Novel Technologies for Food Processing and Shelf Life Extension
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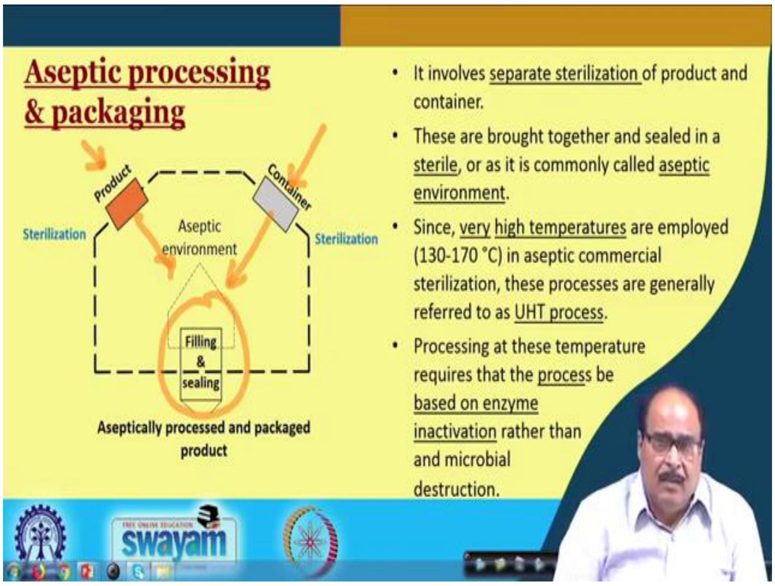
Lecture – 26
Aseptic Processing & Packaging

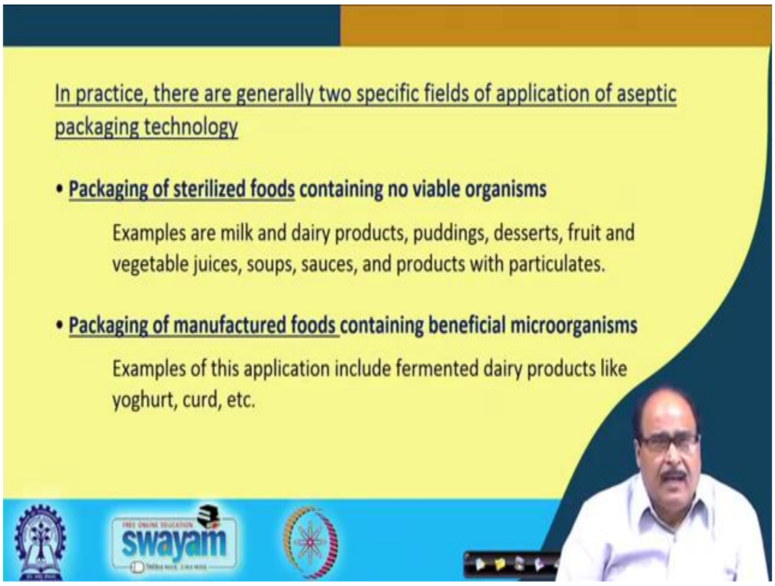
In this lecture, aseptic processing and packaging will be studied.

Technology of commercial sterilization

- There are two basic methods used to obtain commercial sterility in foods.
  - ✓ Heating the food after it has been placed in the container, and
  - ✓ Heating and cooling the food and then packaging it aseptically.
- The first process is the conventional canning method and is, in principle, the same method that was used by Appert, the French man who invented canning.
- The second method is generally referred to as aseptic processing.
- Aseptic processing & packaging results in improved product quality, energy savings and provides economic packaging alternatives.



A pictorial representation of the aseptic packaging technology is shown. The product sterilization line and sterilization of the container or the packaging material can be seen in figure. And, then these come in the aseptic environment where they are filled and sealed using appropriate machines and systems like form fill seal system or blow fill seal systems. And, since generally higher temperature may be to the tune of 130 to 170 °C are common in aseptic commercial sterilization. These processes are referred to as UHT (ultra high temperature) processes. Processing at these temperatures requires that the process be based on enzyme inactivation rather than microbial destruction.



In practice there are generally two specific fields of application of aseptic packaging technologies accordingly i.e. there are two types of aseptically packaged products available in the market: One set of the products are those where the sterilized foods are packaged; means the food inside the package does not contain any viable organism. For example, milk, dairy products, puddings, deserts, fruits and vegetable juices, soups, sauces and even other products with particulates etc. like pea in brine solution and so on.

There are other types of like fermented dairy products or other products where the live bacteria are present. So, such type of products are prepared in good condition by having good manufacturing practices and by following good hygienic practices etc. in their manufacturing line and then these manufactured products are packaged under aseptic environment. Examples of such products include yogurt, curd etc.

Aseptic processing facility design

- **Aseptic processing area**

  Area where critical process steps are carried out.

