed to the calculated time and temperature combination, that is required for giving the desired commercial sterility. Once the material is brought to the specific temperature, then it is taken to the whole tube, where it is held for the desired time, so that the complete sterility is obtained.

Finally, the product is again from the hold tube, is conveyed to the cooling line, where it is cooled, plot down and then sent to the filling and packaging line.



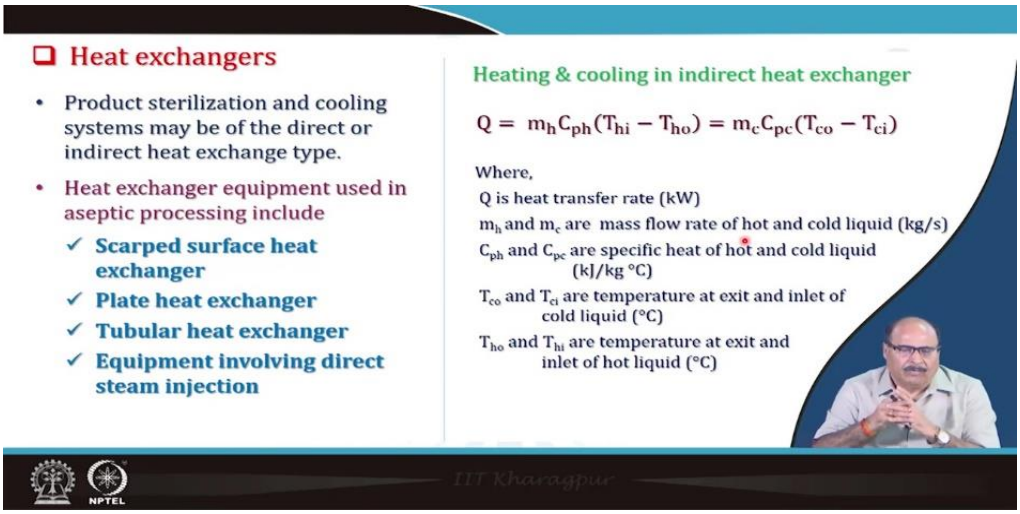
Feed Tanks

The feed tank is the product supply tank provided with a mixer to keep the product suspended while feeding the system. Here, the proper mixing is required, so that there is not settling or solids etc. Therefore, a homogeneous uniform mixture is going out. The outlet of this bulk tank is connected to a pump. The level sensor on the tank is used to control the level in the tank, so that the pump does not run dry and cause unnecessary damage to the pump. Temperature in the feed tank can be controlled by having a jacketed tank or having a steam coil. Coolants (water or ethylene glycol) can be circulated to keep the product under refrigeration or steam can be used to keep the product at an elevated temperature.



Pumps

The figure shows the schematics of the different pumps and how they work. Food grade pump for the aseptic systems is used to push the product throughout the system and because of the process design and lethality requirements in the hold tubes, positive displacement provides a constant flow rate and hence, a defined fluid velocity and the residence time in the hold tube. Each stroke or revolution of the pump pushes a fixed amount of fluid regardless of the other factors; thus, it positively displaces a fixed amount of fluid in the system.



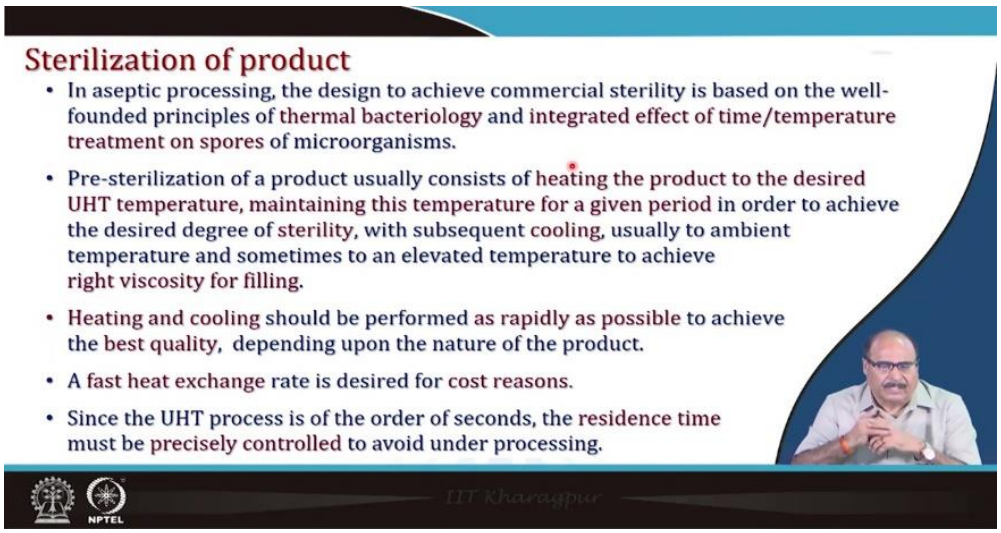
Heat exchangers

Then from the pump process, the material goes into the heat exchanger. The heat exchangers are the systems, which are the product sterilization and cooling systems. They may be of direct or indirect heat exchangers type. Heat exchangers equipment used in the aseptic processing line include scraped surface heat exchangers, plate heat exchangers, tubular heat exchangers, equipment involving direct steam injection etc.

Heat transfer can be calculated by using the following equation.

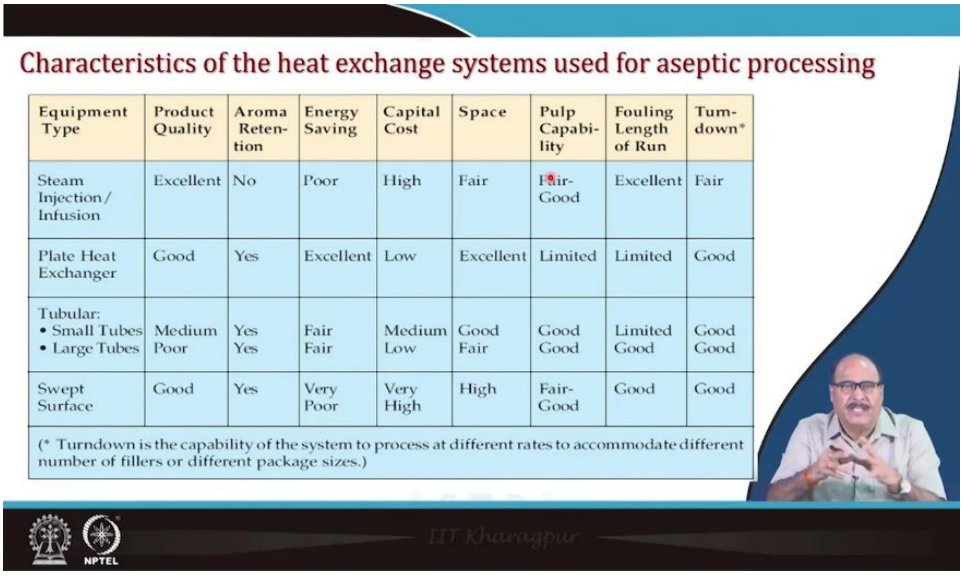
$$Q = m_h C_{ph} (T_{hi} - T_{ho}) = m_c C_{pc} (T_{ho} - T_{ci})$$

where Q is the heat transfer rate (kW), m_h and m_c are the mass flow rate of the hot and cold liquid (kg/s), C_{ph} and C_{pc} are the specific heat of the hot and cold liquid (kJ/kg °C), T_{co} and T_{ci} are the temperature at the exit and inlet of the cold liquid (°C) and T_{ho} and T_{hi} are the temperature at the exit and inlet of the hot liquid (°C). Accordingly, using this equation one can calculate the heat transfer rate and accordingly, the heat required to get the desired sterility can also be calculated.



