Lecture 7 - Canning and bottling of fruit and Vegetables

Introduction
The term canning refers to a process which involves heating food stuff in hermetically sealed containers for a specific time at specific temperature to eliminate microbial pathogens that endanger public health and micro-organisms as well as enzymes that deteriorate food during storage.

History of canning: Important historical developments in canning are as under:

- The credit for invention of canning goes to Nicholas Appert, a French confectioner who was awarded a prize in 1809 by the French government for developing new method of heat preservation of food in sealed container and after whose name the process of canning is known as Appertization.
- In year 1810, Appert published the first book on canning entitled "The Art of Preserving Animal and vegetable substances for many years" which is the first known work on canning.
- The work of Appert consists of packing food in glass bottles, closing with corks and heating the container in boiling water for several minutes depending upon the type of the food.
- In 1810, Peter Durand got first British Patent on canning of foods in tin or metal containers.
- In 1813, Doukin, Hall and Gamble introduced the practice of post processing incubation of canned foods.
- In 1825 T Kensett and E Duggett were granted US patent for preserving food in cans.
- In 1825, Thomas Kenett, an American developed first kettle pan.
- 1837 Winshow was first to can corn from cob.
- 1839 Tin cans came into wide use in limited states.
- 1845 S. Elliott introduced canning in Australia.
- Louis Pasteur (1864) discovered that food spoilage was caused by micro-organisms which were destroyed at elevated temperature and technique was known as Pasteurization. This understanding helped to form a scientific basis for establishing and revolutionizing the canning industry.
- 1873 Andrew Shriver developed first retort pressure cooker.
- 1890 Max Ann developed first double seaming machine.
- 1895 Russel made first bacteriological study of canning.
- 1916 Bitting gave the index of processing time and temperature relationships for food products.
- 1920 Ball, a mathematician developed mathematical calculation for heat sterilization.
- 1921 Magoon and Culpepper, horticulturist by trade, gave idea of exhausting and vacuumin processed products.
- 1928 Heat process calculations were completed for the canning industry.
- The civil war in America and later the Boer war and the Great European war of 1914 with their enormous requirement of foods for the fighting forces gave a further impetus to the canning industry.

Presently large quantity of fruit, vegetables, meat, sauces, and confectionary products are preserved by canning. There is a great scope for the development of canning industry as it is one of the processes which does not involve the use of any chemical in preservation.

Manufacturing of cans: Metal cans are mainly used in the national and international trade for canning of fruits and vegetables. Open top sanitary (OTS) cans are made from tin plates which are very thin sheets of steel lightly coated with tin (0.00025 cm thick) on both sides. Tin can is cut into proper sizes with a trimming and slitting machine. The pieces provide body blanks. After notching and slitting, the flat can body is passed through an edging machine where hooks are formed. The can body is then bent into a cylindrical shape and side seam is soldered. These operations are carried in the can manufacturing factory. Now the cans are supplied in the flattened form to the users to lower the packing and transportation costs. The can ends are supplied separately along with the cans.

During preparation of can, the first step consists of reforming the cans in can reformer to give them a cylindrical shape. The cans are then flanged by using a flanger, which curls the rims/edges outward at each end. One end of the

can is now fixed to the flanged can body by means of a double seaming machine which firstly form the seam and secondly tightens it. The finished cans are now tested for any leaks with the help of a vacuum/air pressure tester. Finally, after the filling of the cans with fruits or vegetables the second lid (end cover) after coding is fixed similarly for airtight sealing of cans.

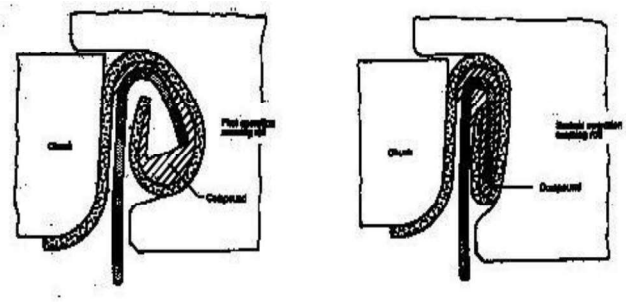

Figure 7.1: Cross section of the seam after the first operation and second operation (Courtesy o Standards Association of Australia.)

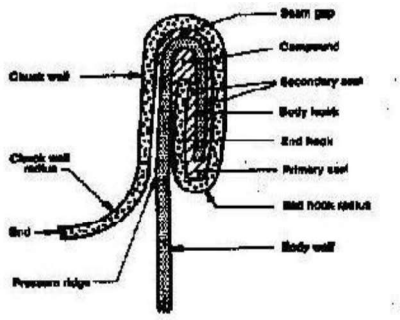

Figure 7.2: Cross-section of a double seam away from the side seam (Courtesy of Standards Association of Australia.)