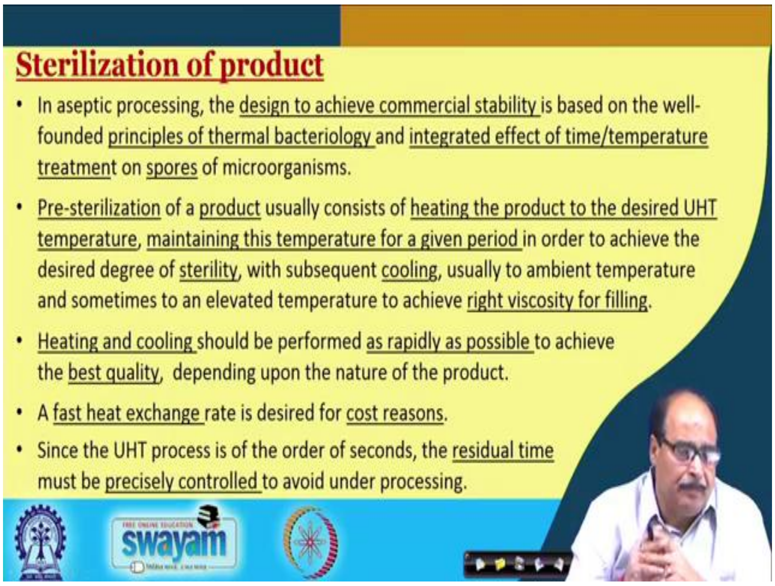
  - ***Critical process steps***

Activities during which the sterilised product and container/closures are exposed to atmosphere.

- **Material handling & conveying system**
- **Product sterilization system**
- **Packaging material sterilization**
- **Form, fill & seal (FFS) packaging**

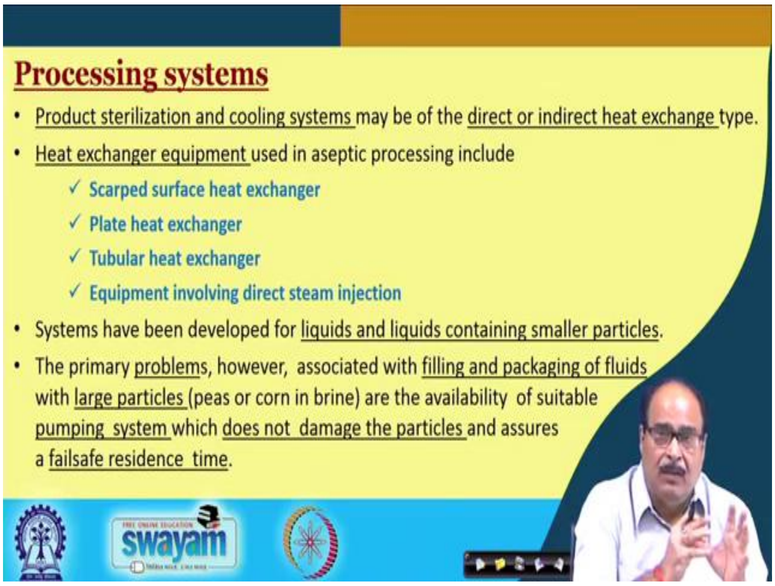
- **Design must minimise challenge to aseptic processing area**

Flow of raw materials, infrastructure facility, building, processing hall, material conveying system, components, product containers, closures, in-process materials, food products and all other facilities should be appropriately designed to prevent contamination in the processing line.



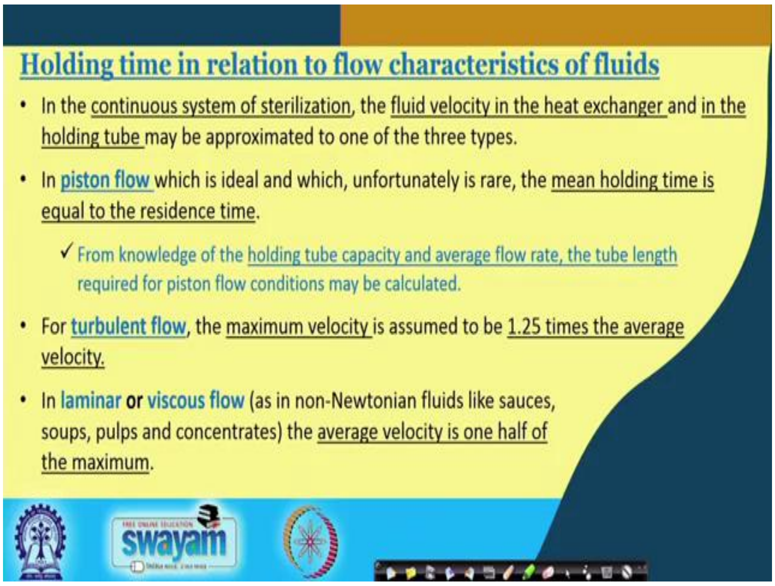
Sterilization of product

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



Processing systems

- Product sterilization and cooling systems may be of the direct or indirect heat exchange type.
- Heat exchanger equipment used in aseptic processing include
  - ✓ Scraped surface heat exchanger
  - ✓ Plate heat exchanger
  - ✓ Tubular heat exchanger
  - ✓ Equipment involving direct steam injection
- Systems have been developed for liquids and liquids containing smaller particles.
- The primary problems, however, associated with filling and packaging of fluids with large particles (peas or corn in brine) are the availability of suitable pumping system which does not damage the particles and assures a failsafe residence time.