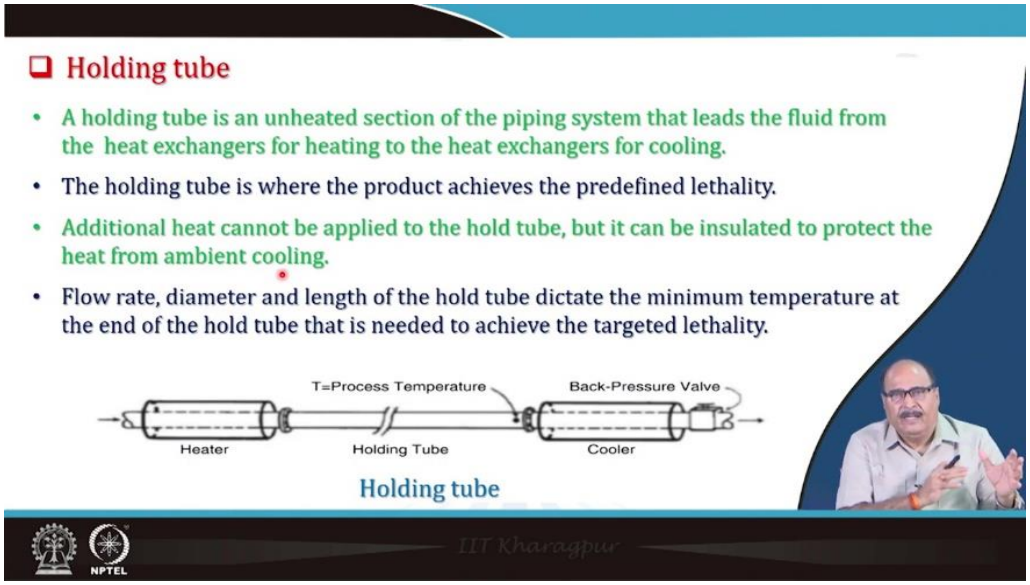
Sterilization of product

In the aseptic processing, the design to achieve commercial sterility is based on the well-established principles of thermal bacteriology and integrated effect of the time or temperature treatment on the spores of the microorganisms. Pre-sterilization of a product usually consist of heating the product to the desired UHT temperature, maintaining the temperature for a given period in order to achieve the desired degree of sterility, with subsequent cooling usually at to ambient temperature and some time to an elevated temperature to achieve the right viscosity for filling. Heating and cooling should be performed as rapidly as possible to achieve best quality depending upon the nature of the product. A fast heat exchanger rate is desired for cost reasons. Since the UHT process is of the order of seconds, the residence time must be precisely controlled to avoid any under processing.



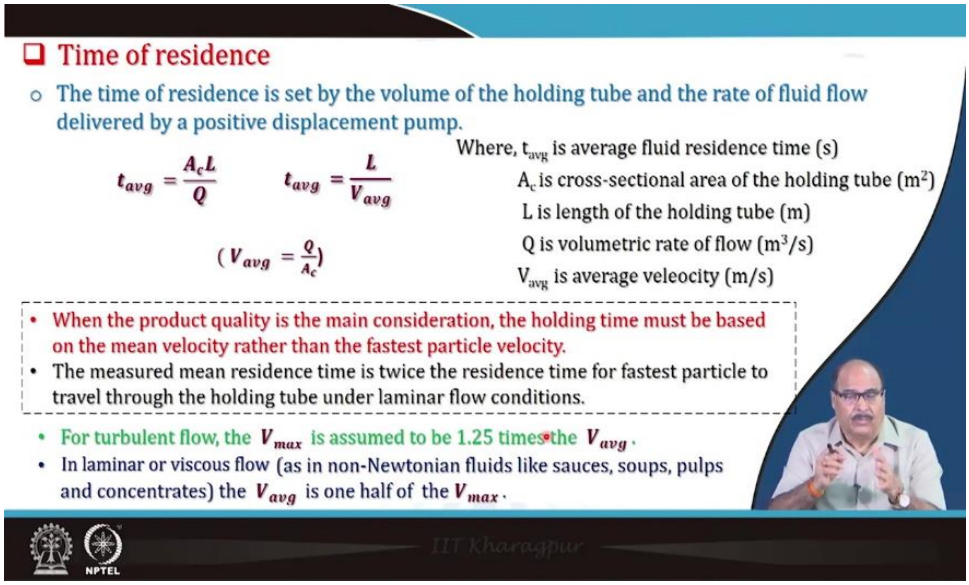
Characteristics of the heat exchange systems used for aseptic processing

The table shows a comparison of various types of heat exchangers. In case of steam injection or steam infusion heat exchanger, the product quality is excellent, but there is no aroma returns i.e., most of the aroma get destroyed. Energy savings in this case is also poor. Its capital cost is high, space requirement is fair. Turn down is the capability of the system to process at different rates to accommodate a different number of pillars or different packaging sizes etc. This turn-down is also fair for steam injection or steam infusion heat exchanger. In case of the tubular heat exchanger, like small tubes or large tubes, the product quality is medium to poor and the aroma retain. Energy saving is also fair to poor in this case. The capital cost in the small tubes is medium and in large tube is low. The turn-down here also is good. In case of plate heat exchangers, they give fairly good product quality, aroma retention is also good, energy saving is excellent, cost required is also less. Space requirements in this case is also excellent. The turn-down period is good.



Holding tube

It can be seen from the figure; a holding tube is an unheated section of the piping system that leads the fluid from the heat exchangers for heating to the heat exchanger for cooling. So, from the heat exchanger, the holding tube holds the material for desired period and then it sends to the cooling. The holding tube is where the product achieves the predefined lethality. Additional heat cannot be applied in the holding tube, but it can be insulated to protect the heat from ambient cooling. Flow rate, diameter and length of the hold tube dictate the minimum temperature at the end of the hold tube that is needed to achieve the targeted lethality.



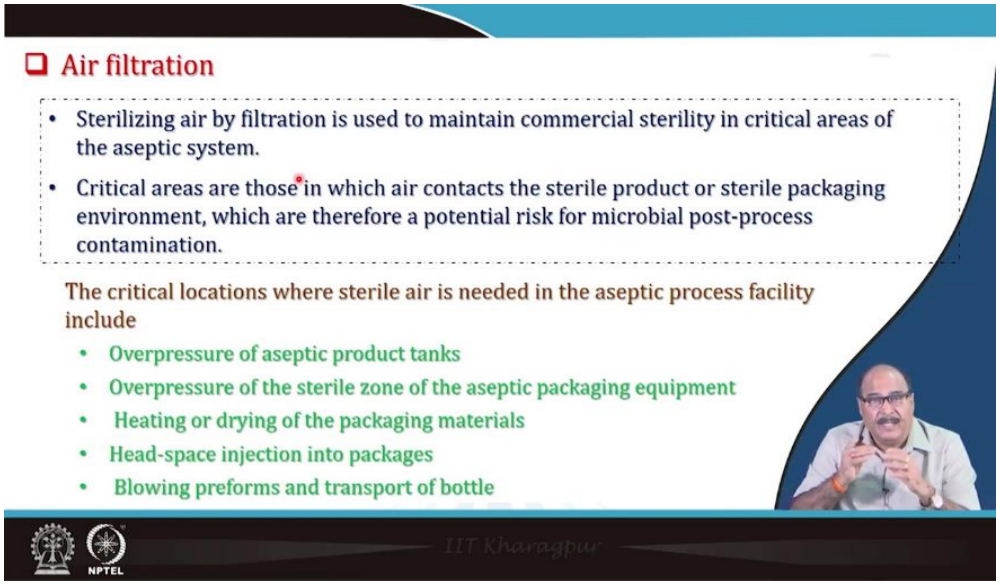
Time of residence

The time of residence is set by the volume of the holding tube and the rate of fluid flow delivered by a positive displacement pump. Time of residence can be represented by the various equations.