The empty can after placing lid on both the sides can be tested for any leakage by using empty can tester. For testing, the probe of empty can tester is sealed empty can to which air is pumped to about 15-20 psi. Any leakage is judged by immersing can in water. In case of any leakage, the defect in the double seamer needs to be rectified before starting any production. Different sizes of the cans used in canning are showed in Table-7.1.

Table7.1: Trade name and sizes of cans used in canning of fruits and vegetables.

Trade name	Trade size	Size mm
A1	211×400	68×102
1 lb jam	301×309	78×90
A1 tall	301×411	78×119
A2	307×408	87×114
1 lb butter	401×212	103×70
2 lb jam	401×400	103×102
A 2 1/2	401×411	103×119
7 lb jam	603×513	157×148
A10	603×700	157×178

Canning of fruits and Vegetables

Fruit and vegetables are canned in the season when the raw material is available in plenty. Canned products are sold in off season and fetch better returns to the grower as well as processor. The canning of fruit and vegetables broadly involves the following steps (Fig. 7.3).

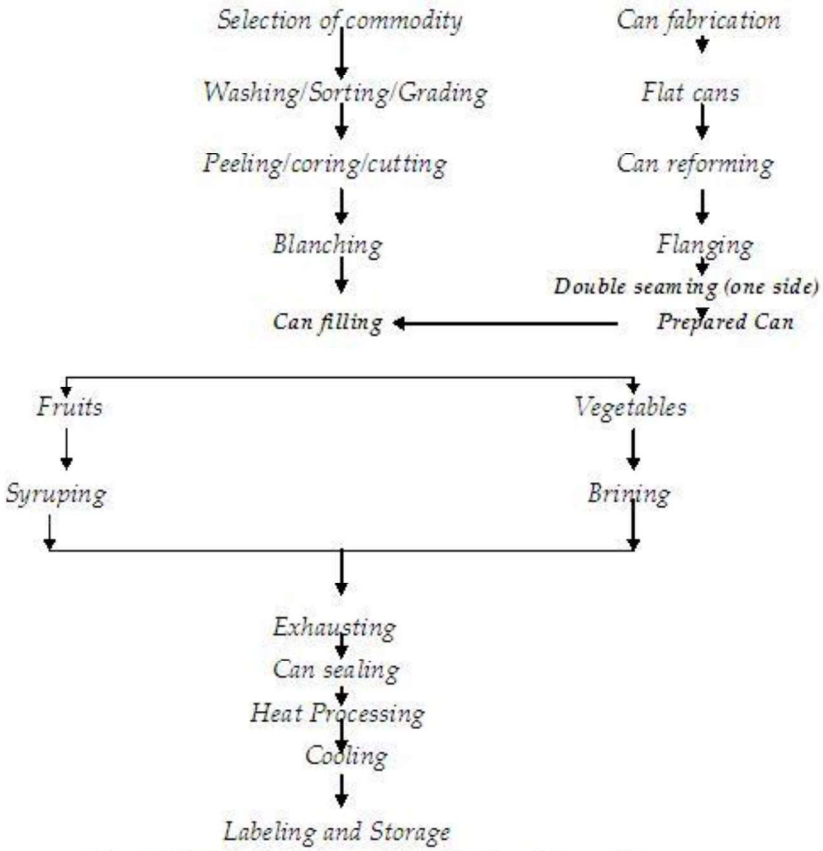

Figure 7.1: Flow sheet for canning of fruits and vegetables

Steps involved in canning of fruits and vegetables

1. Preparation of fruit and vegetables: Preparation of food commodity for canning consists of washing, sorting, grading, peeling, halving, blanching etc.

2. Raw material selection/receiving: For canning, fruits should be ripe but firm, evenly matured, free from blemishes, insect damage and malformation. Thus, harvesting at proper maturity is an important step in selection of raw material for canning.

- Most fruits are harvested at soft ripe stage. However, apple, pear, peach and banana harvested at mature stage are preferred for canning.
- Over ripe fruits yield poor quality product, while under ripe/immature fruit generally shrivel or toughen on canning.
- Vegetables except peas, beans etc are harvested at mature stage to enable them to withstand cooking during sterilization.
- Vegetables like green beans, green peas, ladies finger should be tender and free from soil, dirt etc.
- Tomatoes should however, be firm, fully ripe and uniformly deep red in colour.

The specific requirements for canning of fruits and vegetables are given under Table 7.2 and 7.3.