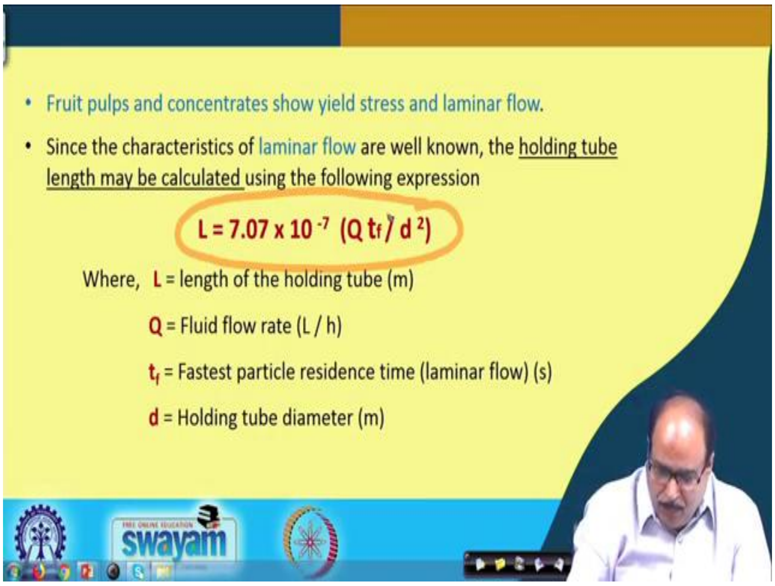
Holding time in relation to flow characteristics of fluids

- In the continuous system of sterilization, the fluid velocity in the heat exchanger and in the holding tube may be approximated to one of the three types.
- In **piston flow** which is ideal and which, unfortunately is rare, the mean holding time is equal to the residence time.

✓ From knowledge of the holding tube capacity and average flow rate, the tube length required for piston flow conditions may be calculated.

- For **turbulent flow**, the maximum velocity is assumed to be 1.25 times the average velocity.
- In **laminar or viscous flow** (as in non-Newtonian fluids like sauces, soups, pulps and concentrates) the average velocity is one half of the maximum.

These assumptions hold importance in calculation of the tube length and processing time.



Fruit pulps and concentrates show yield stress and laminar flow. And, since the characteristics of laminar flow is well known, the holding tube length can be calculated using this formula:

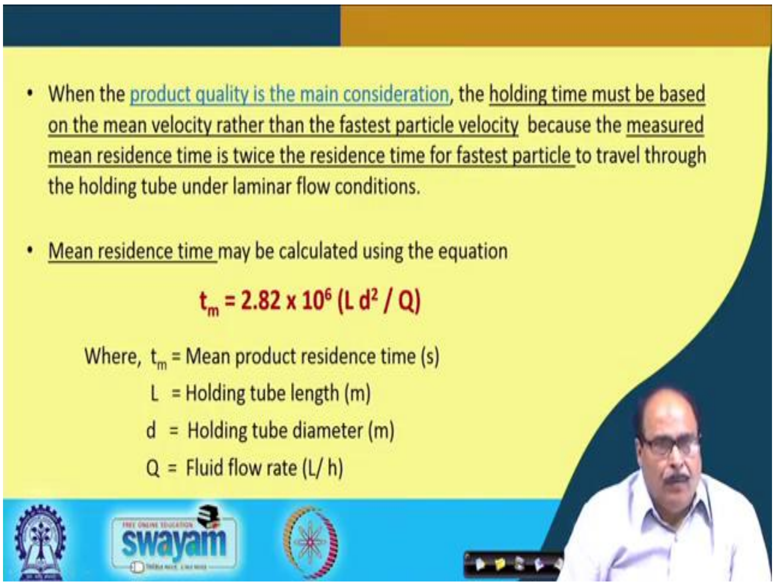
$L = 7.07 \times 10^{-7} (Q\ tf / d^{2})$

Where, **L** = length of the holding tube (m)

Q = Fluid flow rate (L / h)

t_f = Fastest particle residence time (laminar flow) (s)

d = Holding tube diameter (m)



When the product quality is the main consideration, the holding time must be based on the mean velocity rather than the fastest particle velocity because the measured mean residence time is twice the residence time for fastest particle to travel through the holding tube under laminar flow conditions.