$$t_{avg} = A_c L/Q$$

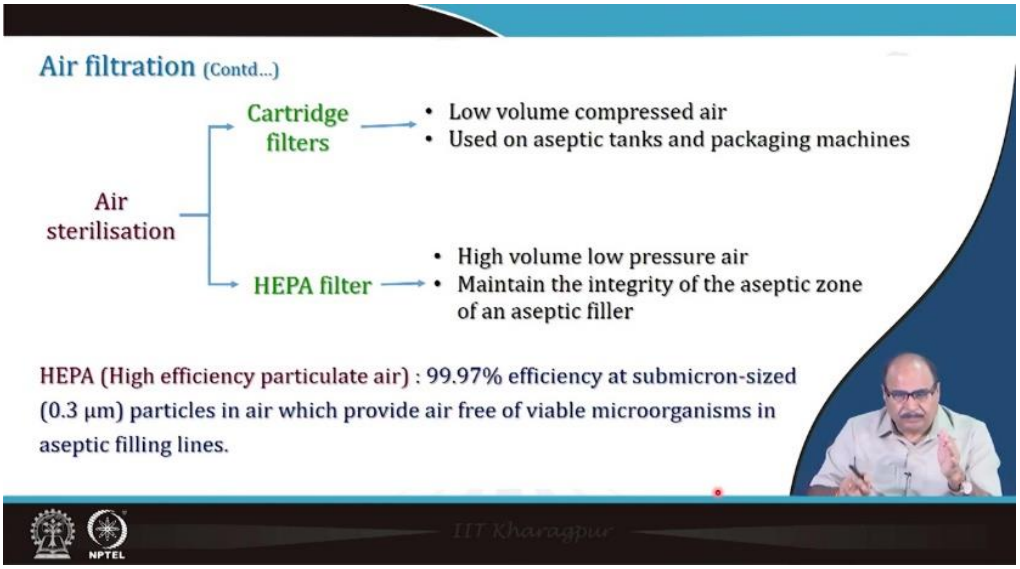
$$t_{avg} = L/V_{avg} \quad V_{avg} = Q/A_c$$

Here, t_{avg} is the average fluid residence time (s), Ac is the cross-sectional area of the holding tube (m^2), L is the length of the holding tube (m), Q is the volumetric rate of the flow (m^3/s) and V_{avg} it the average velocity (m/s). When the product quality is the main consideration, the holding time must be based on the mean velocity rather than the fastest particle velocity. The measured mean residence time is twice the residence time for the fastest particle to travel through the holding tube under laminar flow conditions. For turbulent flow, the maximum velocity i.e., V_{max} is assumed to be 1.25 times the average velocity i.e., V_{avg}. In the laminar or viscous flow (as in non-Newtonian fluids like sauces, pulps, and concentrates) the V_{avg} is one half of the V_{max}.

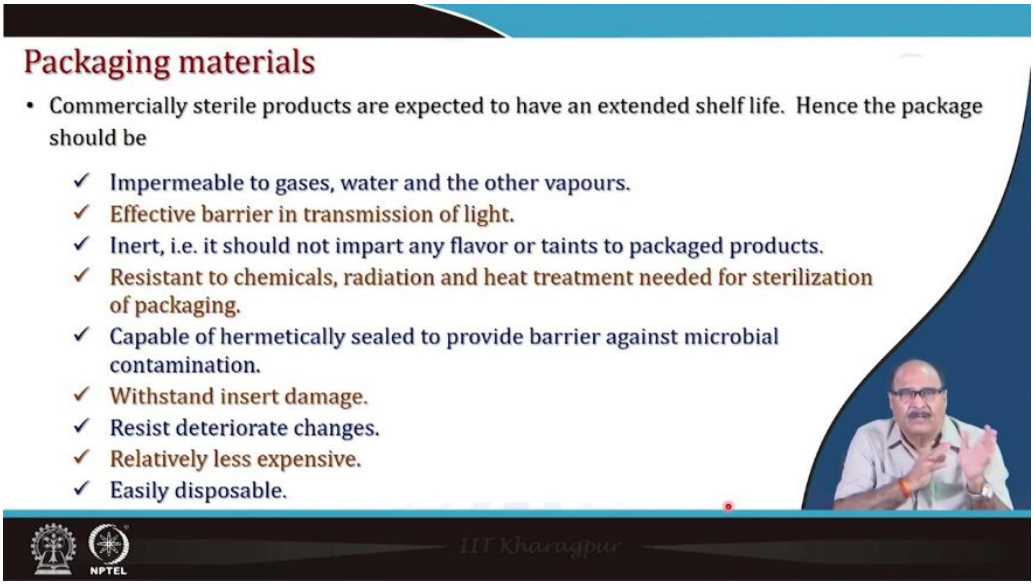


Air Filtration

Sterilizing air by filtration is used to maintain the commercial sterility in critical areas of the aseptic system. Critical areas are those in which the air contact the sterile product or sterile packaging environment, which are therefore a potential risk for microbial post-process contamination. The critical locations, where sterile air is needed in the aseptic process facility include overpressure of the aseptic process tanks, overpressure of the sterile zone of the aseptic packaging equipment, heating or drying of the packaging materials, headspace injection into packages or blowing performs and transport of the bottles.

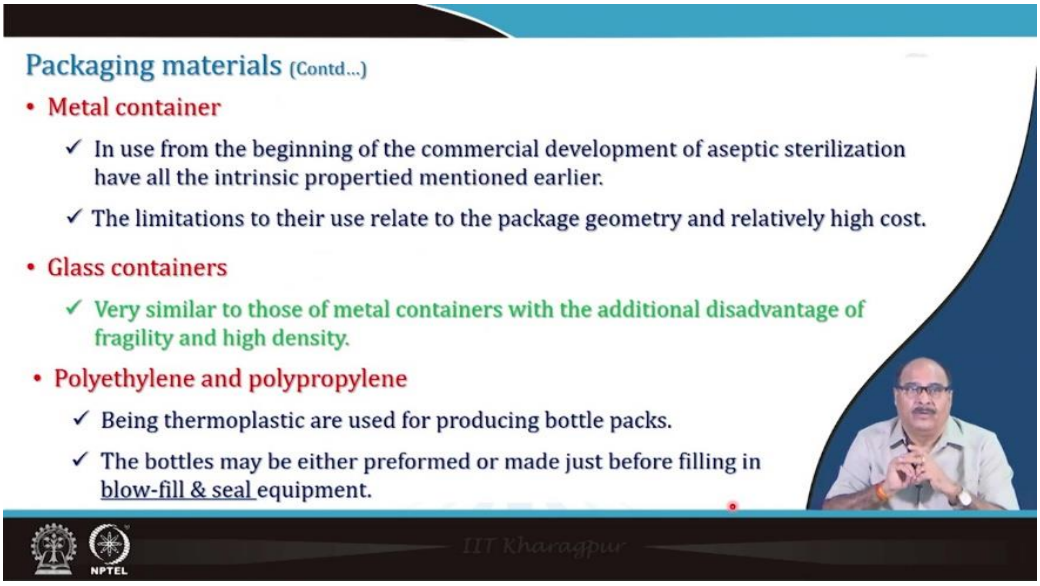


The cartridge filters or HEPA filters can be used for air sterilization. HEPA (High efficiency particulate air) filter generally gives 99.97% efficiency at submicron-sized (0.3 μm) particles in air, which provide air free of viable microorganisms in aseptic filling lines.