Table 7.2 Specific requirement for canning of fruits

Fruits	Preparation	Syrup Strength (°B)	Exhaust	Processing time at 100°C A2½ can) minutes	Type of can
Apricot	Use whole or halves, peel by dipping in boiling lye solution (2% NaOH) for 30 seconds to 1 minute, dip in cold water, cut two halves, remove pit, keep immersed in 2%salt solution until filled in can.	40 + 0.1 % citric acid	Exhaust can at 82-100°C for 6-10 minutes or until temperature in can center reaches 79°C.	20-25	Plain
Peach	Use whole fruit ,peel by dipping in boiling lye solution (2% (NaOH) for 30 seconds to 1 minute dip in cold water, cut two halves, remove pit, keep immersed in 2% salt solution until filled in can.	40	-do-	25	Plain
Banana	Peel, cut in to slices 12mm thick	30	-do-	25	plain
Grape fruit	Dip fruit in hot water at 93°C-96°C for 3-5 minutes, remove skin. Dip the peeled whole fruit in 2% hot lye, wash and separate the segments, fill segments in can.	60	Exhaust can at 82-87°C for 25-30 minutes or until temperature at center of can reaches 79°C.	30-40	Plain
Guava	Peel, cut into pieces, remove seeds and keep in 2% brine to prevent browning and fill in can.	40	-do-	20	plain
Litchi	Peel by hand, remove pits.	40+0.5% citric acid	-do-	25	plain
Pineapple	Peel, core and slice fruit, punch circular rings (5.6-8.8 cm diameter)	40	-do-	25	plain
Pear	Peel by hand, cut longitudinally into two halves, core and keep in 2% brine to prevent browning until filled in cans.	40+0.1%citric acid	-do-	20-25	plain
Jack fruit	Cut fruit into pieces, remove bulbs, separate seed from bulbs, use whole, halves or quarters.	50 + 0.5-0.75% citric acid	-do-	20-25	plain
Loquat	Cut into halves	40	-do-	25	plain
Mango	Peel ,cut into slice, dip in 2% salt solution until filled in can.	40+0.3%citric acid	-do-	25	plain
Papaya	Peel, cut into slices, discard seed	45+ 0.5% citric acid	-do-	25	plain

Table 7.3 Specific requirement for canning of vegetables.

Vegetable	Preparation	Brine strength (%)	Exhaust	Processing (A2½ can) at 121°C (0.7 kg/cm² steam pressure)	Type of can
Asparagus	Wash, grade, cut lengthwise into pieces of desired size, blanch for 2-3 min.	2.25%	Exhaust can at 90-100°C for 7-10 minutes, (79°C in can center)	24	Plain /sulphur resistant
Beans	Use tender, stringless beans, slice 2.5cm length, blanch and fill in can.	2.25	-do-	40	Plain/ sulphur resistant
Cabbage	Shred cabbage, blanch in 1% citric acid boiling solution for 5-6 min, cool in 2% brine prevents discolouration fill in cans	2.0	-do-	40	Plain
Cauliflower	-do-	2	-do-	20	Plain
Carrot	Wash, scrape and blanch for 5-10 minutes in boiling water	2	-do-	25	Plain
Mushroom	Use tight buttons, blanch for 4-5 minutes, immerse in 2% salt solution, fill in cans.	2.0+ 0.3 % citric acid+ 1% sugar	-do-	25	Plain
Peas	Shell, grade, boil for 3-5 min	2+2.5% sugar	-do-	45	Sulphur resistant
Potato	Peel, keep in 2% brine, blanch in boiling water for 2-3 min, keep in 2.5% $CaCl_2$ for 1 hour, wash and fill in cans.	2	-do-	45	Plain
Okra	Tender whole, blanch in boiling water for 1-2 minutes, cool in brine solution of 1-2% for 10 minutes, fill in can.	2 or in tomato sauce	-do-	35	Plain

3. Washing: Fruit and vegetables are generally washed with water to remove dust, dirt and adhering surface micro-flora. Fruits like peach, apricot etc are lye peeled so not washed before peeling. On the other hand, washing after peeling removes vitamins and minerals and should be discouraged. Different methods of washing include soaking or agitating in water, washing with cold or hot water sprays etc.

- Mechanical washers involve agitating or tumbling the commodity on moving belts or revolving screens while they are immersed in water or subjected to water sprays.
- Washing by using high pressure sprays is most satisfactory.
- Detergents are frequently used in the wash or rinse water.
- Vegetables may be soaked in dilute solution of potassium permanganate or chlorine (25-50 ppm) for disinfection.
- The water temperature should be kept low to keep the fruit firm and to reduce leaching losses.
- High pressure sprays should not injure the fruits.