Mean residence time_may be calculated using the equation

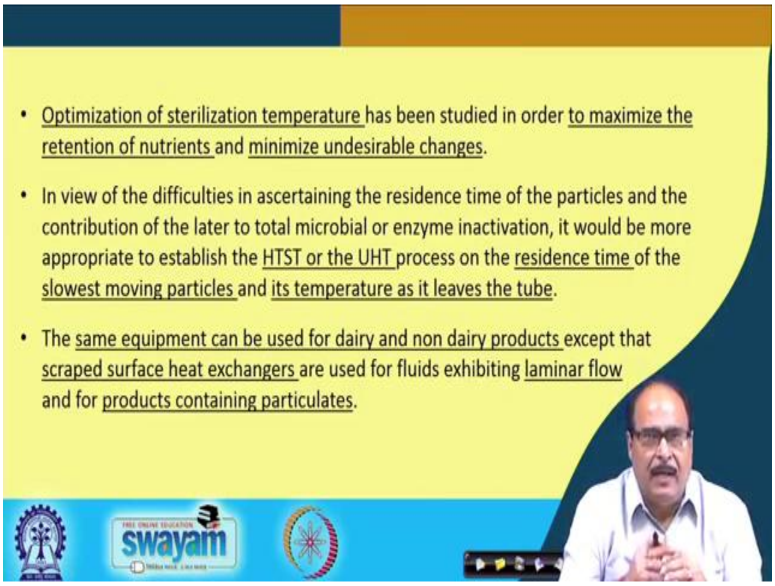
$$\mathbf{t_m = 2.82 \times 10^6 (L\, d^2 / Q)}$$

Where, t_m = Mean product residence time (s)

L = Holding tube length (m)

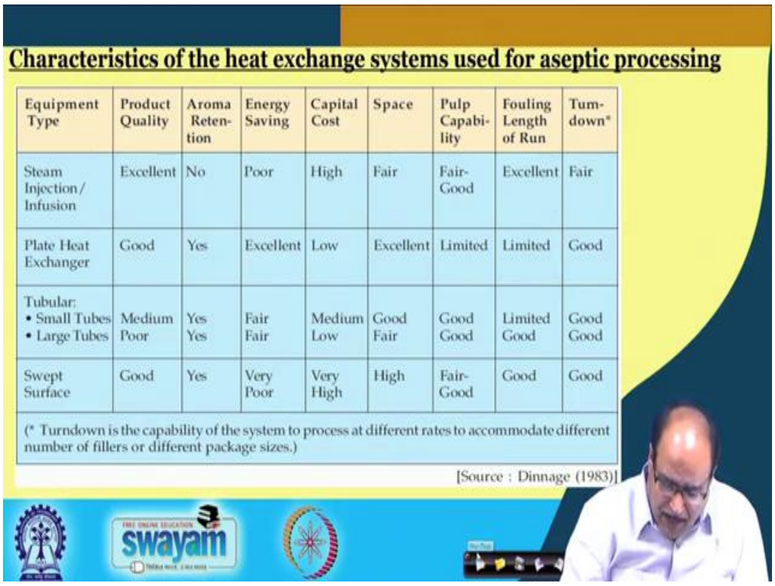
d = Holding tube diameter (m)

Q = Fluid flow rate (L/ h)



- Optimization of sterilization temperature has been studied in order to maximize the retention of nutrients and minimize undesirable changes.
- In view of the difficulties in ascertaining the residence time of the particles and the contribution of the later to total microbial or enzyme inactivation, it would be more appropriate to establish the HTST or the UHT process on the residence time of the slowest moving particles and its temperature as it leaves the tube.

- The same equipment can be used for dairy and non dairy products except that scraped surface heat exchangers are used for fluids exhibiting laminar flow and for products containing particulates.

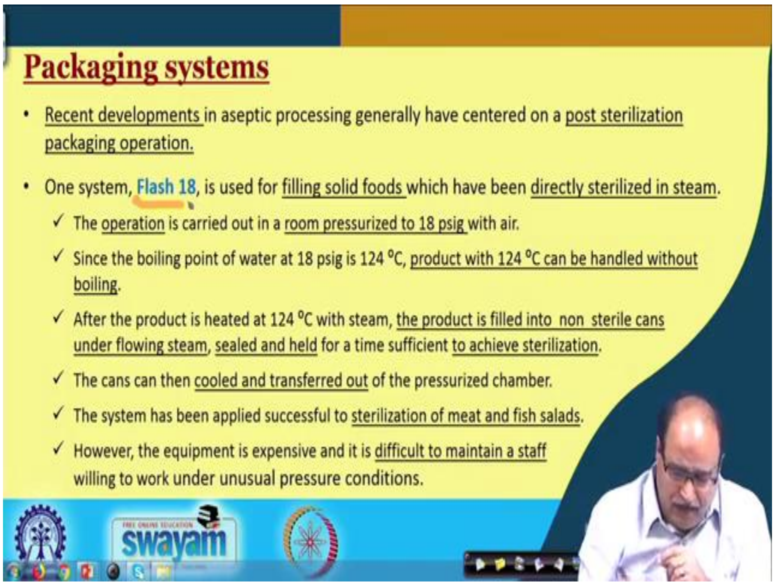


<u>Characteristics of the heat exchange systems used for aseptic processing</u>

Equipment Type	Product Quality	Aroma Reten-tion	Energy Saving	Capital Cost	Space	Pulp Capabi-lity	Fouling Length of Run	Turn-down*
Steam Injection / Infusion	Excellent	No	Poor	High	Fair	Fair-Good	Excellent	Fair
Plate Heat Exchanger	Good	Yes	Excellent	Low	Excellent	Limited	Limited	Good
Tubular: • Small Tubes • Large Tubes	 Medium Poor	 Yes Yes	 Fair Fair	 Medium Low	 Good Fair	 Good Good	 Limited Good	 Good Good
Swept Surface	Good	Yes	Very Poor	Very High	High	Fair-Good	Good	Good
(* Turndown is the capability of the system to process at different rates to accommodate different number of fillers or different package sizes.)								