Packaging materials

Commercially sterile products are expected to have an extended shelf life. Hence the packaging material should be impermeable to gases, water, and other vapours. It should provide effective barrier in transmission of light. Inert, i.e., it should not impart any flavor or taints to the packaged products. Resistant to chemicals, radiation and heat treatment needed for sterilization of the packaging material. It should be capable of hermetically sealed to provide barrier against microbial contamination. It should withstand insert damage. It should resist deterioration changes, relatively less expensive. it should be easily disposable.



Metal container

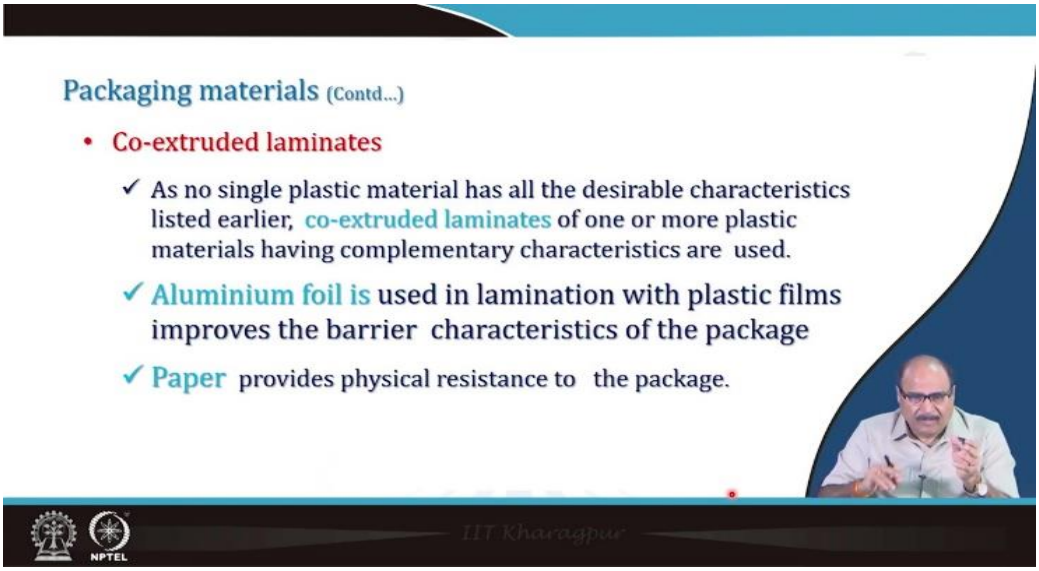
In use from the beginning of the commercial development of the aseptic sterilization process, it has almost all the intrinsic properties mentioned earlier. The limitations of their use relate to the package geometry and relatively high cost.

Glass containers

They are very similar to those of the metal containers with the additional disadvantage of fragility and high density.

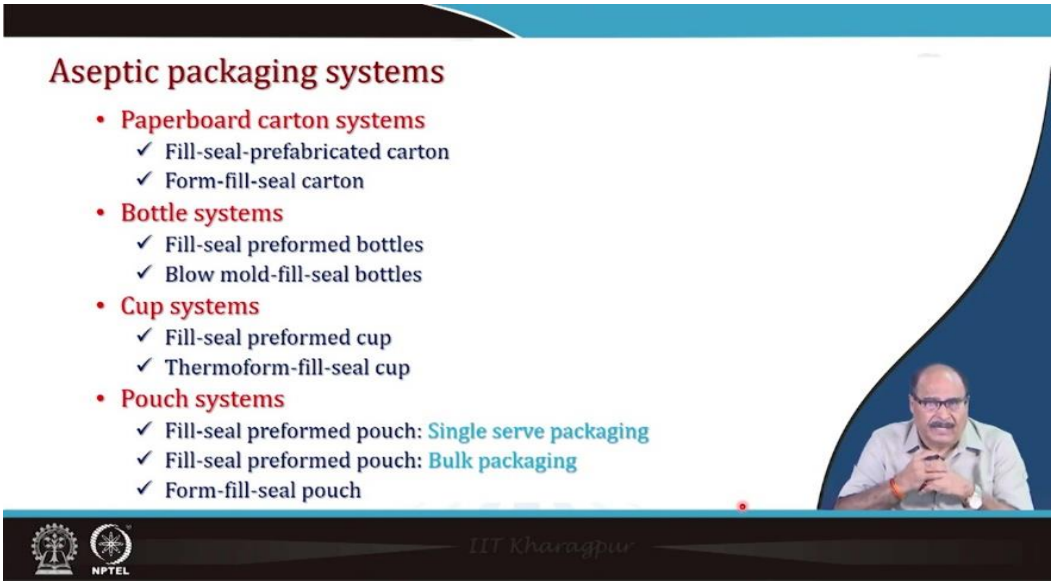
Polyethylene and polypropylene

They provide various consumer attractive packages, flexible packages, in different forms etc. Flexible packaging material like polyethylene, polypropylene etc. are being thermoplastic are used for producing bottle packs. The bottles may be either preformed or made just before filling in the blow-fill and seal equipment.



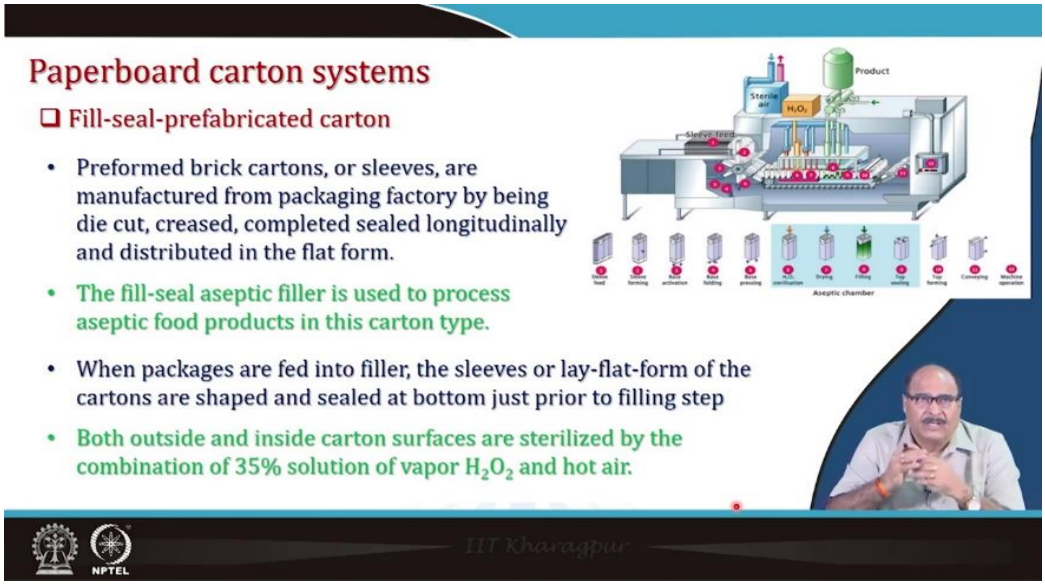
Co-extruded laminates

As no other single plastic material has all the desirable characteristics listed earlier, co-extruded laminates of one or more plastic materials having complementary characteristics are used. Aluminum foil is used in lamination with plastic films, which improves the barrier characteristics of the package. Paper provides the physical resistance to the package.