Bacteria and other contaminants can accumulate in the wash water and hence appropriate cleaning and chlorination practices be followed.

4. Sorting and grading: Sorting and grading ensures the removal of inferior or damaged commodity. For sorting, inspection belt can be used, in addition to trained personnel who detect poor quality produce unsuitable for canning.

- Automatic colour sorters can be used for sorting to reduce labour cost.
- The fruit and vegetables are graded to obtain uniform quality with respect to size, colour etc. after preliminary sorting.
- Grading can be done either manually or with the help of grading machines.
- For mechanical grading, the fruit and vegetables are passed over screens with holes of different diameter.
- Different types of mechanical graders include screen grader, roller grader, rope or cable grader etc. Screen graders fitted with vibrating screens of copper with circular openings are most commonly used. A set of six screens is generally provided to accommodate different sizes.
- Soft and berry fruits are generally graded manually.
- Plums, cherries and olives are graded whole while peaches, apricot, pears, mangoes etc are graded after cutting them into halves or slices for canning.
- White button mushrooms are graded on cap size basis. Only healthy and light buttons with cap diameter up to 2.5cm and compact head are graded as A grade while, cap diameter beyond 2.5cm as B grade.

5. Peeling, coring and pitting: These are the primary unit operations for preparing fruit and vegetables for canning. Depending upon the type of commodity, peeling and coring methods are selected such as (1) by hand or knife (2) by machine (3) by heat treatment (4) by using lye solution. Cores and pits in fruits like apple, peach, apricot etc are removed by hand or by machine (de-corer).

Typical examples of different methods of peeling fruit and vegetables are given in the Table-7.4.

a) Peeling by hand: Many fruit and vegetables are peeled and cut by hand with the help of peeling knives. The peeling knife with a curved blade and a special guard to regulate the depth of peeling can be used for uniform peeling in case of irregular fruit shapes.

Table-7.4: Common methods for the peeling of fruit and vegetables

S.No.	Peeling method	Commodity
1.	Knife peeling (manual)	All fruit and vegetables
2.	Mechanical knife peeling	Apple, pear, pineapple
3	Hot water peeling	Tomato
4	High pressure steam/water peeling	Potato, tomato
5	Abrasive peeling	Potato, ginger, carrots
6	Flame peeling	Brinjal, onion, garlic
7	Lye peeling	Orange segments, peach, apricot, nectarines, pears.

b) Mechanical peeling: Mechanical peeling, coring and cubing machines are used for peeling pears, apples, carrots, turnip, potatoes etc. Similarly, automatic peelers are used for peeling of peaches and cherries.

c) Mechanical /Knife peeling: Mechanical knife peelers are used for peeling of fruits like apples and pears. In mechanical knife peeler either stationary blades are pressed against surface of rotating food commodity or the rotating blades are pressed against the stationary food to remove the skin.

d) Abrasive peeling: It is used for peeling potatoes, ginger, carrots etc. The food commodity is fed on to the carborundum rollers or placed into a rotating bowl which is lined with carborundum crystal acting as abrasive surface. With the continuous supply of water, the rotating abrasive surface removes the skin from the surface of the food.

e) Flame peeling: Flame peeling is used in onions, garlic and brinjal. The peeler consists of a conveyor belt which carries and rotates food through a furnace heated to more than 1000oC. The outer layer and root hairs of onion are burnt off and charred skin is removed manually.

f) Peeling by heat or hot water: In this method peaches and potatoes are scalded in steam or boiling water to soften and loosen skin, which is subsequently removed manually. Infra-red heat peeling can also be used for peeling of apples and tomatoes.

g) Flash steam peeling: In flash-steam peeling, the fruit and vegetables are fed into a slow rotating (4-6 rpm) pressure vessel. High pressure steam (1500 kPa) is then introduced into the rotating vessel to expose all food surfaces to the steam for specified period depending upon the type of fruit. When the pressure is instantly released, the steam formed under the skin causes the surface of the food to flashes off. Most of the peeled material is discharged with the steam and finishing is done with additional water sprays to remove any skin traces.

h) Lye peeling: Lye is an boiling aqueous solution of caustic soda (Sodium hydroxide) or Potassium hydroxide (1-2%) used in conjunction with ample water supply and heat source for peeling. Fruit and vegetables like peaches, nectarines, apricot, sweet orange segments, carrots and sweet potatoes are peeled by dipping them in boiling caustic soda (1-2%) for 1-2 minutes (depending upon the strength of lye, temperature/maturity and nature of fruit or vegetable) followed by dipping in cold water. The hot lye loosens the skin from the flesh underneath which is removed by gentle rubbing of fruit by hand. The fruit can also be dipped in a dilute solution of hydrochloric acid or citric acid for few seconds to neutralize the alkali. The method is very quick and efficient to reduce wastage and peeling cost. The effectiveness of lye peeling depends upon lye concentration and temperature, product holding time and agitation.

