Food Beverages

24.1 Definition of Beverage

Beverages are an integral part of human diet, starting from new born. The cycle starts with the infant formulas- highly complex drink, rich in many key nutrients. As human age and their nutritional requirements change, product designer keeps pace by developing new and innovative beverages to meet these needs.

Beverages can be defined as **"any fluid which is consumed by drinking"**. It consists of diverse group of food products, usually liquids that include the most essential drink "water" to wide range of commercially available fluids like fruit beverage, synthetic drinks, alcoholic beverage, milk, dairy beverages, tea, coffee, chocolate drinks etc. Despite differences in their properties one common feature that exists in all beverages is their ability to act as thirst quencher. In simple words beverages can be defined as "liquid which is essentially designed or developed for human consumption". The beverages are rarely consumed for its food value but it is vital for life. Although their prime role is to fulfill the human need but these are part of our culture. However there are important pre-requisite for beverages:-

- All are made from food ingredients
- All are subject to pure food law
- Consumed in enormous quantities – sometimes safer than potable supply

24.2 Health Importance of Beverages

Beverages are essential for growth, development as well for carrying out various physiological processes that are critical for living a healthy life.

- In adult individuals 70 percent of body weight, 73 percent of lean muscle, 25 percent of adipose tissues, 22 percent of bone and 80 percent of blood consists of water. Consumption of beverages help in maintaining the water content in body and prevent dehydration

- The water assists in digestion, assimilation and excretion of foods. It also helps in removing the toxic substances produced in body as a result of metabolisms such as urea, uric acid, ammonia etc. through kidney.

- Water in beverages help in regulating the temperature of body through the process of sweating.

- Beverages specially the fruit and vegetable based ones are source of micronutrients (vitamins and minerals) and anti-oxidants (carotenoids, flavonoids).

•Certain beverages like tea and coffee contain alkaloids which stimulate the central nervous system.

•Consumption of alcoholic beverages specialy wine is recommended for its heart healthy image due to the presence of flavonoids.

•Fermented dairy beverages are consumed because of the beneficial microflora present in them which assist in restoration and improvement of gastro-intestinal health.

24.3 Classification of Beverages

Beverages may be classified on various ways. The classification criteria may depends on various factors as mentioned below:

•Natural and Synthetic (Ingredients used in manufacture)
•Carbonated and Non-carbonated (Degree of mechanical carbonation)
•Alcoholic and Non-alcoholic (presence or absence of alcohol)
•Hot and Cold (Temperature of serving)
•Stimulating and Non-stimulating (Based on physiological effect)

24.3.1 Natural and synthetic beverages

The natural beverages are prepared from the naturally derived ingredients including fruit juices or milk or malt, sugar, acid, flavouring and colouring materials. The examples of this group are fruit based beverages, malt beverages and dairy beverages.

Synthetic beverages are analogue of natural beverages and may contain ingredients which are prepared synthetically like flavouring and colouring materials. These are primarily developed to offer pleasure to consumers at affordable cost. The major group of synthetic beverages is soft drinks which contain flavoured sugar syrup as base material that may or may not be carbonated. The high potency sweetener based beverages also belong to the category of synthetic beverages as they contain artificial sweeteners mainly to reduce the calorific value.

24.3.2 Carbonated and non-carbonated beverages

Carbonated beverages are the one where carbon dioxide is dissolved in syrup or water. The presence of carbon dioxide creates bubbles upon release of pressure and fizzing in the beverage. The carbonated beverages are

commonly referred as “Soft Drink”. Cola or lemonade beverages are typical examples of carbonated beverages. The process of fermentation also produces carbon dioxide in certain beverages like beer. Carbonation is done for various reasons. Consumers find the fizzy sensation pleasant, and like the slightly different taste that dissolved carbonic acid provides. Soda water is another popular type of carbonated beverage which may also be flavoured.

Majority of fruit and dairy based beverages falls into the category of non-carbonated beverages. The category also includes hot beverages and alcoholic beverages that do not contain carbon dioxide.

24.3.3 Alcoholic and non-alcoholic beverages

Alcoholic beverages contain ethyl alcohol which can be consumed for its intoxicating and mind-altering effects. Alcoholic beverages are produced by the process of natural or controlled fermentation. On the basis of raw material used and process technology used in their manufacture alcoholic beverages may be classified into three major groups:

a) Beer

It is the world‟s third most consumed beverage. Beer is prepared by fermenting the "wort" (soluble liquid of barley malt digest) with appropriate yeast to attain an alcohol level in the range of 4-8 percent. Apart from alcohol, beer is also characterized by the "effervescence" i.e. foam which is produced by carbon dioxide and bitterness. The bitterness and aroma in beer is contributed by the hops (*Humulus lupulus*) solids as αiso-acids and other polyphenols. There are many variants of beer but two are more popular. These are called as "Lager" beer which is fermented by bottom yeast i.e. *Saccharomyces pastorianus* at lower temperature (7-12 ^{O}C) for longer period, while the "Ale" is manufactured by using top fermenting yeast i.e. *Saccharomyces cerevisiae* at relatively higher temperature (18-25^{0}C) (Fig. 24.1).

b) Wine

Wines are made from variety of fruits. Such as grapes, peach, plum or apricots. However, the most commonly used one is grapes, both green as well as red grapes. The grapes are macerated to release juice which is fermented naturally by wide range of yeasts including *Saccharomyces spp., Pichia spp., Stellata spp*. and certain lactic acid bacteria. The duration of fermentation is also longer as compared to beer and mostly fermented wine is aged (months to year) to develop desirable sensory characteristics (Figure 24.1). There are two major type of wines i.e. white wine (made from green grapes) and red wine (from red or blue grapes). The red wine contain anthocyanin (as colouring pigment) and subjected to secondary fermentation termed as **"Malolactic fermentation"** to mellow the flavour of wine. The alcohol content in wine ranges from 9-16% (v/v). Sparkling wines are characterized by "effervescence" produced by carbon dioxide and clarity, example: Champagne.

c) Spirit

Spirit is a class of alcoholic beverages which are unsweetened and produced by distillation of fermented base. The fermented base may be molasses (by-product of sugar industry), fruit juices, cereal extract or sometime a combination of many fermentable substrates. Spirits are characterized by relatively higher alcohol content which may be as high as 20 percent. The process of distillation increases the concentration of alcohol but reduced the level of congeners. Some of the alcoholic beverages belonging to the category of spirit are listed in Table 24.1.