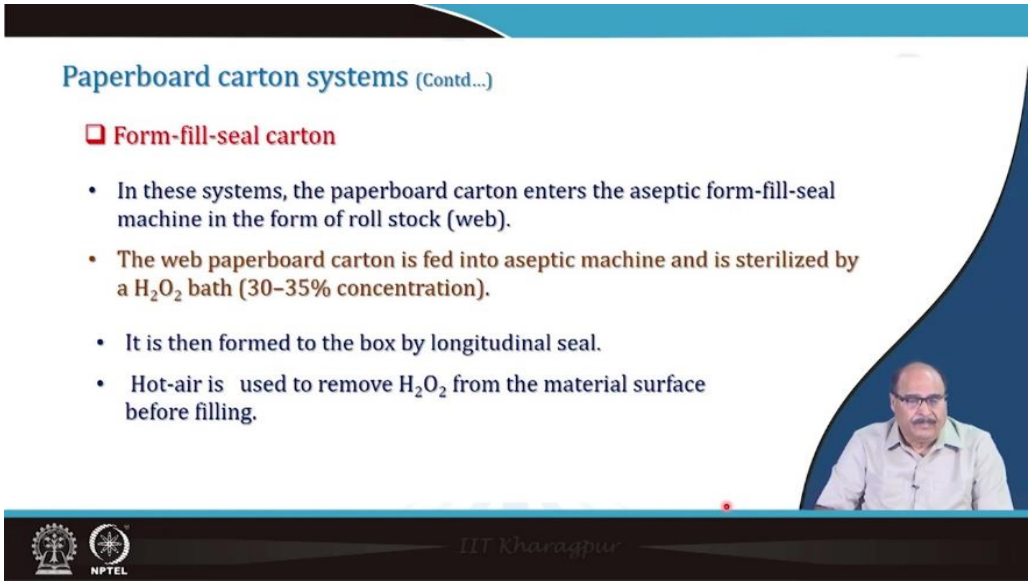
Aseptic packaging systems

The aseptic packaging systems are various paperboard systems, carton systems or bottle systems, cup systems, pouch systems. All these are prepared by different setup either using a form-fill machines or there are fill-seal preformed systems etc., which are used.



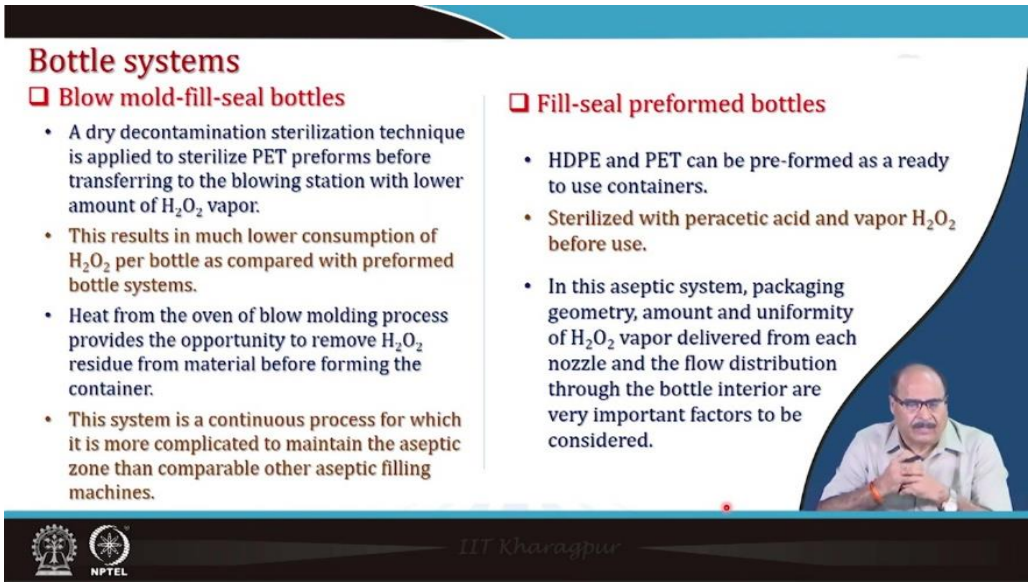
Paperboard carton systems

The preformed brick cartons, or sleeves, are manufactured from the packaging factory by being die cut, creased, completed sealed longitudinally and distributed at the plat form. The fill-seal aseptic filler is used to process aseptic food products in the carton type. When packages are fed into the filler, the sleeves or lay-flat-form of the cartons are shaped and sealed at the bottom just prior to filling step. Both outside and inside carton surfaces are sterilized by the combination of 35% solution of vapor H_2O_2 and hot air.



Form-fill seal carton

In these systems, the paperboard carton enters the aseptic form-fill-seal machine in the form of roll stock (web). The web paperboard carton is fed into the aseptic machine and is sterilized by a H_2O_2 bath (30 to 35% concentration of hydrogen peroxide). It is then formed to the box by the longitudinal seal. Hot-air is used to remove H_2O_2 from the material surface before filling.



Bottle systems

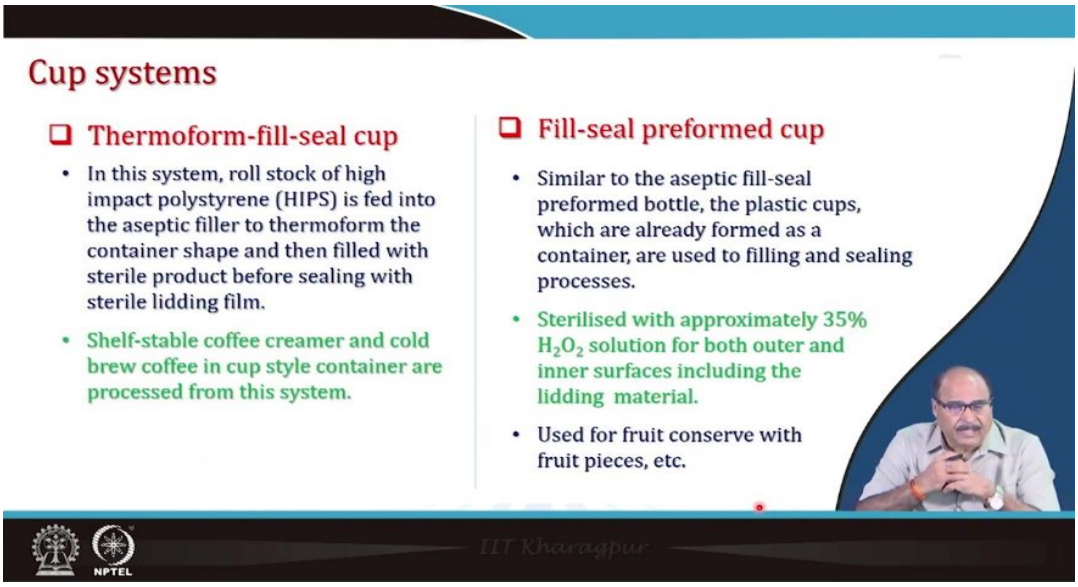
Blow mold-fill-seal bottles

A dry decontamination sterilization technique is applied to a sterilized PET performs before transferring to the blowing station with lower amount of H_2O_2 vapor. This results in much lower consumption of H_2O_2 per bottle as compared with preformed bottle systems. Heat from the oven of blow molding process provides the opportunity to remove H_2O_2 residue from

material before harming the container. This system is a continuous process for which it is more complicated to maintain the aseptic zone than comparable with other aseptic filling machines.

Fill-seal preformed bottle

HDPE or PET can be pre-formed as a ready to use containers. They are sterilized using H_2O_2 vapors. In this aseptic system, packaging geometry, amount, and uniformity of H_2O_2 vapor delivered from each nozzle and the flow distribution through the bottle interior are very important factors to be considered.