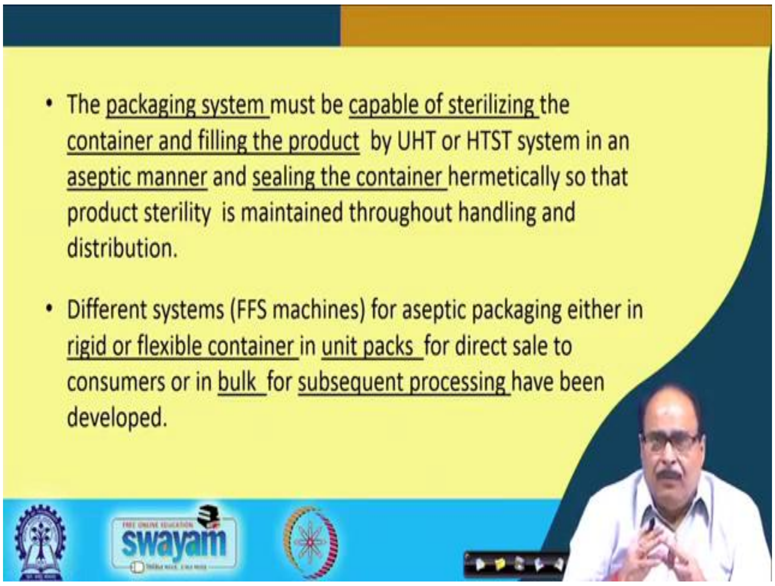
[Source : Dinnage (1983)]

The table can be read and understood.

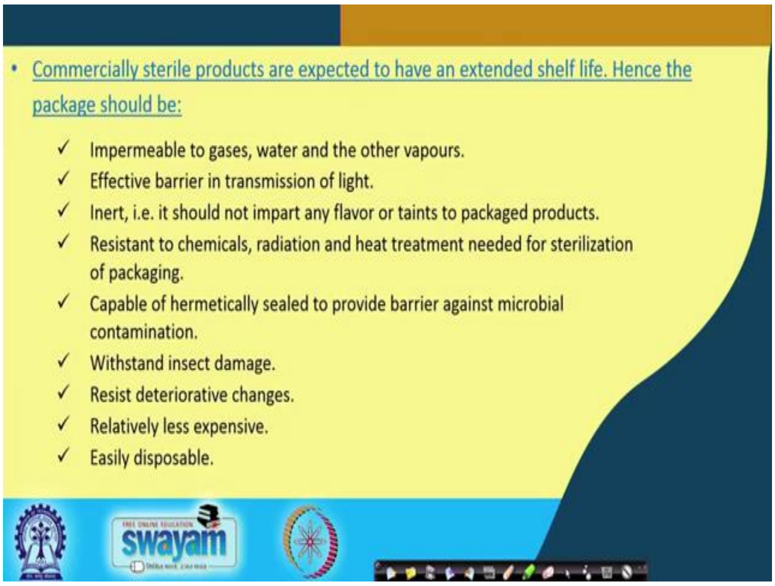


Packaging systems

- Recent developments in aseptic processing generally have centered on a post sterilization packaging operation.
- One system, Flash 18, is used for filling solid foods which have been directly sterilized in steam.
    - ✓ The operation is carried out in a room pressurized to 18 psig with air.
    - ✓ Since the boiling point of water at 18 psig is 124 ^{0}C, product with 124 ^{0}C can be handled without boiling.
    - ✓ After the product is heated at 124 ^{0}C with steam, the product is filled into non sterile cans under flowing steam, sealed and held for a time sufficient to achieve sterilization.
    - ✓ The cans can then be cooled and transferred out of the pressurized chamber.
    - ✓ The system has been applied successful to sterilization of meat and fish salads.
    - ✓ However, the equipment is expensive and it is difficult to maintain a staff willing to work under unusual pressure conditions.

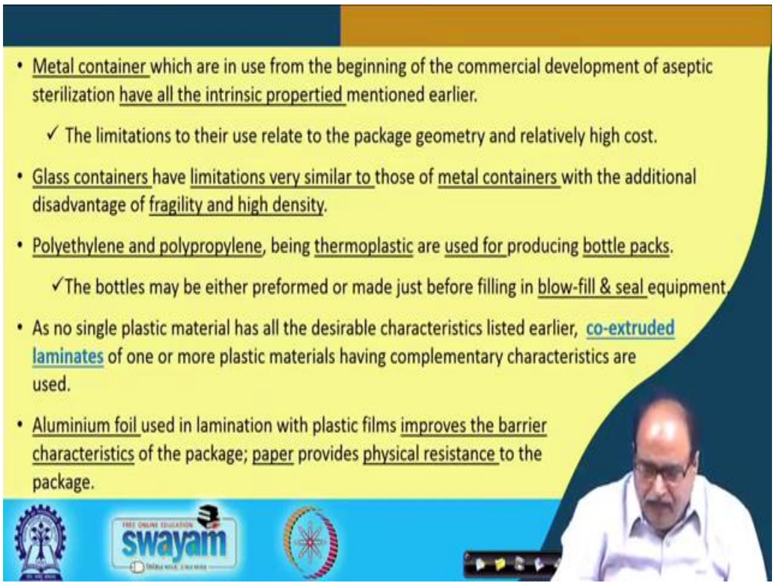


- The packaging system must be capable of sterilizing the container and filling the product by UHT or HTST system in an aseptic manner and sealing the container hermetically so that product sterility is maintained throughout handling and distribution.
- Different systems (FFS machines) for aseptic packaging either in rigid or flexible container in unit packs for direct sale to consumers or in bulk for subsequent processing have been developed.