Table 24.1 Alcoholic beverages belonging to the category of spirit

Alcoholic Beverage	**Base Material**	**Alcohol Content (by volume)**	**Remark**
Brandy	Fruit Juices mainly grapes	35-60%	Normally consumed after-dinner, preferred for medicinal purpose. Aged in oak barrels
Rum	Molasses or sugarcane juice	40-55%	Dark Coloured and quite popular in Caribbean nations. Aged for not less than three years
Gin	Wheat & rye may contain herbs	37.5-50	Flavoured and not aged. Mostly consumed with citrus juices
Whisky	Cereal (Barley, Rye,	40-55%	Most famous one is "Scotch Whisky"
	corn malt)		
Vodka	Malted cereals, potatoes etc.	38-40%	Popular in Russian federation countries, two variants white and flavoured Vodka
Cider	Apple juice and other temperate fruits	2-7%	Characterized by acidic-alcoholic taste

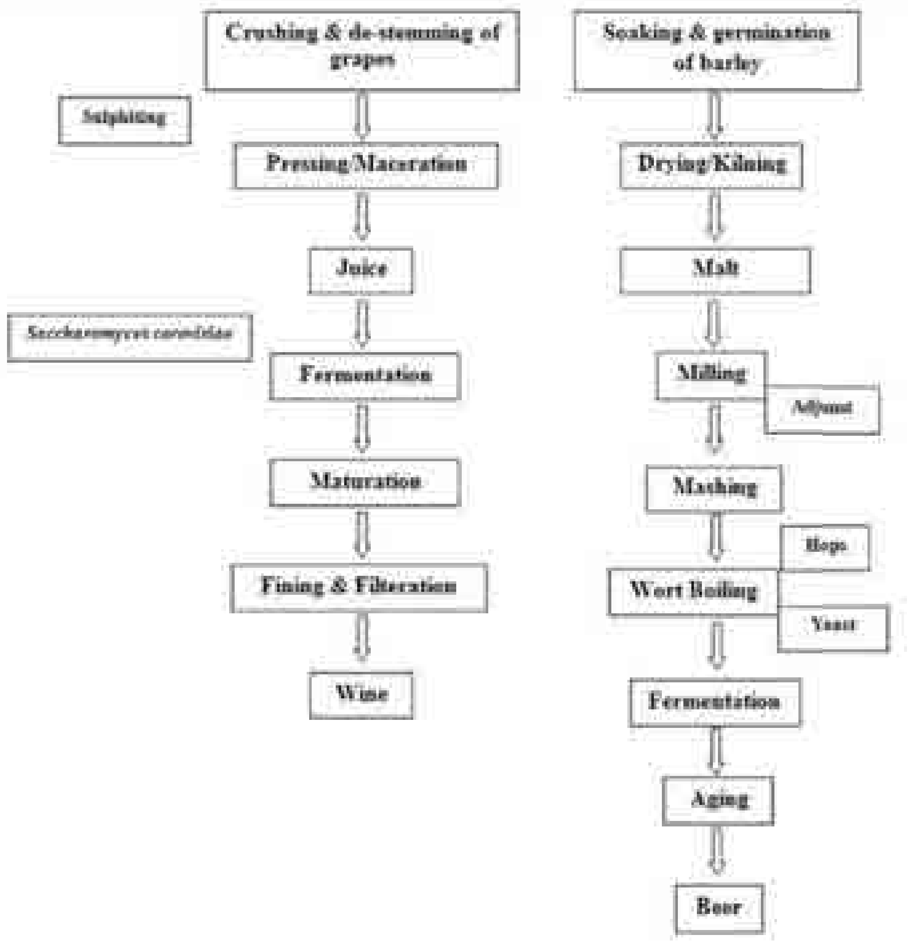


Fig. 24.1 Manufacture technology for beer and wine

24.3.4 Hot and cold beverages

Another criterion for classifying beverages is the temperature of serving. Certain beverages are consumed only hot i.e. temperature above 65-70^{0}C which are termed as "Hot beverage" while those served at chilled temperature are called as "cold beverages". The examples of hot beverages are tea, coffee, chocolate and milk. However, iced tea and cold coffee are served chilled. Most of the fruit beverages, dairy drinks, alcoholic drinks and soft drinks are example of cold drinks. Term "cold drink" is synonymous to "carbonated drinks" as well.

24.3.5 Stimulating and non-stimulating beverages

Consumption of some beverage stimulates the body systems mainly to nervous system and circulatory system. It is mainly due to the presence of certain chemical compounds like caffeine in coffee and tea, many phenolic compounds in herbal drinks and ethyl alcohol in alcoholic beverages. The chemical constituents present in these beverages influence the physiological processes as follows:-

- Increase in basic metabolic rate (BMR)
- Increase in blood circulation and heart beat
- Stimulation of central nervous system (CNS) and release of neuro transmitter
- Diuretic (increase in frequency of urination)
- Enhancement in secretion of gastric juice

24.3.6 Other beverages

There are many other categories of beverages and it includes nomenclature like herbal drinks, mood drinks, energy drinks and sports drinks.

Energy drinks are those beverages which boost energy and mainly contain sugar and caffeine. In recent past there has been rapid growth in the demand of energy drinks. These drinks may also contain variety of stimulants and vitamins.

Herbal drinks are prepared by using the infusion of herbs in water. A wide variety of herbs may be used in preparation of such drinks. Many herbs like aloe vera, ginseng, *shatavari*, *Arjuna*, lemongrass, thyme etc. may be used for as base material for herbal drinks.

Sports beverages are also called as "electrolyte drinks" are basically designed to replenish the loss of fluid & electrolytes and provide quick energy during the exercise and sports activity. The mono-saccharides such as dextrose, glucose syrup are added so that they can be transported easily into the muscle cells and produce energy apart from sucrose and malto-dextrin. The carbohydrate content of sports beverage varied in the range of 4-8 percent. Electrolytes are many essential minerals such as chloride, calcium, phosphate, magnesium, sodium, and potassium. Electrolytes control osmosis of water between body compartments and help maintain the acid base balance required for normal cellular activities.

There are three types of sports drinks all of which contain various levels of fluid, electrolytes, and carbohydrate.

- Isotonic drinks have fluid, electrolytes and 6-8% carbohydrate. Isotonic drinks quickly replace fluids lost by sweating and supply a boost of carbohydrate. This kind of drink is the choice for most athletes especially middle and long distance running or team sports.
- Hypotonic drinks have fluids, electrolytes and a low level of carbohydrates. Hypotonic drinks quickly replace flids lost by sweating. This kind of drink is suitable for athletes who need fluid without the boost of carbohydrates such as gymnasts.
- Hypertonic drinks have high levels of carbohydrates. Hypertonic drinks can be used to supplement daily carbohydrate intake normally after exercise to top up muscle glycogen stores. In long distance events high levels of energy are required and hypertonic drinks

can be taken during exercise to meet the energy requirements. If used during exercise, hypertonic drinks need to be used in conjunction with isotonic drinks to replace fluids.

26.3.1 Syrup preparation

Syrup is usually prepared by mixing 1 part (volume) syrup to 3-6 parts (volume) water in stainless steel tanks fitted with top driven agitators. In sugar based product the syrup typically consists of sugar syrup of 67º Brix strength, citric acid, flavouring, colourings, preservatives and water. Sugar syrup is passed through a plate heat exchanger to decrease the microbial load. Syrup is pre-prepared, tested and diverted to proportioner for mixing with water and carbonation. Flow meters are most frequently used for proportioning. The syrup is dosed through a mass flow meter and the water dosing is done volumetrically by using a magnetic induction flow meter.

26.3.2 Carbonation and filling

Carbonation may be considered as the impregnation of a liquid with CO_2 gas. Earlier some the pre-syruping method was employed in which carbonated water and sugar syrup were metered separately into the bottle or other container. This method has been replaced in modern plants by pre-mix filling in which sugar syrup; water and CO_2 gas are combined in the correct ratio before transfer to the filler. The final beverage thus prepared before filling and regulation of carbonation and of the relative proportions of syrup and the water is of critical importance. The fundamental role of the carbonator is to obtain close contact between CO_2 gas and the liquid being carbonated. Factors determining the degree of carbonation are:

- Operating pressure in the system and temperature of the liquid
- Contact time between the liquid and CO_2
- Area of the interface between the liquid and CO_2
- The affinity of the liquid for CO_2 (affinity decrease as the sugar content increases); □ Presence of other gases.