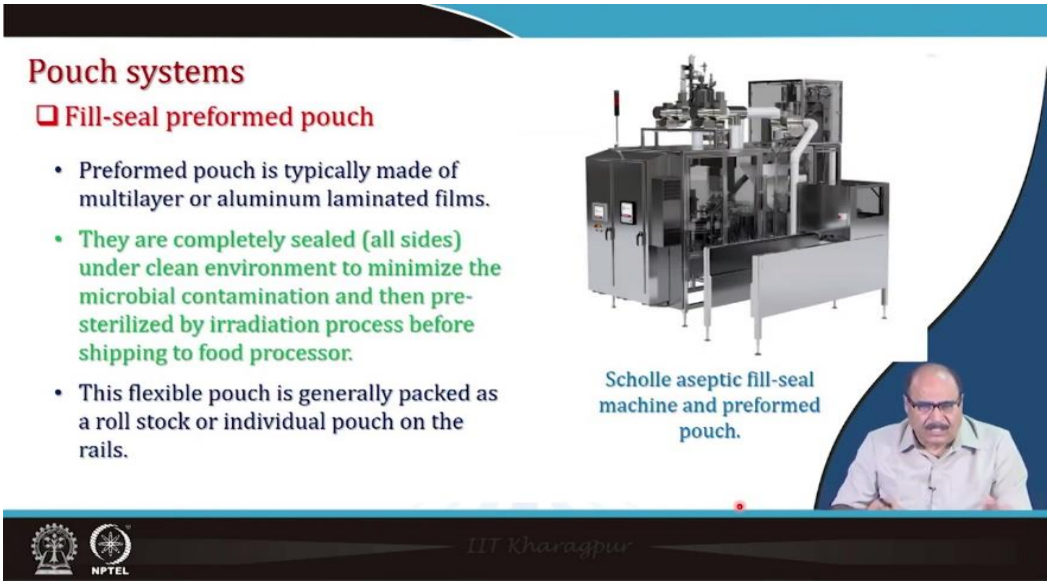
Cup systems

Thermoform-fill-seal cup

In this system, roll stock of high impact polystyrene (HIPS) is fed into the aseptic filler to thermoform the container shape and then filled with the sterile product before sealing with sterile leading fill. Shelf-stable coffee creamer and cold brew coffee in the cup style container are processed from this system.

Fill-seal pre-formed cup

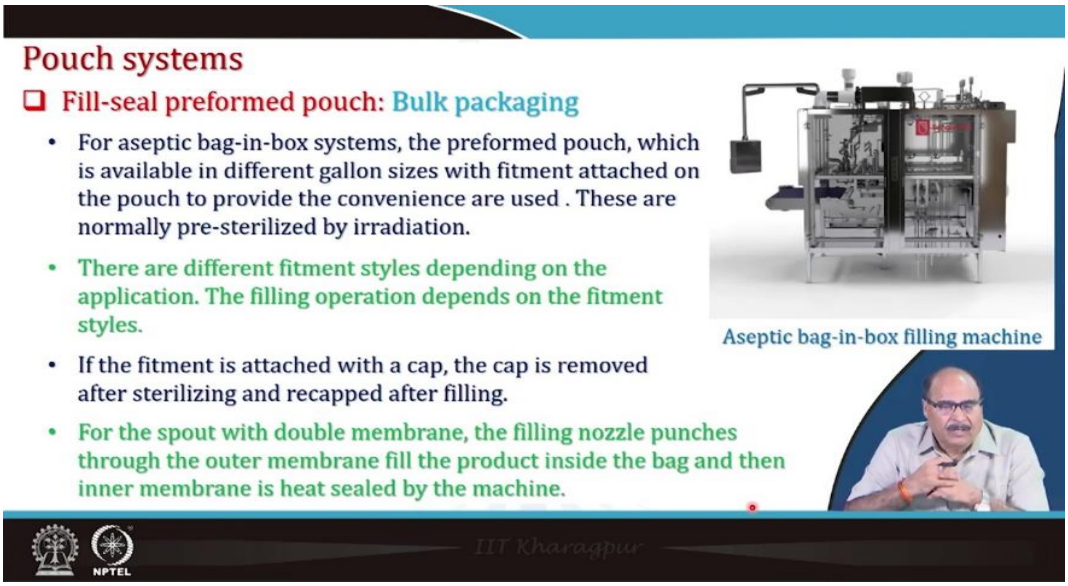
It is the similar to the aseptic fill-seal preformed bottle, the plastic cups, which are already formed as a container are used for filling and sealing process. 35% concentrated H_2O_2 is used as a sterilizing agent and it is used for fruit conserves with fruit pieces.



Pouch systems

Fill-seal preformed pouch

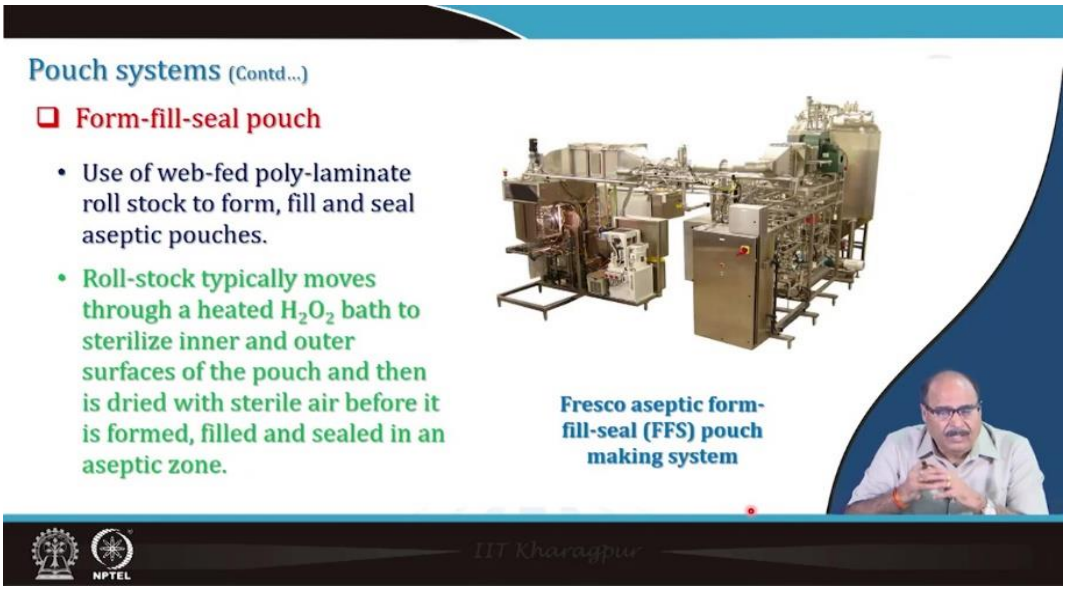
Preformed pouch is typically made of multilayer or aluminum laminated films. They are completely sealed (all sides) under clean environment to minimize the microbial contamination and then pre-sterilized by irradiation process before shipping to food processor. This flexible pouch is generally packed as a roll stock individual pouch on the rails.