- Lye peeling equipment varies from simple stainless steel (SS) pan for lye solution with SS baskets as cages for holding the food commodity to fully automatic system.
- In cottage and small scale canning units, the peeling system consists of three SS tanks attached in series, the one of which is having provision for steam, the second tank contain dilute solution of citric acid or hydrochloric acid while the third is filled with tap water.
- The fruit or vegetables placed in perforated SS crates/ basket or cage are dipped in the first tank which contains boiling hot lye solution. After 1-2 minute of dipping treatment, the crates are immediately dipped in second tank to neutralize the lye and final washing is carried out in third tank.

6. Cutting/halving/ slicing: After peeling, the fruits are halved or cored either manually or mechanically. However, peeled fruit should always be kept submerged in either water, containing 1-2 % salt solution or acid to avoid enzymatic browning. Peaches, apricot, pears, tomatoes etc are peeled before canning. However, the fruits which are canned retain better nutrients as compared to peeled fruits.

7. Blanching: Treatment of fruit and vegetables with boiling water or steam for short periods followed by immediate cooling prior to canning is called blanching. The basic objectives of blanching are as under:

- To inactivate enzymes
- To clean the product initially to decrease the microbial load and to preheat the product before processing
- To soften the tissue to facilitate compact packing in the can
- To expel intracellular gases in the raw fruit to prevent excessive pressure built up in the container.
- To allow improved heat transfer during heat processing
- To ensure development of vacuum in the can and to reduce internal can corrosion.

Blanching is carried out either by hot water or using live steam. Water blanching is generally of the immersion type or spray type as the product moves on a conveyer. Only soft water should be used for blanching as hard water toughens the tissue and destroys the natural texture.

8. Prevention of browning: Some fruits which cannot be blanched due to their delicate tissue structure are treated with some chemicals to prevent oxidative browning, occurring due to exposure to oxygen during peeling and slicing. Oxidative browning is caused by action of oxidase enzyme with catechol and tannins and is common in peach, apple, potato, mushroom, cherry, apricot, grapes and persimmon. Pineapple, tomato and melons are however not prone to browning. Common methods used to prevent browning are as under:

- **Sulphite treatment:** Fruits are dipped in a solution containing 2000-4000 ppm SO2 for 2-5 minutes. SO2 fumigation can also be used commonly for grapes dehydration.
- **Acids:** Common acids used to increase acidity include citric, fumaric, tartaric, acetic, phosphoric etc. Low pH of solution is known to act as inhibitor for enzyme polyphenol oxidase thus inhibits the browning of fruits. The peeled fruits, slices or cut surfaces are dipped in a 1-2 % citric acid solution to prevent browning.
- **Antioxidants:** Ascorbic acid is commonly used as an antioxidant in most canned fruits. It acts as an inhibitor of peroxidase in some fruits like kiwi fruit. It also reduces quinones, which are generated by polyphenol oxidase upon oxidation of polyphenols to phenolic compounds thus preventing their conversion to brown pigments. Ascorbic acid can be used as such or mixed in dry sugar, citric acid or in syrups.
- **Sugars:** Sugar syrup is used to prevent browning in peeled and sliced fruits by inhibiting oxidation by partially excluding air in the tissues. Sugar is mixed with ascorbic acid and citric acid as an effective agent against loss of texture, colour and flavour. Addition of chitosan in filtered apple and pear juices also prevents enzymatic browning.
- **Salt:** Dipping of peeled and sliced fruit and vegetables in 1-2% salt solution also prevent enzymatic browning, as salt acts as inhibitor for polyphenol oxidase.

9. Filling in cans: Tin cans are washed in hot water or in steam jet to remove any adhering dust or foreign matter. The cans are then sterilized by dipping in hot water tank or the cans are passed through a steam sterilizing tunnel before use. Generally plain cans are used however, for coloured fruits like plums, black grapes; strawberries etc lacquered cans are employed. The fruit and vegetable either slices, halves or whole are filled into the cans keeping in view the declared drain weight.

10. Syruping or brining: The cans are filled with hot sugar syrup (35-55%) for fruits and with hot brine (2-10%) concentration for vegetables. The purpose of syruping or brining is to help in transfer of heat within the food pieces during processing. It also improves the taste of the canned product, fill up the inter-space between the fruit or vegetables in the can. The syrup or brine is added to the can at a temperature of 79-820C, leaving 0.32-0.47cm head space either manually or in automatic machines. In automatic machines, the prepared syrup or brine is drawn into the cans through a horizontal pipe having a row of small holes. The cans travel on a continuous belt in an inclined position below the syrup or brine pipe and get filled, the overflowing excess syrup is pumped back into the syrup tank by a centrifugal pump.