Presence of air in syrup or water affects the carbonation process. Presence of air in beverage may also lead to mould growth and other oxidative reactions. Generally 1 volume of air exclude 50 volumes of CO_2.

Carbonation may be done in three different ways as follows:

I. Pre-syruping or syruping-filling process or post mix process: Containers are filled with flavoured syrup and now carbonated water is added in it to prepare carbonated drink.

II. Finished Product filling or Pre-mix: Flavoured syrup is added to water in correct proportion and then homogenous mix is carbonated to produce beverage.

III. Carbonation of water is done in the first stage, then flavoured syrup is metered and added into it to prepare carbonated beverage.

Degree of carbonation is judged by the amount of effervescence produced and it is most important characteristic of carbonated beverages. The optimum level of carbonation varies with the type of beverage. Higher level of carbonation in orange type of carbonated beverages and too low in cola or ginger ale is not liked by consumers. The level of carbonation varies between 1 to 4.5 volumes of CO_2 per litre of beverage; 1 volume for fruit based carbonated drinks, 2-3 volumes for colas and around 4.5 volumes for mixer drinks like tonic water, ginger ale. Use of polyethylene terephthalate (PET) bottles also requires slightly higher level of carbonation as some loss of CO_2 is bound to occur during storage. Carbonated soft drinks are filled into either bottles or cans. Thickwalled, reusable, glass bottles were used for many years, but are being replaced by thin-walled, non-reusable glass and increasingly, PET bottles.

26.4 Carbonated Water

The consumption of carbonated water has increased rapidly. As per FSSAI definitions carbonated water conforming to the standards prescribed for packaged drinking water under Food Safety and Standard act, 2006 impregnated with carbon dioxide under pressure and may contain any of the listed additives singly or in combination. Permitted additives include sweeteners (sugar, liquid glucose, dextrose monohydrate, invert sugar, fructose, Honey) fruits & vegetables extractive, permitted flavouring, colouring matter, preservatives, emulsifying and stabilizing agents, acidulants (citric acid, fumaric acid and sorbitol, tartaric acid, phosphoric acid, lactic acid, ascorbic acid, malic acid), edible gums, salts of sodium, calcium and magnesium, vitamins, caffeine not exceeding 145 ppm, ester gum not exceeding 100 ppm and quinine salts not exceeding 100 ppm. It may contain Sodium saccharin not exceeding 100 ppm or Acesulfame-k 300 ppm or Aspartame not exceeding 700 ppm or sucralose not exceeding 300 ppm.

26.5 Mineral Water

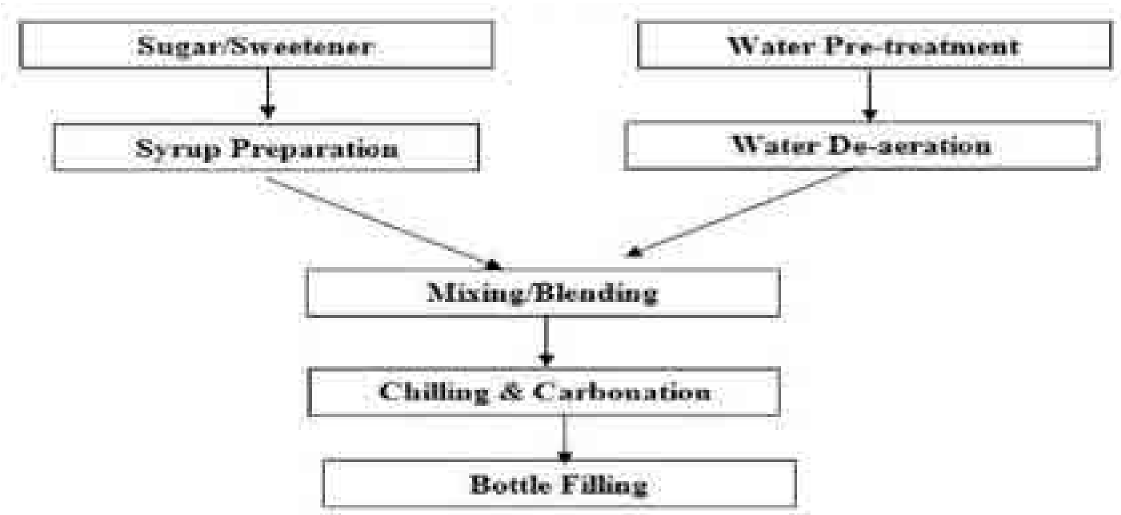
As per FSSAI guidelines mineral water means all kinds o mineral water or natural mineral water by whatever name it is called or sold. All mineral waters shall conform to the following standards, namely:-

S. No.	Characteristics	Requirements
1	Colour, Hazen unit/True	Not more than 2
2	Odour	Agreeable
3	Taste	Agreeable
4	Turbidity (Turbidity unit, NTU)	Not more than 2 nephelometric
5	Total Dissolved Solids (TDS)	150-170 mg/Litre
6	pH	6.5-8.5

Besides these levels of mineral salts, heavy metals, toxic elements, environmental contaminants and microbial counts have also been specified.

26.6 Packaged Drinking Water (other than mineral water)

It can be defined as water derived from the surface water or underground water or sea water which is subjected to herein-under specified treatments, namely decantation, filtration, combination of filtration, aerations, filtration with membrane filter depth filter, cartridge filter, activated carbon filtration, de-mineralization, remineralization, reverse osmosis and packed after disinfecting the water to a level that shall not lead any harmful contamination in the drinking water by means of chemical agents or physical methods to reduce the number of micro-organisms to level beyond scientifically accepted level for foods safety or its susceptibility. The standards, packaging and labelling requirements have also been specified under FSSAI rules.



FRUIT BEVERAGES AND DRINKS

27.1 Introduction

Fruit beverages and drinks are one of the popular categories of beverages that are consumed across the globe. The fruit beverages and drinks are easily digestible, highly refreshing, thirst quenching, appetizing and nutritionally far superior to most of the synthetic and aerated drinks. In recent past the consumption of fruit based beverages and drinks has increased at a fast rate. Fruit juices or pulp used for the preparation of these products are subjected to minimal processing operations like filteration, clarification and pasteurization. The fruit juice or pulp, are mixed with ingredients like sugar, acid, stabilizers, micronutrients and preservative to develop beverages and drinks. There are various categories of fruit juice or pulp based beverages and drinks which are listed below.

Natural fruit juices, sweetened juices, ready-to-serve beverages, nectar, cordial, squash, crush, syrup, fruit juice concentrate and fruit juice powder belong to the category of non-alcoholic and non-carbonated beverages. The principle groups of fruit beverages are as follows:

- Ready-to-Serve (RTS) pre-packaged Beverages
- Fruit juice and Nectars
- Dilutable beverages

27.2 Ready-to-Serve (RTS) Beverages

The ready-to-serve beverages as per FSSAI specifications should contain at least 10 percent fruit content and not less than 10 percent TSS besides 0.3% acid maximum as citric acid. The levels of permitted preservatives include 70 ppm (maximum) for sulphur dioxide and 120 ppm (maximum) for benzoic acid. The total plate count and yeast and mold counts should not exceed, to 50.0 cfu/ml and 2.0 cfu/ml, respectively. The Coliform counts should be nil in 100 ml beverage samples.