Fill-seal preformed pouch: Bulk packaging

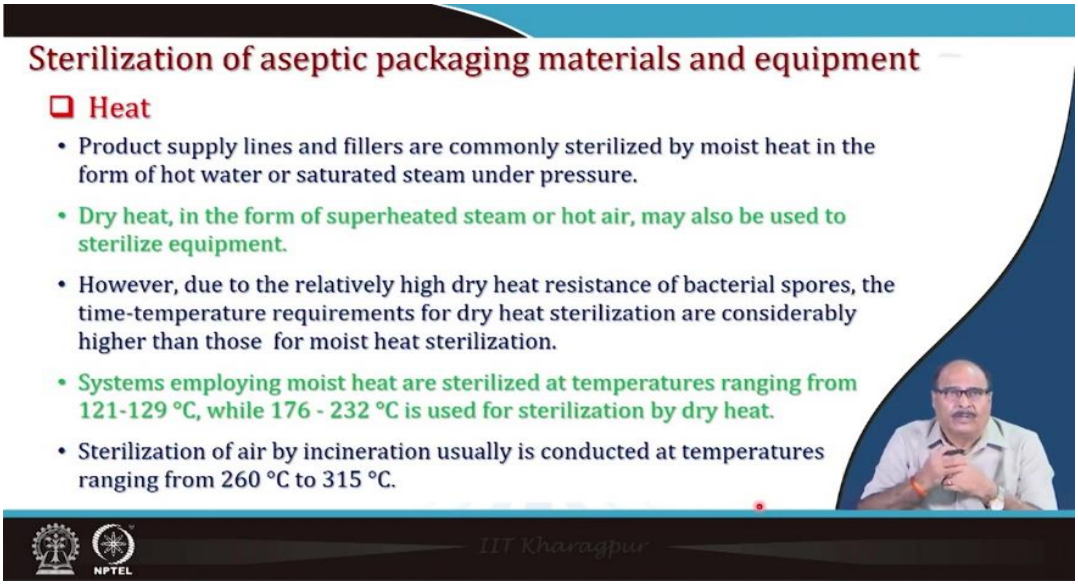
For aseptic bag-in-box systems, the preformed pouch, which is available in different gallon sizes with fitment attachment on the pouch to provide the convenience are used. These are normally pre-sterilized by irradiation. There are different fitment styles depending on the application. The filling operation depends on the fitment styles. If the fitment is attached with a cup, the cup is removed after sterilization and recapped after filling. For the spout with double

membrane, the filling nozzles punches through the outer membrane, fill the product inside the bag and then inner membrane is heat sealed by the machine.



Form-fill-seal pouch

Web-fed poly-laminates roll stock is used to fill and seal the aseptic pouches. Roll stock typically moves through a heated H_2O_2 bath to sterilize inner and outer surfaces of the pouch and then is dried with sterile air before it is formed, filled, and sealed in the aseptic zone.

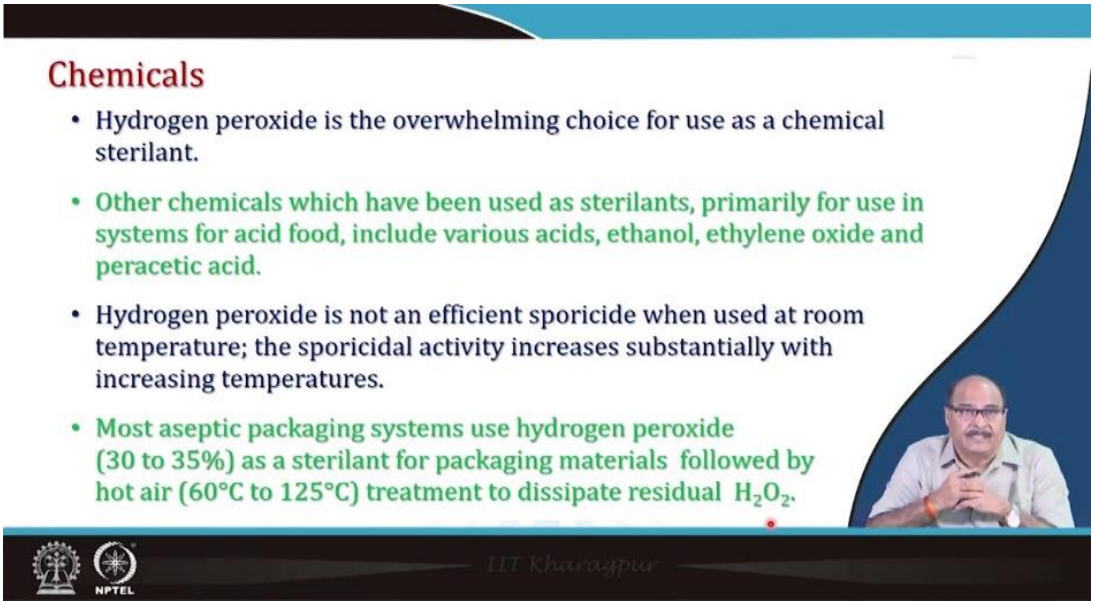


Sterilization of aseptic packaging materials and equipment

Heat

Only heat is used for the sterilization of the aseptic packaging system and the materials. The product supply lines and fillers are commonly sterilized by heat in the form of hot water or saturated steam under pressure. Dry heat, in the form of superheated steam or hot air, may also be used to sterilize equipment. However, due to the relatively high dry heat resistance of

bacterial spores, the time-temperature requirement for dry heat sterilization is considerably higher than those for the moist heat sterilization. Systems employing moist heat are sterilized at a temperature ranging from 121 to 129 °C, while 176 to 232 °C is used for sterilization by dry heat. Sterilization of air by incineration usually is considered at temperatures ranging from 260 °C to as high as 315 °C.