11. Exhausting: Exhausting is a unit operation in which practically all air from the contents in the can is removed before sealing. The purpose of exhausting and creation of vacuum is to create an anaerobic environment in the can that would inhibit microbial spoilage. The removal of air from the contents also reduces the risk of corrosion and pin holing of the tin plate and discoloration of can contents. Exhausting helps in better retention of vitamin C. Expansion and shriveling of contents during heating help to avoid over filling or under filling of the can. (Corn and peas expand on boiling in brine while strawberries shrivel upon heating in sugar syrup). The vacuum in can prevents bulging of the can during storage at higher attitudes or in hot climate. It also prevents excessive pressure and strain during sterilization.

Methods of exhausting: There are generally three methods of exhausting the cans to remove headspace gas and creation of vacuum.

a) Heat/thermal exhausting: Heat exhausting is used in cans. The can covered with the lid or loosely sealed or

clinched is passed through a tank of hot water at about 82-87oC or on a moving belt through a covered steam box. In water exhaust box, the cans are placed in such a manner that the level of water is 1.3-2.5 cm below their tops. The time of exhausting varies from 5 to 25 minutes depending upon the nature of the product. At the end of the exhausting, the temperature at the centre of the can should be about 79oC. During exhausting, the steam replaces the air inside the can and it is sealed while still hot.

b) Steam flow or steam-vacuum closing: In this system, high steam pressure is injected into the can headspace (at 100oC for 5-8 minutes) just prior to closing. Thus, all the air inside the can is quickly replaced with steam, which will condense and form vacuum following seaming. Steam vacuum closure coupled with hot fill, assures very high vacuum in the can.

c) Mechanical vacuum sealing: In high speed mechanical vacuum sealing, the cans filled with the product and covering syrup or brine, are passed through a clincher that clinches the cans (first operation roll seam) but does not form an airtight seal. The cans are subjected to a vacuum for a short period of time to remove the free headspace air but not all dissolved gases within the product. However, during this process some syrup may be drawn along with the dissolved air. To avoid syrup spillage, a pre-vacuumizing step before vacuum closing is recommended. High vacuum closing is also used in case of glass jars where the jar is placed in a closed chamber in which high vacuum is maintained.

12. Seaming/closing: Immediately after exhausting, the cans are sealed by using a double seamer. Double seaming is a two step operation. In the first operation, the can lid is inserted on the can body hook by holding and rotating the lid-in-position can between two rollers. This operation is called as clinching; during which first operation roller gently guides the lid in the body hook. The next step is to press the seam using the second operation roller, which results in an appropriate overlap of the body hook and cover hook which results in an appropriate countersink. Between the cover hook and body hook lies a layer of sealing compound which ensures the sealing process. The critical parameters for an ideal hermetic seam are body hook, cover hook, seam thickness, seam width and overlap which need to be carefully controlled to prevent leakage in the can.
Immediate closing of the cans is required to prevent excessive cooking of the surface of the product. Double seamers are of different designs and capacities like hand operated, semi-automatic and fully automatic. Modern double seamers operate at high speeds (300 cans per minute) while liquid products are sealed in cans at speed of up to 1600 per minute.

13. Coding/Embossing: Coding of lid of the can is essential to identify the can, once it is closed. The code provides the necessary information about the product like name of canning unit, product packed in the can, date of packing; lot number etc. Coding is done on the second lid (end cover) of the can just before sealing.

14. Heat processing: The cans after sealing are immediately transferred to the heating retorts to achieve sterilization of contents. Heat processing consists of heating cans to a predetermined time and temperature of heating to eliminate all possibilities of microbial spoilage. Over cooking should be avoided as it spoils the texture, flavour and appearance of the product. Generally all fruits and acid vegetables can be processed satisfactorily in boiling water (100oC) as the presence of acid retards the growth of bacteria and their spores. While non acidic vegetables (except tomato and rhubarb) are processed at higher temperatures of about 115-121oC under pressure. It needs to be ensured that required temperature reach the centre of the can. The temperature at the centre of the can should be maintained for sufficiently long period to destroy spores of more heat resistant bacteria.

Processing methods: Processing methods differ with the kind of fruit and vegetables to be processed. The cans containing most fruit and acid vegetables (pH < 4.5) are heated in open cookers, continuous non-agitating cookers and continuous agitating cookers.