Since these beverages are consumed as such without dilution, hence are termed as “Ready-to-serve” beverage. The majority of packaged fruit beverages belong to this category. Wide range of fruits including mango, citrus fruits, berries, litchi, guava, pineapple, grapes etc. are preferred for RTS beverages. Required amount of sugar, acid, stabilizer, colouring and flavouring ingredients are added in juice or pulp along with water and the mixture is blending properly, filtered if desired. The RTS mix is pasteurized (80-90^{0}C) in bottle (20-30 min), continuous juice pasteurizer (few seconds to one minute) and cooled immediately. Nowadays, UHT processing of RTS beverages is quite popular because of longer shelf-life and less loss of nutrients during processing.

The amount of fruit juice or pulp may vary according to fruit and cost effectiveness. The presence of oxygen in headspace often leads to oxidation resulting in off-flavour and loss of nutritive value, hence anti-oxidants such as ascorbic acid is often added in RTS beverages. Besides it, colour and flavour ingredients which are stable to heat and oxygen are preferred.

27.2.1 Natural fruit juice

Natural fruit juices also falls in the category of RTS beverage. It may be defined as pure juice which is extracted from ripe and mature fruits and contain 100 percent fruit content. The juice is extracted by various methods and contains mainly sugars, acids, vitamins, minerals and other minor components. These are preserved by thermal processing and freezing. The commonly available fruit juices are apple, pineapple, citrus, grapes, pomegranate and mango.

The sweetened juices are beverages which possess at least 85 percent juice and 10 percent TSS. The sugar and acids are added to increase the TSS content and also to balance the acid-to-sugar ratio. A wide variety of fruit juices are used for the purpose. Sometime two or more juices are mixed to develop a palatable and refreshing drink with better flavour and balanced nutrition. Such beverages are also called as "fruit punch". In certain fruits the blending or mixing of juices is done to balance the acidity and minimize the flavor changes. Use of fruit juice concentrate with suitable dilution with water is mostly used on commercial scale to produce uniform quality product.

Example:

- Very sweet (grape) and very bitter (grapefruit)
- Highly acidic (lime, lemon, sour cherry) with bland tasting fruits (pear, apple)
- Highly flavoured (guava, banana) with bland & insipid tasting fruits (pear, loquat)

The freshly squeezed juices have very short shelf-life; hence they have to be stored at 0-5^{0}C to check spoilage. Some of them may have low pH (below 4.5) hence they require thermal processing in the range of 85-95^{0}C for a minimal period to ensure commercial sterility. The minimum TSS and acidity for various natural fruit juices has been specified by FSSAI.

27.3 Nectar

Nectar is prepared from the tropical fruits pulp such as mango, litchi, guava, papaya, citrus fruits and pineapple by adding sugar, acid and other ingredients. As per FSSAI specifications nectar should contain TSS not less than 15^o Brix and not less than 20 per cent fruit content, except for pineapple and citrus fruits where fruit content should not be less than 40 percent. Fruit pulp or puree or juice or concentrate may be used as starting material. The acidity of the nectar should not be more than 3.5 per cent as anhydrous citric acid. The maximum permissible limit of preservative in nectar is sorbic acid at 50 ppm. The sorbic acid is added as sodium or potassium salt of sorbic acid. Nectar is also not diluted before consumption. Nectar is also characterized by cloudy appearance and thick mouthfeel. The cloudiness in nectar and other beverages is because of the presence of polysaccharides such as pectin, cellulose, hemicellulose and starch. The loss of cloudiness specially in citrus juices is due to the activity of pectin methyl esterase (PME), which cause deesterification of pectin molecule resulting in settling down of pectin and loss of cloudiness. Therefore, citrus juices or comminutes must be thermally treated to inactive the PME. Sometime hydrocolloids are added to stabilize the cloudiness. Preservation of nectar is achieved in similar way as mentioned for RTS beverages.

The limited shelf-life of nectar (few days at refrigeration temperature) could be overcome by following any of the desired processing operation.

27.3.1 Flash pasteurization

The nectar may be pasteurized in plate type pasteurizer which is provided with heat recovery and cooling unit. Temperature in the range of 85-95^{0}C for 15 to 60 seconds is used for most of the products; however it again depends on type of the juice and initial microbial load. The products where both enzyme and microbial inactivation is desired slightly higher temperature i.e. 90-95^{0}C for not more than 15 seconds is used. Tubular pasteurizer is preferred for slightly viscous nectars. For aseptic packaging operations, pasteurizer is integrated with aseptic packaging unit either directly or via an aseptic buffer tank.

27.3.2 In-pack pasteurization

In-pack pasteurization is most preferred methods on small scale units. The juice is filled in packs, mainly bottles and immersed in heated water tanks which are held at 80-90^{0}C. The pasteurization conditions are 8085^{0}C for up to 20 minutes to ensure safety of the product. The treated bottles are air-dried and then labeled. Care must be taken to ensure that pack is sealed properly and product is processed at intended temperature.

27.3.3 Hot fill operation

Hot filling offer a simpler mean of ensuring microbial integrity of the nectars. The bulk product is heated to a pre-determined temperature then filled hot (70-85^{0}C) in packs and sealed immediately. In case of glass bottle they should be pre-heated to minimize thermal shock. The packs are inverted for proper mixing of the nectar and held at desired temperature for required time. Finally they are cooled in hydro-cooler to 25^{0}C, surface is air-dried and labeled.

27.4 Dilutable Beverages

Dilutable beverages are the one which are consumed after mixing with suitable diluents like water, alcoholic drinks or milk. The process for making such beverages is quite similar to the syrup manufacture meant for carbonated beverages. These products offer a number of advantages including the ability to use different syrup to water ratio, reduction in bulk, utilization of surplus and bland tasting fruits and offer novel innovations in formulations. The various ingredients and their role in manufacturing of dilutable beverages are listed in Table27.1. The process diagram for the manufacture of dilutable beverages is outlined in Figure 27.1.

Table 27.1 Ingredients used in dilutable beverages

S. No.	Ingredient	Remark
1	**Fruit Components**	Added in the form of fruit juice or pulp or comminute (whole fruit preparation), required amount should be more than 25%. For uniformity concentrated fruit juice or pulp or comminute of standard degree brix is used. Source of fruit sugar, acid, pectin, colouring pigments, flavouring compounds and micronutrients.
2	**Syrup**	Carbohydrate syrup is added in various forms like sucrose, invert syrup, glucose syrup or modified syrup. Provide body, impart sweetness; assist in development of flavour, mild preservative effect. Always added after filtration and sterization.
3	**Acid**	Citric acid is most preferred acidulant, other that may be used are malic, lactic and tartaric. Balance acid to sugar ratio, anti-microbial. Impart flavour as well.
4	**Preservatives**	Mainly added to prevent growth of fungi, yeast, lactic acid bacteria. Permitted are sulphur dioxide, benzoic acid and sorbic acid.
5	**Flavourings**	Mostly natural or natural identical flavourings are used. Must improve the flavour of beverages without affecting other properties.
6	**Colourings**	A permitted food colour that may enhance the aesthetic appeal of the beverage is used. It may include natural, natural identical or synthetic dyes. Maximum permissible limit is 100 ppm for coal tar dyes.
7	**Other Additives**	It may include stabilizers to keep the fruit solids in suspension and improve mouthfeel of the beverage. Acidity regulators, emulsifiers, anti-oxidants and clouding agents are also used to enhance the acceptability of these beverages.