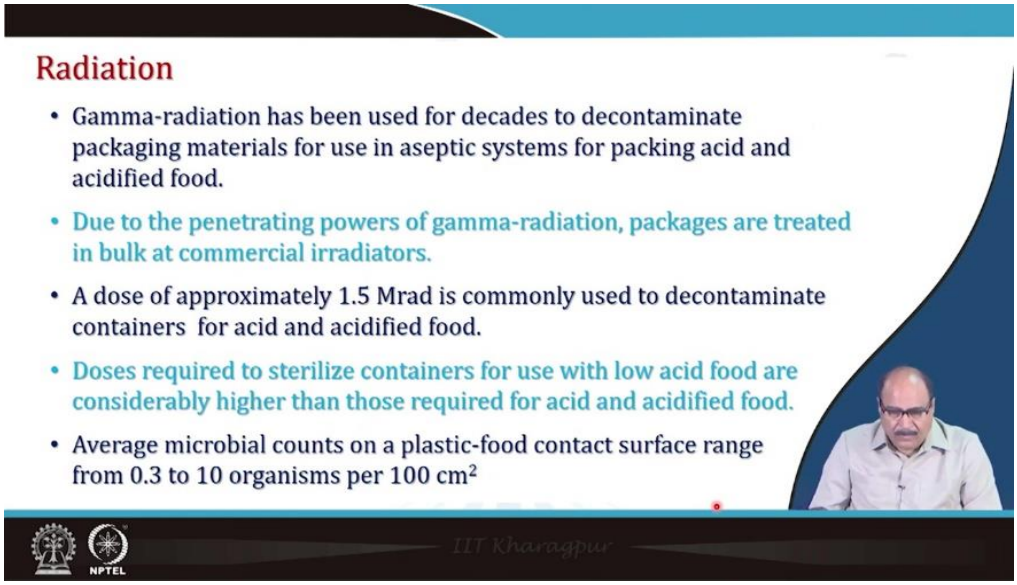


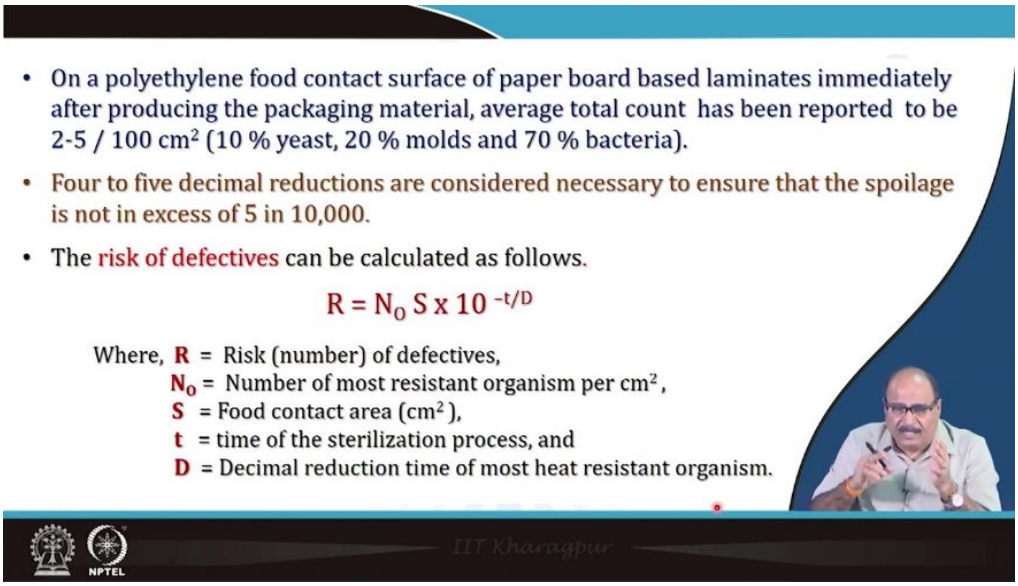
Chemicals

Hydrogen peroxide is the overwhelming choice for use as a chemical sterilant. Other chemicals which have been used as sterilant, primarily for use in systems for acidic food, including various acids, ethanol, ethylene oxide and peracetic acid etc. Hydrogen peroxide is not an efficient sporicide when used at room temperature; the sporicidal activity increases subsequently with the increasing temperatures. So, a combination of hydrogen peroxide and its temperature is used. Most aseptic packaging systems use hydrogen peroxide (30 to 35%) as a sterilant for packaging materials followed by hot air (60 to 125 °C) treatment to dissipate the residual H_2O_2.

Radiation

Gamma radiation has been used for decades to decontaminate packaging materials for use in the aseptic system for packing acid and acidified food. Due to the penetrating powers of the gamma-radiation, packages are treated in bulk at commercial irradiators. A dose of approximately 1.5 Mrad is commonly used to decontaminate containers for acid and acidified food. Doses required to sterilize containers for use with low acid foods are considerably higher than those required for the high acid or acidified food. Average microbial counts on a plastic-food contact surface ranges from 0.3 to 10 organism per 100 cm^2.



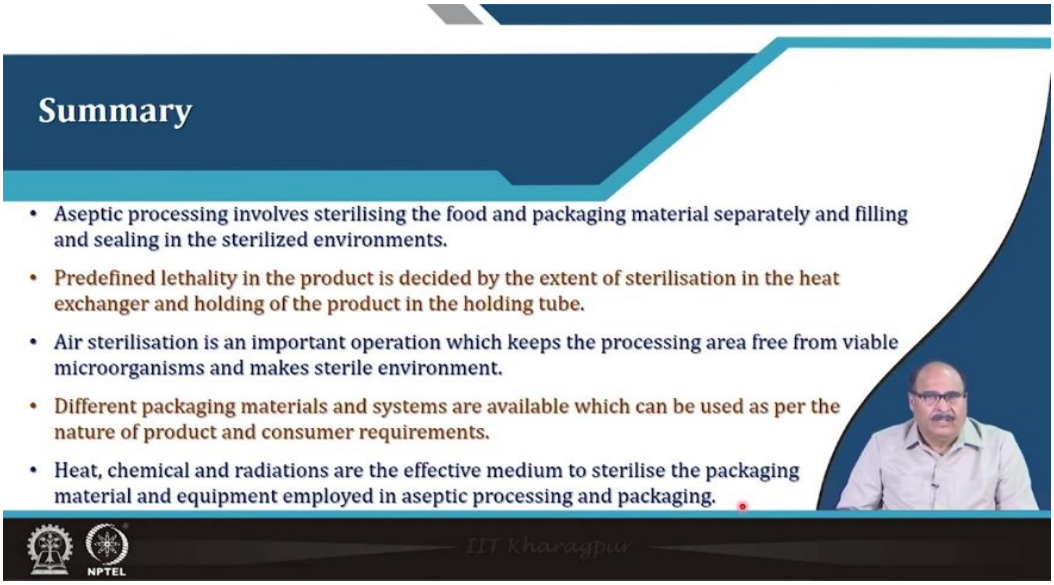


On a polythene food contact surface of paper board-based laminates immediately after producing the packaging material, average total count has been reported as 2-5/100 cm^2 (10% yeast, 20 % mold and about 70 % is bacteria). Four to five decimal reductions are considered necessary to ensure that the spoilage is not in excess of 5 in 10,000 containers.

The risk of defective (R) can be calculated as follows.

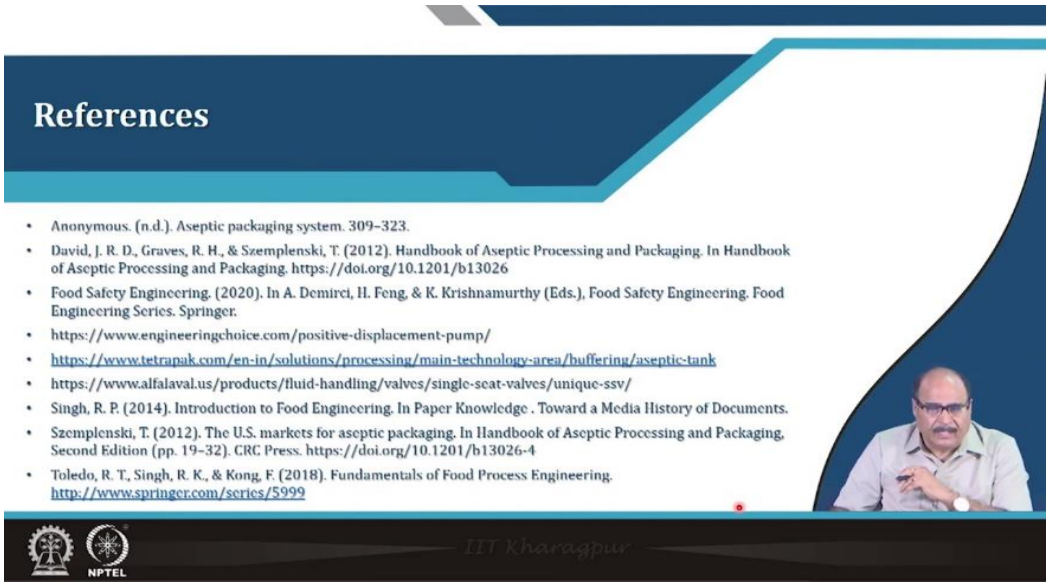
$$R = N_0 S \times 10^{-t/D}$$

Here, N_0 is the number of most resistant organism per cm^2 of the food packaging contact surface, S is the food contact area in cm^2, t is the time of sterilization process and d is the decimal reduction time of most heat resistant organism.



Summary

It can be said in summary that the aseptically processed and packaged materials are stored well. Although they have good stability under normal atmospheric conditions, but the sealing should be proper, the residence time in the sterilization must be ensured, packaging should be properly sterilized. Both the product and the package should be properly sterilized. Then they are kept in the aseptic environment.



The references used in this lecture are mentioned above.