- Open cooker consists of stainless steel (SS) or galvanized iron tanks to which perforated water pipes are placed underneath the false bottom to supply the steam for heating of water. The sealed cans are placed in SS or GI crates and immersed in the tank containing boiling water.
- In continuous non-agitating cookers, the cans travel in boiling water in crates carried by over-head conveyors on a continuous moving belt.

- While in continuous agitating cookers, the sealed cans while moving on the belt are rotated by a special mechanical device to agitate the contents of the cans. This helps in reducing the processing time.
- For low acid foods like vegetables (pH > 4.5), with hard texture, the processing is carried out in a pressurized vessel (retorts) at elevated temperatures (= 110oC) under higher steam pressure (2-3 atmospheres). The retorts vary in shape and size (horizontal or vertical), type of operation (batch to continuous, non-agitating to agitating) and with different types of heating media such as water, steam, steam/air or flame.
- In small scale canning units, vertical stationary retorts are generally used. They are made of cast iron cylinders and are fitted with a lid which can be bottled steam tight. They are provided with steam and water feeds, drain cock, safety valve, pressure gauge and thermometers.

Factors effecting sterilization

- **Altitude:** As boiling point of the water decreases with the increase in altitude, the processing time for a particular product standardized at sea level should be increased with the increase in altitude.
    - For every increase of 152 meters above mean sea level (a.m.s.l.) in altitude, the boiling point of water decrease by about 1oC and normal processing time has to be increased by about two minutes.
    - Similarly, as the altitude above mean sea level increases, the pressure required to maintain the specified processing temperature also increases.
    - It is necessary to maintain higher gauge pressure if processing is carried out at altitude greater than 305 meter a.m.s.l. (1000 ft a.m.s.l.).

- **pH:** Inherent pH value of the food commodity greatly influence the processing schedule to achieve required destruction of micro-organisms. The lower the pH, the greater is the ease with which a product can be processed or sterilized. On the basis of pH, the foods are classified into following four distinct classes:

i) Low acid foods (pH = 5.0): The low acid foods is the class of foods which require greater care in its preservation as they are subjected to spoilage by thermophilic and mesophilic putrefactive anaerobes including Clostridium botulinum. These foods include most of the vegetables like peas, beans, corn, asparagus, mushroom and corn etc. They are necessarily required to be processed above 110ºC temperature and under steam pressure.

ii) Medium acid foods (pH 5.0-4.5): Medium acid foods like meat and vegetable mixtures, spaghetti, soups and sauces also need processing above 110ºC under steam pressure. They are subjected to spoilage by thermophilic and mesophilic anaerobes. They also include thermophilic anaerobes not producing hydrogen sulphide but causing flat sours.

iii) Acidic foods (pH 4.5-3.7): Most of the fruits including peas, fig, pineapple, nectarines, mango, apple, tomato, subject to spoilage by non spore forming aciduric, butyric anaerobe like Clostridium pasteurinum and thermophilic anaerobe are classified as acidic foods. They can be processed in boiling water at temperature of 100ºC.

iv) Highly acidic foods (pH = 3.7): Highly acidic foods like Sauerkraut, berries, citrus juices, grapefruit, rhubarb and pickles are included in this group. As the bacterial spores do not germinate and grow at pH values below 4.5 and do not harm the product even if they are not destroyed in canned fruits. A canned product having pH value of less than 4.5, can be processed in boiling water at 100ºC, but a product with a pH value above 4.5 requires processing at 115-121ºC under pressure of 0.7 to 1.05 kg cm-2(10-15 pounds inch-2).

15. Cooling: Immediately after processing, the sealed cans are rapidly cooled to approximately 35-40ºC to stop the cooking process and to prevent stack burning. Prolonged heating results in an inferior and uneven product, like peaches and pears become dark in colour, tomatoes turn brownish and become bitter in taste while peas becomes mushy with a cooked taste. Cooling is done by immersing or passing hot cans in cold water tanks, by spraying cans

with jet of cold water, by passing cold water in to a pressure cooker or exposing cans to air. Water used for cooling should be non corrosive, low in bacterial and yeast count and chlorinated with 2 ppm of available chlorine.

16. Storage: After cooling, the cans are stacked to allow the outer surface to dry, as even a small traces of moisture are likely to induce rusting. The cans are then labelled either manually or by using labeling machine and packed in wooden or corrugated cartons. They should be stored in cool and dry place (below 30^0C). Adequately processed cans usually ensure an acceptable product quality up to at least one year. Storage of cans at higher temperatures should be avoided to prevent the risk of thermophilic growth and spoilage.