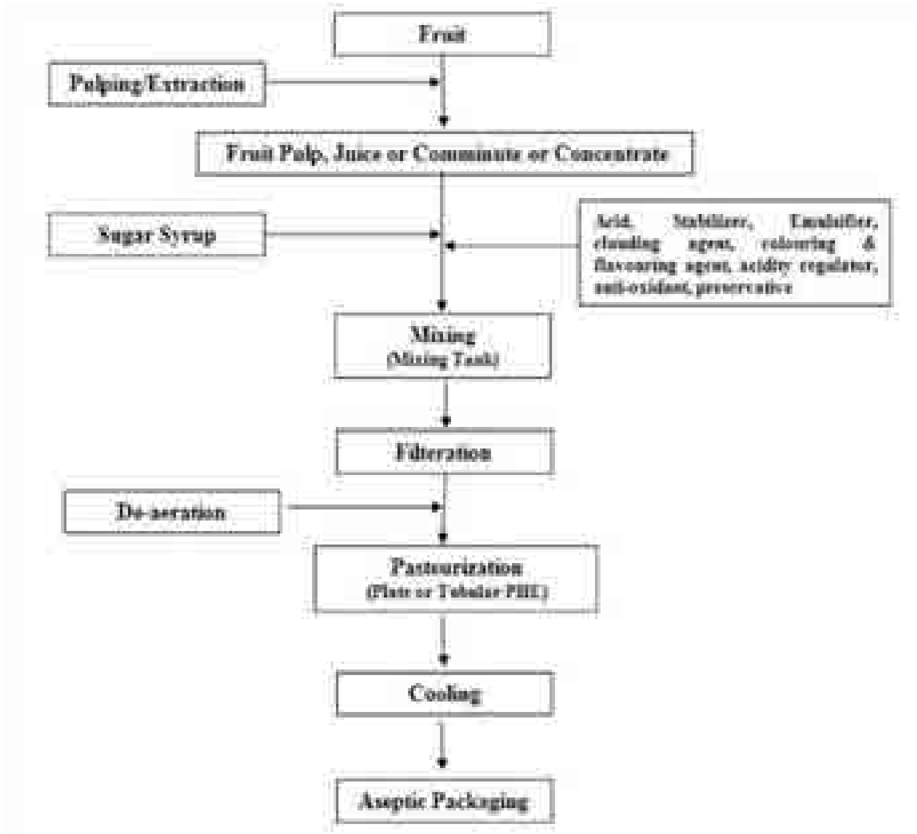


Fig.27.1 Process flow diagram for the manufacture of dilutable beverages

Two major products fall into the category of Dilutable beverages are discussed hereunder.

27.4.1 Cordial

Fruit juice cordial is a sparkling clear sweetened fruit beverage from which all the pulp and other suspended materials have been completely eliminated. Cordial is prepared by mixing clarified fruit juice, with sugar syrup, acid and other ingredients. As per FSSAI specification, cordial should contain not less than 25 percent fruit content and the TSS content should not be less than 30° Brix .The acidity of the cordial should not be more than 3.5 per cent as anhydrous citric acid. The maximum permissible limit of preservative in cordial is 350 ppm of sulphur dioxide or 600 ppm of benzoic acid. The citrus juices such as lime and lemon are preferred for making cordial. The cordial are generally consumed by mixing with alcoholic beverages like gin.

The fruit juices are either stored for longer period to remove suspended solids and pectinous materials or it may be treated with commercial enzyme preparations like pectinase to hydrolyze pectin. The clarified juice is used for cordial preparation.

27.4.2 Squashes and crushes

Squash is the product, which is prepared by mixing of calculated quantity of fruit juice or pulp, with sugar, acid and other ingredients. As per FSSAI specifications, squash should contain not less than 25 per cent fruit content in finished product and the total soluble solids content should not be less than 40° Brix. The acidity of the squash should not be more than 3.5 per cent as anhydrous citric acid. Mango, orange, lemon, pineapples, grape and litchi are used for making squash commercially. Squash can also be prepared from lemon, bael, guava, pear, apricot, muskmelon, papaya, passion fruit, peach, plum, mulberry, raspberry, strawberry, grapefruit, etc. The maximum permissible limit of preservative in squash is 350 ppm of sulphur dioxide or 600 ppm of benzoic acid. Potassium metabisulphite is not added in dark coloured fruits as it may bleach the anthocyanin pigments. In such beverages sodium benzoate is used.

Commercially available squash contain 40 to 50 percent sugar and around 1.0 percent acid. They are diluted in the ratio of 1:4 before consumption. There is another category of dilutable beverage called crush. As per FSSAI guidelines, crush must contain not less than 25 percent fruit content and 55 percent TSS. Mostly, the comminutes of citrus fruits and pineapple are used for crush manufacture.

Syrup is a type of fruit beverage that contains at least 25 percent fruit juice or pulp and not less than 65 percent TSS. It also contains 1.25-1.5 percent acid and diluted before consumption. The syrups from rose petals, almond, mint, khus, sandal and kewra are quite popular.

GENERAL STEPS IN JUICE PROCESSING

12.1 Fruit Juice Processing

Juice and juice products represent a very important segment of the total processed fruit industry. Juice products are being marketed as refrigerated, shelf-stable, and frozen, in a variety of packages with increased emphasis on functionality, health attributes, new flavors or blends, and in some cases fortified with vitamins and minerals. High-quality juice operations are dependent upon a source of high-quality raw material.

Most fruit juices are excellent sources of vitamin C, several are good sources of carotene and many contain moderate amounts of pyridoxine, inositol, folic acid and biotin. Fruit juice is regarded as source of energy due to their rich carbohydrate content. The organic acids present in the fruit juice plays a significant role in the maintenance of the acid-base balance in the body.

The process starts with sound fruit, freshly harvested from the field or taken from refrigerated or frozen storage. Thorough washing is usually necessary to remove dirt and foreign objects and may be followed by a sanitation step to decrease the load of contaminants. Sorting to remove decayed and moldy fruit is necessary to make sure that the final juice will not have a high microbial load, undesirable flavors, or mycotoxin contamination. For most fruits, preparation steps such as pitting and grinding is required prior to juice extraction. Heating and addition of enzymes might also be included before the mash is transferred to the extraction stage. Juice extraction can be performed by pressing or by enzymatic treatment followed by decanting. The extracted juice will then be treated according to the characteristics of the final product.

For cloudy juices, further clarification might not be necessary or may involve a coarse filtration or a controlled centrifugation to remove large insoluble particles. For clear juices, complete de-pectinization by addition of enzymes, fine filtration, or high speed centrifugation is required to achieve visual clarity. The next step is usually a heat treatment or equivalent non-thermal process to achieve a safe and stable juice and final packaging if single-strength juice is being produced. For a concentrate, the juice is fed to an evaporator to remove water until the desired concentration level is obtained. Other processes used for water removal include reverse osmosis and freeze concentration, which are best suited for heat-sensitive juices. The concentrate is then ready for final processing, packaging, and storage.