Commercially sterile products are expected to have an extended shelf life. Hence the package should be:

- ✓ Impermeable to gases, water and the other vapours.
- ✓ Effective barrier in transmission of light.
- ✓ Inert, i.e. it should not impart any flavor or taints to packaged products.
- ✓ Resistant to chemicals, radiation and heat treatment needed for sterilization of packaging.
- ✓ Capable of hermetically sealed to provide barrier against microbial contamination.
- ✓ Withstand insect damage.
- ✓ Resist deteriorate changes.
- ✓ Relatively less expensive.
- ✓ Easily disposable.



- Metal container which are in use from the beginning of the commercial development of aseptic sterilization have all the intrinsic properties mentioned earlier.
    - ✓ The limitations to their use relate to the package geometry and relatively high cost.
- Glass containers have limitations very similar to those of metal containers with the additional disadvantage of fragility and high density. So, the metal and glass containers used in aseptic processing and packaging are normally avoided.

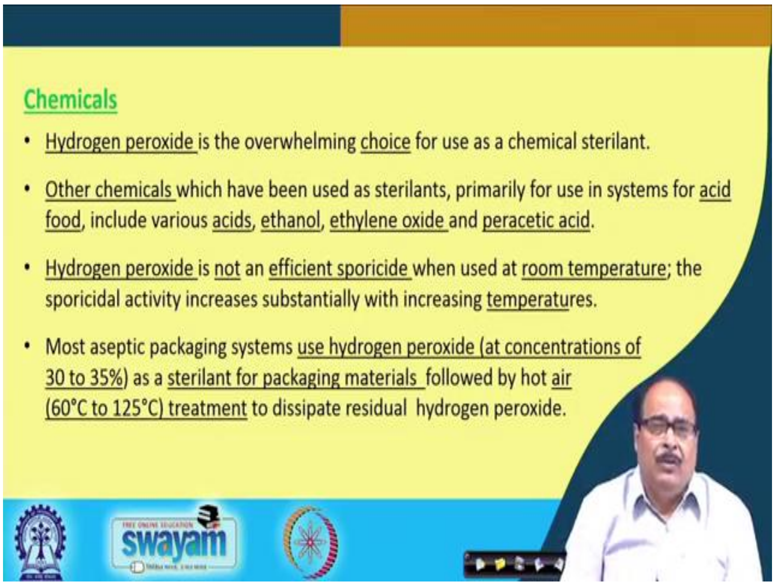
- Polyethylene and polypropylene, being thermoplastic are used for producing bottle packs.
    - ✓ The bottles may be either preformed or made just before filling in blow-fill & seal equipment.
- As no single plastic material has all the desirable characteristics listed earlier, co-extruded laminates of one or more plastic materials having complementary characteristics are used.
- Aluminium foil used in lamination with plastic films improves the barrier characteristics of the package; paper provides physical resistance to the package.

Sterilization of Aseptic Packaging Materials and Equipment

Heat

- Product supply lines and fillers are commonly sterilized by moist 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 requirements for dry heat sterilization are considerably higher than those for moist heat sterilization.
- Systems employing moist heat are sterilized at temperatures ranging from 121-129 °C, while 176-232 °C is used for sterilization by dry heat.

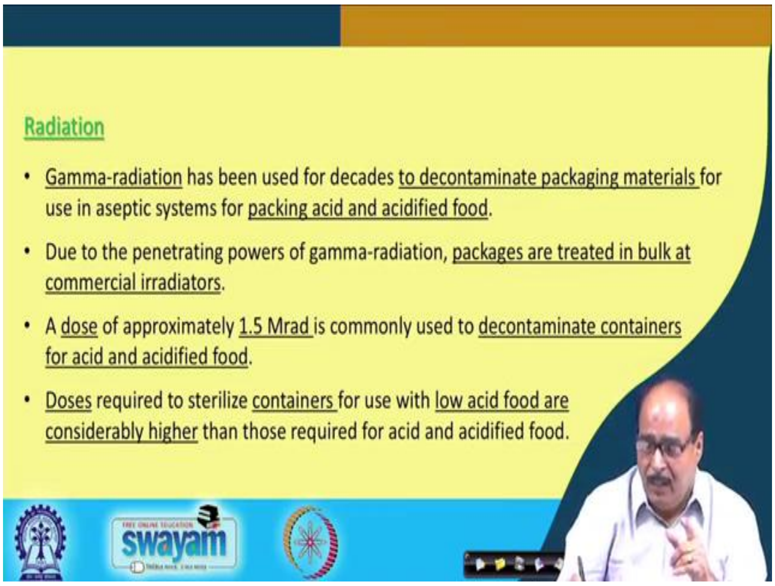
- Sterilization of air by incineration usually is conducted at temperatures ranging from 260°C to 315°C.