Bottling of fruits and vegetables

Bottles have proved to be very good containers for home preservation of fruits. Although their initial cost is high, they can be used several times and last for many years if carefully handled. The fruits look attractive through the glass and do not develop metallic flavour. Bottling does not need a sealing machine but is not suitable from the manufacturer's point of view as the initial capital required is high. There are many types of glass containers of different shapes and sizes and with various types of hermetic seals. Jars fitted with wire clamps are considered to be the best. The products remain in a very hygienic condition and do not come into contact with rubber or metal.

Glass containers: Glass containers are chemically inert, clear, transparent, rigid, resist internal pressure, heat resistant and are cheap in comparison to other packaging materials. Glass containers are the excellent barriers to solid, liquids and gases. They preserve food against odor and flavour contaminations. But when faulty closures are used odour and flavour contamination may occur, hence; the closure should be air tight. Glass does not deteriorate with age in comparison to other packaging material but are light in weight and are fragile (breakable) with thermal shock and impact.

Types of glass containers

1. **Bottles:** The bottles have narrow neck and small closure over the top. Narrow neck facilitates pouring and reduces the size of closure. Bottles are used for packing liquids and small sized solids.
2. **Jars:** They do not have any appreciable neck but are wide mouthed bottles. They are easy to clean and easy to take out product from them. They are used for packing jams and powders.
3. **Tumblers:** They are similar to jars but do not have any neck and no finish. They can be used for packing jams and jellies.
4. **Jugs:** These are large sized bottles with carrying handlers. Used for packing liquids, foods in large quantities like ½ gallon or more.
5. **Vials:** These are small glass containers. Vials used for packing pharmaceuticals while ampoules are used for packing small quantity like spices, food colors, aroma, essences etc.

Properties of glass containers

1. Glass containers are chemically inert: Almost all types of chemicals can be packed in the glass containers except hydrofluoric acid (it eats the glass hence packed in plastic container). Oils and fats have no reaction with the glass. Water has little or negligible reaction with the glass at low temperature. The products like drugs and transfusion liquids are packed in specially treated glass containers as at higher temperature (during sterilization) the hydrogen from the water is displaced.

2. Clarity of glass containers: Products packed in glass containers are easily visualized from outside especially useful for the products kept on the shelves. But some nutrients are packed in colored bottles e.g. brown bottles, amber colored bottles. Opal glass is a ground glass, in which visibility is lost. Gin or opal glass is also used in bathrooms.

3. Glass containers are rigid containers

- Rigidity helps in filling of containers and
- Make it possible for stacking
- It also helps in loading and vacuum filling of containers. It also provides support to the material.

4. Glass containers resist the internal pressure: Glass containers offers resistant against internal pressure brought about by CO_2 or other gases in the product e.g. beer, beverages, soft drinks etc.

5. Heat resistant: Glass containers are heat resistant in comparison to other packaging material except cans. A temperature of 1500^0C is applied during manufacturing of glass. Melting point of alumina is 2000^0C, which is used for making glass. Viscous hot materials are poured into glass containers while they are still hot.

Disadvantages of glass

- Glass containers are fragile/brittle, hence great care is required to be exercised during handling.
- Glass containers are heavy in weight.
- Glass containers are not easy to dispose.

Closures: Closures should prevent loss of contents and must make reseal (crown corks do not make reseal). Closure should not react with the product e.g. in ketchup, formation of black neck takes place. Different types of closures are Crown corks, roll on cap, lug cap, vacuum seal, temper proof, snap fit, press on caps and screw caps.

Procedure for bottling

- The bottles are thoroughly washed and sterilized.
- The fruit slices are filled leaving about 3 cm space at the top of the jar or bottle.
- The sugar syrup recommended for different fruits is filled boiling hot leaving a head space of 1-1.5 cm.
- Exhausting and sterilization: Separate exhausting of bottles is not required and it is done simultaneously with sterilization by putting a pad of cloth (false bottom) under the bottles.
- The bottles should not be abruptly immersed in hot water, otherwise they may break because of sudden rise in temperature. The temperature of the water should be about the same as that of the contents and should be raised gradually and the bottles kept in the boiling water for the required time.
- At the start of sterilization the lids are left loose and the level of boiling water should come up to the neck of the bottle.
- When sterilization is over, the mouths of bottles and jars should be immediately closed or corked tightly.
- Cooling of bottles is done and the bottles are labeled after drying. The products preserved in bottles require more attractive labels.
- Store in cool and dry place.

Thus, canning and bottling is a well tested acceptable method of preservation of fruit and vegetable for conversion into stable products. For canning no chemical preservative is used. Shelf-life of adequately processed product in cans is around one year. Keeping in view the versatility of the process, canning and bottling of fruit and vegetable can be adopted as a successful enterprise.

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