The generalized flow chart for preparing fruit juice is shown in Figure 12.1.

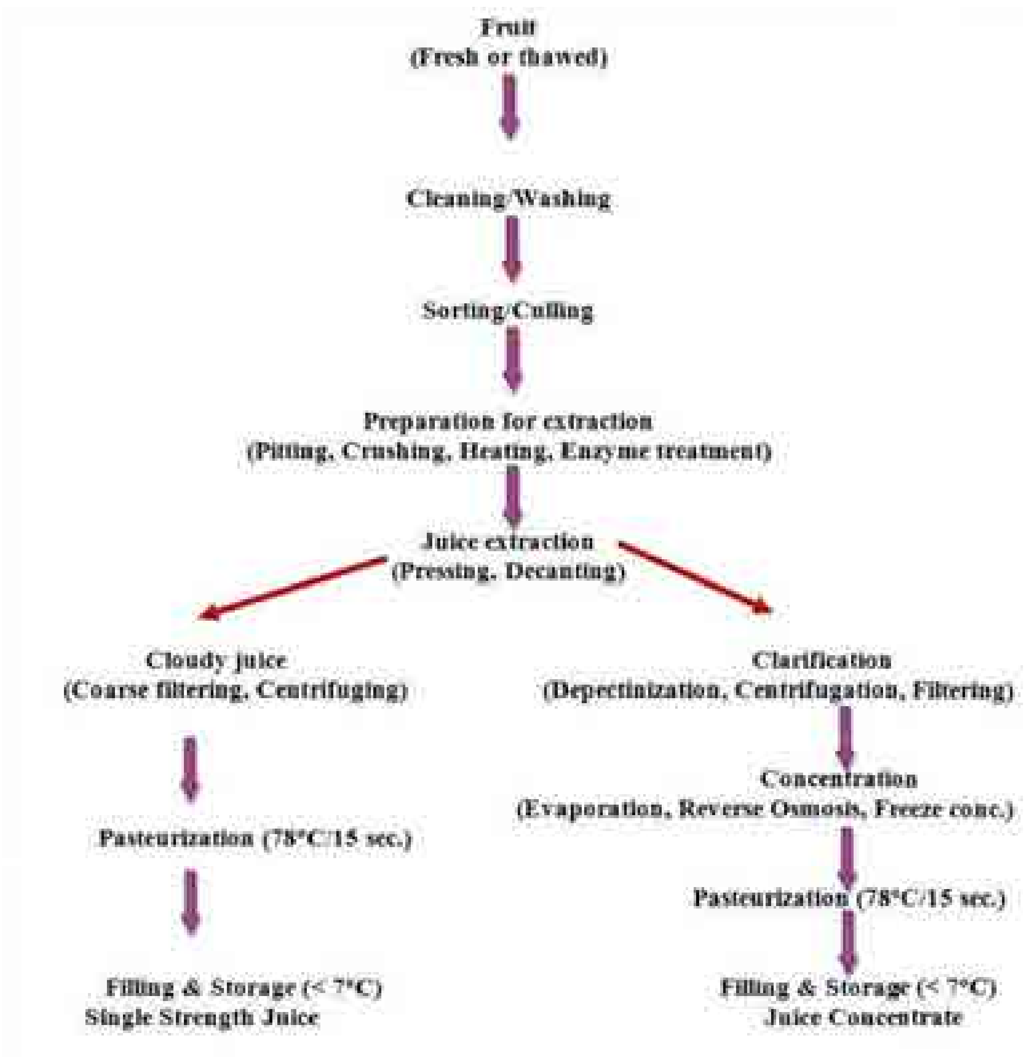


Fig.12.1 Generalized flow chart for fruit juice production

12.2 Significance of Few Important Steps in Fruit Juice Production

12.2.1 Straining/Filtration/Clarification

- Extracted fruit juice contains varying amount of suspended solids – broken fruit tissue, seed, skin & various gums, pectic substances and proteins in colloidal suspension.

- Coarse particles removed by straining (non-corrodible metallic screens) or sedimentation.

- If clear juice required (grape, apple, lime juice cordial) complete removal of all suspensions effected through filtration or clarification with the help of fining agents and enzymes.

- Fining agents (i) Enzymes (pectolytic, starch liquefying, proteolytic), (ii) Mechanical finings (Infusorial earth), (iii) Chemical finings (Gelatin, albumin, casein).

- Apple juice – 0.5-1.5 oz. of tannin and 1.5-6.0 oz. of gelatin per 100 gal. of juice – fining purpose.

12.2.2 Disintegration

Juicing process starts with crushing, a step to break down the cell tissue. This may be accomplished using various type of mills viz., hammer mill, grinding disk mill, grating mill, crushers, stoned fruit mill or even turbo extractors.

12.2.3 Hot break process

In order to maximize juice yield and color-flavour extraction, a hot break process is often used.

12.2.4 Mash enzyme treatment

This step might not be used for the production of high quality, single-strength, cloudy and clear juices, where the preservation of the fresh flavor is imperative. Depectinization is designed to reduce the viscosity and slipperiness of the pulp and thus permit the effective use of decanters and presses with proper press aids as needed. It is especially useful in processing mature and stored fruit that results in low juice yield.

12.2.5 Fruit juice extraction process

Hydraulic rack and frame press is the most common batch press system used in small scale operations. Other type of extractors include horizontal piston press, bladder press, belt press, screw press or even decanter centrifuge.

12.2.6 Deaeration

Pure orange juice which is extremely susceptible to the adverse action of the residual air, is subjected, immediately after extraction, to a high vacuum whereby most of the air as well as other gases are removed.

12.3 Role of Enzymes in Fruit Juice Extraction

The use of enzymes in juice industry has contributed in increasing the yield and production of various types of juices. The addition of pectinases aims in particular to degrade the pectic substances, in the cell wall and middle lamella of the cells of plants, aiming to minimise the impacts of these compounds on the characteristics of the final product, such as colour, turbidity and viscosity.

Enzymes are also able to remove bitterness of citrus juice, extract pigments, among other applications, and have also had great interest in the juice industry.

12.3.1 Pectinase, cellulase and hemicellulase

Pectinases, cellulases and hemicellulases are used for clarification of fruit juices, juice extraction, improvement of cloud stability of vegetable and fruit juices and nectars, liquefaction and maceration of fruits and vegetables, reduction of cooking time of pulses and improvement of rehydration characteristics of dried vegetables.
These enzymes degrade structural polysaccharides that interfere with juice extraction, filtration, clarification and concentration. These enzymes are termed „macerating or mash enzymes‟ that finds application in extraction of juice from citrus fruits and from tropical fruits such as mango, banana and papaya and pineapple. For Apple and Pears, pectic enzymes are used to facilitate pressing or juice extraction, to aid in separation of flocculent precipitate by sedimentation, filtration or centrifugation.

Combination of pectinolytic enzymes are added to fruit and pressed fruit juice to reduce juice viscosity. Such viscosity reduction makes juice filtration, clarification and concentration more efficient. In concentrated fruit systems, it improves the efficiency of spray drying.

Aspergillus niger and *A. oryzae* produces mixture of pectinolytic enzymes.