Chemicals

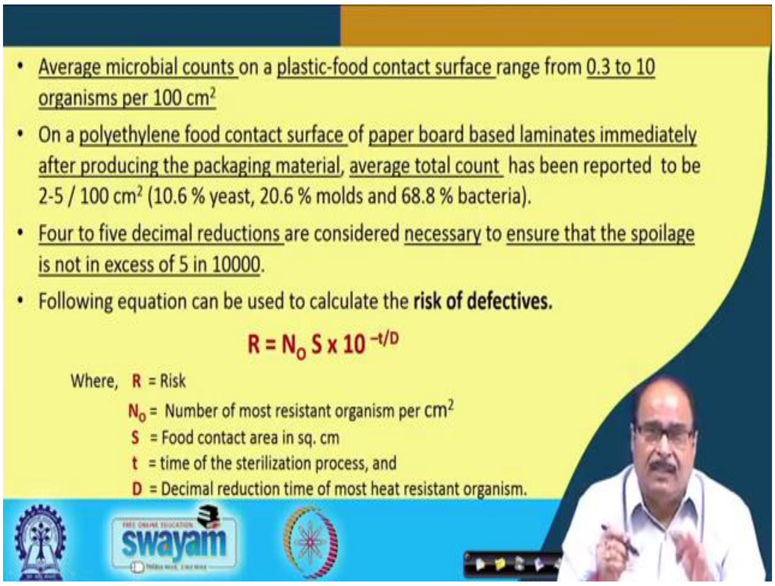
- Hydrogen peroxide is the overwhelming choice for use as a chemical sterilant.
- Other chemicals which have been used as sterilants, primarily for use in systems for acid food, include various acids, ethanol, ethylene oxide and peracetic acid.
- Hydrogen peroxide is not an efficient sporicide when used at room temperature; the sporicidal activity increases substantially with increasing temperatures.

Most aseptic packaging systems use hydrogen peroxide (at concentrations of 30 to 35%) as a sterilant for packaging materials followed by hot air (60°C to 125°C) treatment to dissipate residual hydrogen peroxide.



Radiation

- Gamma-radiation has been used for decades to decontaminate packaging materials for use in aseptic systems for packing acid and acidified food.
- Due to the penetrating powers of 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 food are considerably higher than those required for acid and acidified food.



- Average microbial counts on a plastic-food contact surface range from 0.3 to 10 organisms per 100 cm^2
- On a polyethylene food contact surface of paper board based laminates immediately after producing the packaging material, average total count has been reported to be 2-5 / 100 cm^2 (10.6 % yeast, 20.6 % molds and 68.8 % bacteria).
- Four to five decimal reductions are considered necessary to ensure that the spoilage is not in excess of 5 in 10000.
- Following equation can be used to calculate the risk of defectives.

$$\mathbf{R = N_O\, S \times 10^{-t/D}}$$

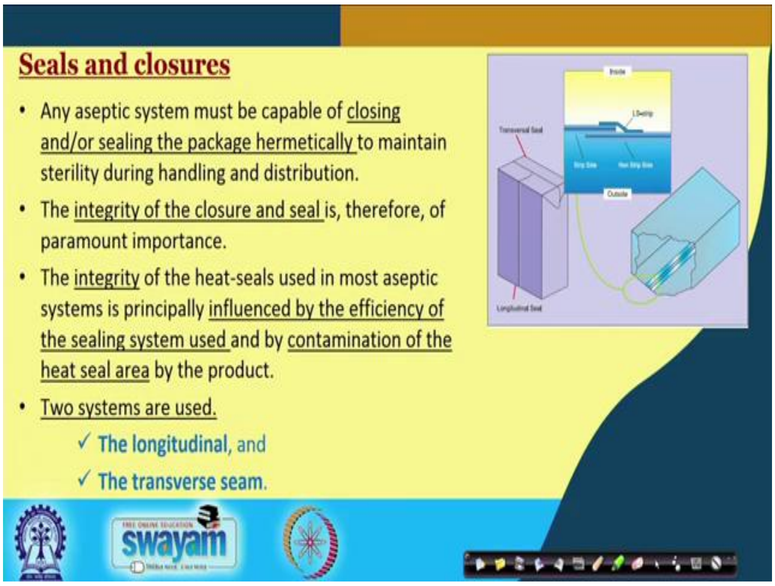
Where, **R** = Risk

N_O = Number of most resistant organism per cm^2

S = Food contact area in sq. cm

t = time of the sterilization process, and

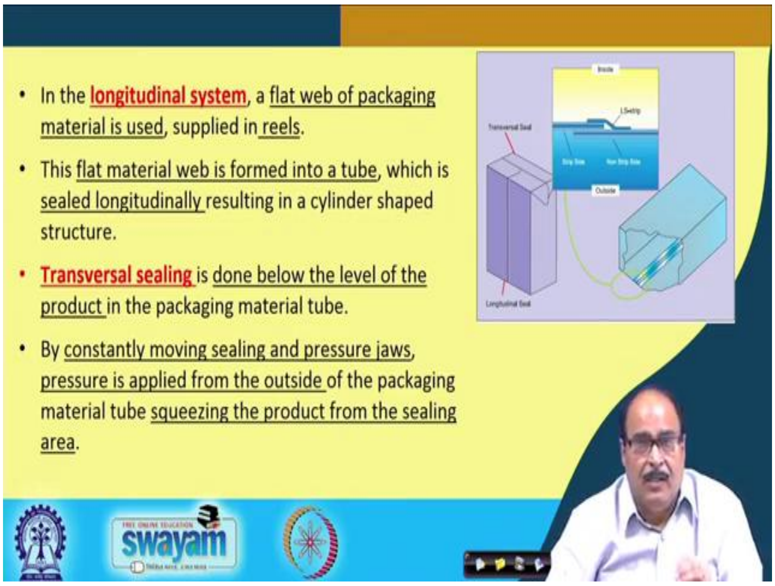
D = Decimal reduction time of most heat resistant organism.



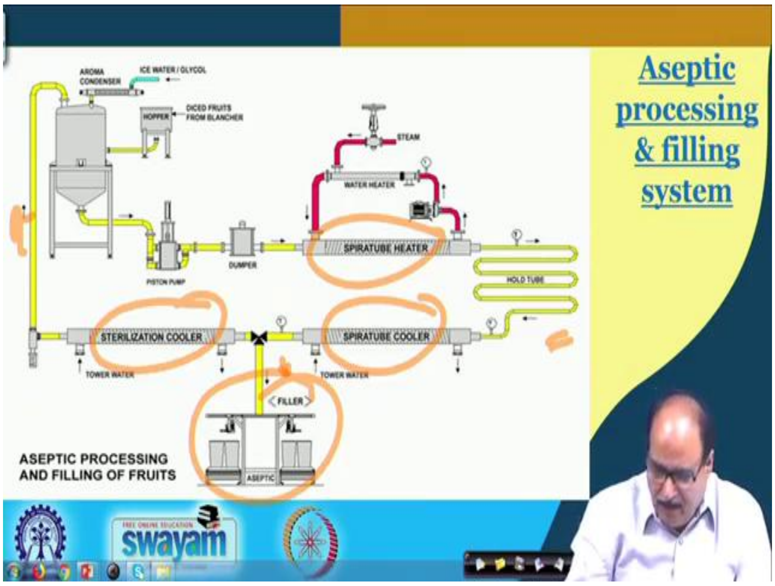
<u>Seals and closures</u>

- Any aseptic system must be capable of closing and/or sealing the package hermetically to maintain sterility during handling and distribution.
- The integrity of the closure and seal is, therefore, of paramount importance.

- The integrity of the heat-seals used in most aseptic systems is principally influenced by the efficiency of the sealing system used and by contamination of the heat seal area by the product.
- Two systems are used.
    - ✓ The longitudinal, and
    - ✓ The transverse seam



- In the longitudinal system, a flat web of packaging material is used, supplied in reels.
- This flat material web is formed into a tube, which is sealed longitudinally resulting in a cylinder shaped structure.
- Transversal sealing is done below the level of the product in the packaging material tube.
- By constantly moving sealing and pressure jaws, pressure is applied from the outside of the packaging material tube squeezing the product from the sealing area.



Aseptic processing & filling system

A schematic representation for aseptic processing and filling of the fruits. The process flow can be seen and understood.

Aseptic packaging systems in consumer or institutional packs

Form	Material	Sterilizing & Filling Method
Cans	• Tin plate, Aluminium, Composite	• Super-heated steam, hot air.
Bottles	• Glass • Granulated thermoplastic	• Chemical sterilization of container and filling in filtered air* • Extruded or low tube and filtered sterile air.
Pouch	• Thermoplastic laminate • Brown polymer	• H_2O_2 for sterilization of pouch and filling in sterile chamber or using filtered air*. • Thermoplastic extrusion, filtered air for filling.
Cups	• Thermoformable plastic and heat sealable lid	• Thermo-formable plastic and sterile air.
Cartons	• Plastic – Paper – Aluminium foil Laminates	• H_2O_2 sterilization of cartons and filling under UV light, steam or sterile air.

* Air designated to class 100 : Less than 100 particles of size greater than 0.5 μ, but less than 1 particle larger than 5 μ per ft^3 obtained using high efficiency particle air (HEPA) filters and laminar air flow systems are used.

Aseptic packaging systems in consumer or institutional packs

The different aseptic packaging systems that are available in consumer packs or in institutional packs i.e. the forms of the pack like cans, bottle, pouch, cups, cartons etc. and different sterilizing & filling methods are summarized in the table which can be studied and understood.

So, this is a very versatile technology for the processing of the product and value addition and shelf life extension; high quality products are obtained in economical forms, in a variety of consumer package using this technology.