12.3.1.1 Pectinases

The two well recognized types of pectolytic enzymes are pectinesterase and polygalacturonase, the actions of which is shown below:

$$\text{Pectin} \xrightarrow{\text{pectinesterase}} \text{Methanol} + \text{Polygalacturonic acid}$$

$$\text{Polygalacturonic acid} \xrightarrow{\text{Polygalacturonase}} \text{Galacturonic acid}$$

Most commercial pectinase enzymes are mixtures of these and probably other enzymes. Commercial pectolytic enzyme preparations containing predominantly polygalacturonase (PG) and pectin and pectate lyase (PLs) are utilized.

Liquefaction is accomplished using both pectolytic and cellulolytic enzymes in combination, taking advantage of observed synergistic effects.

Pectins are colloidal in nature, making solutions viscous and holding other materials in suspension. Pectinesterase removes methyl groups from the pectin molecules exposing carboxyl groups which in the presence of bi- or multivalent cations, such as calcium, form insoluble salts which can readily be removed. At the same time, polygalacturonase degrades macromolecular pectin, causing reduction in viscosity and destroying the protective colloidal action so that suspended materials will settle out.
Extensive use of pectolytic enzymes is made in processing fruit juices. Addition of pectic enzymes to grapes or other fruits during crushing or grinding results in increased yields of juice on pressing. Wine from grapes so treated will usually clear faster when fermentation is complete, and have better color.

Pectic enzymes are necessary for making high density fruit juice concentrates or purees. If apple juice is concentrated to 72°Brix without removal of the naturally occurring pectin, a gel will result rather than the desired liquid concentrate. In most cases, juices are depectinized and filtered before concentration, but in others the pectinase is allowed to act while the juice is being concentrated.

12.3.1.2 Cellulases

Commercial cellulase products capable of hydrolyzing nonpectin polysaccharides such as cellulose, glucans, and xylans are used to fractionate the cell walls and liquefy the remaining solids.

12.3.1.3 Naringinase and Limoninase

Naringinase and Limoninase have been used to hydrolyze naringin and limonin – the bitter compounds that are found in grapefruit juice.

12.3.1.4 Amylase and Arabinase

Starch and araban imparts a cloudy appearance called „haze", when released into the juice from certain fruits. Hazes due to starch are common in juice from early season apples and can be degraded by amylases.

Although araban is not a problem in extracted juice, it produces a permanent haze in concentrated juices, where it has limited solubility. Arabinase can be used to hydrolyze araban so that haze does not develop during storage of juice concentrates.

12.4 Clear Fruit Juice

Juices extracted from ripe fruit contain a significant amount of pectin. Pectin imparts a cloudy appearance to the juice and results in an appearance and mouth feel that many consumers do not find appealing. Pectinases are naturally occurring enzymes that act on pectin yielding a crystal clear juice with the appearance, stability, mouth-feel, taste, and texture characteristics preferred by consumers. While pectinases naturally occur in most fruits used to make juice, the manufacturer often adds more to produce clear juice in a reasonable amount of time.

Most consumers prefer clear fruit juices. The cloud, such as in fresh Cider, is usually material held in suspension by pectin and filtration is difficult. The safest way to accomplish pectin removal without affecting color or flavor is to treat the juice with a pectic enzyme. Juice for jelly manufacture is frequently depectinized since more uniform jelly can be achieved when a standard amount of pectin is added in controlled amounts. The variable quality and quantity of the natural pectin in the juice does not interfere when it is treated with pectinase enzyme.

12.5 Benefits in the use of enzymes

- Increased juice yield
- Improved efficiency of juice filtration
- Improved juice stability and concentration
- Enhanced juice clarity
- Reduced juice bitterness

12.7 Problems encountered during fruit juice processing

Some of the problems that may be faced in preparation of fruit juices are:

- Browning of juice due to action of enzyme Poly phenol oxidase inherent in fruit (i.e. Apples).
- Foaming of fruit juice that may lead to oxidation of vitmin C and pose problem during filling of juice in packages.

- Bitterness of juice due to action of enzyme limonin and naringinase (e.g. in Orange).
- Cloudy juices due to pectinaceous substance (apple juice) or even bitartrates (i.e. argol precipitation) (i.e. in grape juice).

EQUIPMENTS AND METHODS OF EXTRACTION, CLARIFICATION AND PRESERVATION

13.1 Introduction

In order to prepare fruits and vegetable juices at commercial level, several equipments are needed. Some of the important equipments required for processing of specific fruit and vegetables are discussed herein.

13.2 Pome Fruit and Small Fruit Processing

Generally, most pome fruit (e.g. Apple, Pear, Quince) and small stone fruit (e.g. Plum, Olive, Peach, Cherry) can be used for juice extraction. No peeling is needed. Small stone fruit such as apricots and plums might have to be destoned (pitted) depending on the grinding–extraction equipment selection. Cherries, although containing a pit, may be pressed with the pit intact. Breakage of the pit will release benzaldehyde, the familiar aroma of maraschino-type cherries.

13.3 Disintegration

The juicing process starts with the crushing step to break down the cell tissue. Grain sizes of 5 - 8 mm diameter are recommended for presses, while grain sizes of 3 - 5 mm are desirable for decanters.

13.3.1 Hammer mills

These are devices used to crush the whole fruit in preparation for pressing. Hammer mills consist of heavy stainless steel bars spinning from a common axis under high-speed rotation. The fruit is disintegrated until it passes out through a screen of a specific size mounted in the bottom of the mill. With firm fruit, a small screen size should be used, and the mash will be of a finer particle size. Mash from firm fruit will press more easily, and the smaller particle size will allow greater yields.

13.3.2 Grinding mills

They offer an alternative method to disintegrate fruit. The fruit was drawn past fixed knives mounted on a rotating cylinder. Control of the grind was accomplished by adjusting the depth of the knives and, thus, the size of the cut from the fruit.

13.3.3 Grinding disk mills

They offer more flexibility and improved performance. In the Bucher-Guyer unit, the fruit is transported by a feed screw to the grinding area. The screw pressurizes the fruit against a rotating disk equipped with grinding knives in a star pattern, and the milled fruit exits via an adjustable discharge slot. The process can be controlled by adjusting the feeder speed, the rotating speed of the grinding disk, the width of the product discharge slot (up to 10 mm), or by changing the knife size. Better yield is obtained by requisite adjustment corresponding to the fruit ripeness at the time of operation.

13.3.4 Grating mills

These mills are used in small juice operations to produce uniformly sized fruit pieces. Fruit is fed to a rotating– grating disk with fixed aperture, and the shredded fruit is discharged at the bottom. Fruit must be relatively firm with small seeds or pitted.

13.3.5 Stemmer/crushers

These crushers are used in grape juice processing to remove residual stems, leaves, and petioles from grapes and to perform the initial crush of the fruit. These units are designed around a perforated rotating drum, with holes ~ 2.5 cm in diameter. While traversing the rotating drum, the grapes are caught by the perforated drum and knocked from the stems. Individual grapes are broken open or crushed in the process and dropped through the drum. Stems, leaves, etc. continue on to the center of the drum and are discharged at the end for waste. Grapes are generally put through the crusher in order to gently express the juice and free up the flesh, yet still not break the seeds. Breakage of the seeds releases increased amounts of phenolics, adding to the astringency of the juice.

13.3.6 Stoned fruit mills

Such mills are used for plums and apricots to crush the fruit without breaking the stones to avoid juice flavor changes and storage instability. Hard rubber-lobed wheels rotate simultaneously, forcing the fruit down and separating most of the flesh from the intact stone.

13.3.7 Turbo extractors

These are used for extraction of juice and puree from fruits and vegetables. The cold extractor unit has a feeding section with a variable speed screw and a cutting head; a softening section consisting of a stator and rotor (rotopulse); and an extraction area equipped with a rotor with paddles and a perforated cylindrical screen that continuously turns the product by centrifugal force (Figure 13.1). The extractor can be adjusted by changing the feeding speed, the rotor speed, the gap between the rotor and the screen, and the screen size. The fruit can be protected from oxidation by the injection of nitrogen gas or antioxidant solution to the cutting area through built-in openings.

Fig. 13.1 Turbo extractor

13.4 Hot Break Process

In order to maximize juice yield and color-flavor extraction, a hot break process is often used. The most common use is in grape juice processing, but other fruits such as cherries, plums, and berries may also benefit. Increased interest in highly colored juices, rich in phenolic compounds with associated health benefits, is driving the development of better techniques to preserve the functional components while maximizing the extraction. Typically crushed fruit or mash passes through a large bore, tubular heat exchanger where it is heated to 50 to 60°C. This stage, known as the *hot break process,* is designed to extract a large amount of color and assist in maximizing the yield. To the hot fruit, a pectolytic enzyme is added, and in case of red grape juice processing, kraft (wood pulp) paper is also added prior to pressing to serve as a press aid.

The addition of press aid to the mash provides coarseness and channels for the juice to exit. Alternative press aids include rice hulls, bleached kraft-fiber sheets or rolled stock, and ground wood pulp. If the juice is going to be extracted by decanting or centrifugation, then there is no need for press aids.

13.5 Mash Enzyme Treatment

This step might not be used for the production of high quality, single-strength, cloudy and clear juices, where the preservation of the fresh flavor is imperative. Soluble pectin found in fresh juice as a result of the activity of pectolytic enzymes that are located in the fruit cell wall. The soluble pectin is the cause for difficulty in juice extraction due to increased juice viscosity and the lubrication it affords the press cake. Typically, the fruit mash is heated to 45 to 50°C followed by the addition of pectolytic enzymes. Reaction time can take up to 1 - 2 h.

De-pectinization is designed to reduce the viscosity and slipperiness of the pulp and thus permit the effective use of decanters and presses with proper press aids. It is especially useful in processing mature and stored fruit that results in low juice yield. Several depectinizing tanks are employed so that a continuous flow may be maintained to the presses or decanters. Treatment of the mash with enzymes is expected to increase the yield, reduce the processing time, and improve the extraction of valued components of the fruit.

13.6 Fruit Juice Extraction Equipments

13.6.1 Rack and frame hydraulic press

The hydraulic rack and frame press is a very common batch press system found in small juice operations (Figure 13.2). Heavy cotton or nylon cloths are filled with a set amount of mash and then folded to produce what is called a *cheese.* The individual cheese is stacked and separated by a wooden, stainless steel, or plastic spacer platen. The combined stack is then compressed using a hydraulic ram, during which the juice is expressed. The process delivers good yield but is labor intensive.

Fig. 13.2 Hydraulic Rack and Frame Press

13.6.2 Horizontal piston press

One of the most successful press systems in the fruit juice market is the Bucher horizontal piston press, Switzerland. This press is capable of pressing berries, stone fruit, and vegetables. It operates in batch mode with loads of up to 14 t/filling. Flexible drainage elements covered with a nylon filter cloth carry the expressed juice out to a manifold.

The Bucher-Guyer Press is a highly automated pressing system used in a batch pressing operation. Generally, this system consists of a rotatable basket or cylinder with a hydraulic ram used for juice expression. Within the cylinder are fabric-covered flexible rubber rods with longitudinal grooves in them, that allow the juice to transport easily to the discharge port.

13.6.3 Bladder press

The Willmes Press is a commonly used system for grape juice pressing. It is a pneumatic-based system that consists of a perforated, rotatable, horizontal cylinder with an inflatable rubber tube (air bag) in the center. The cylinder is filled with grape mash through a door on the cylinder wall, which is rotated to the top position. After filling, the press is rotated to ensure even filling. During this rotation, the air bag is filled, creating the mash compression action. The bag is then collapsed, and the cylinder is rotated. The rotation and pneumatic compression of the mash is repeated many times with increasing air pressure.

13.6.4 Belt press

The continuous belt press is effective for grape and apple juice processing. In belt presses, a layer of mash is pumped onto the belt entering the machine. Press aid may be added for improved yield and reduced suspended solids. The belt is either folded over or another belt is layered on top of the one carrying the mash. A series of pressurized rollers compress the enveloped mash. Expressed juice is caught in drip pans. The cake is discharged from the last pressure roller.

13.6.5 Screw press

A typical screw press consists of a reinforced, stainless steel cylindrical screen enclosing a large bore screw with narrow clearance between the screw and the screen (Figure 13.3). Breaker bars are located between the screw intervals in order to disrupt the compressing mash. Back pressure is provided at the end of the chamber and is usually adjustable. Capacities for screw presses with diameters of 30.5 and 41.0 cm are 5,080 and 15,240 kg/h, respectively.

Fig. 13.3 Conical Screw Press

13.6.6 Decanter centrifuge

In addition to sieving technology, the separation of juice from the mash can be performed by sedimentation through increased gravity in a decanter. Centrifugal force is used to accelerate the settling of higher density insoluble particles present in the juice. Enzyme-treated mash is best suited for juicing by decanters, as the reduced viscosity and higher temperatures result in faster and more effective separation. The photograph of such decanter is furnished in Figure 13.4.

Fig. 13.4 Decanter centrifuge

13.6.7 Pulper cum finisher

The separation of liquid and solids is accomplished by means of paddles rotating concentrically within a cylindrical screen. The liquid and desired amount of solids passes through the screen. The balance of the solids (pomace) is discharged through a large non-plugging port. The dryness of the pomace with a given screen can be controlled by paddle speed, pitch, clearance, or feed rate. Production throughput is dependent on the type of product being prepared, screen hole size and open area, paddle speed and pitch. An inlet impellor for breaking or macerating is available as an optional accessory.

Diverse type of materials viz. apricots, tomatoes, pumpkin, pears, apple, plums, berries, prunes and figs can be satisfactorily reduced to pulp, free of seeds, skins and fiber. Products such as citrus juices, jam, soup, peanut butter, jelly and fruit nectar can be finished to uniform clarification consistency. The picture of such machine is shown in Figure 13.5.

Fig. 13.5 Pulper cum Finisher

13.7 Mechanical Separation

For clarification of juice, after the enzyme (Pectinase) treatment, the sedimentable particulates are separated by mechanical means. The equipments used for such process are as follows:

13.7.1 Decanters and finishers

A high-solids stream can be partially clarified using decanters and finishers. Both pieces of equipment operate on the same principle with a spinning central cone, drum, and set of paddles pushing the juice through a screen of some type. The unit is typically mounted horizontally, and throughput is relatively high. Total suspended solids may be reduced to $< 1\%$ during operation, depending upon the characteristics of the feed stream and operating conditions of the separator.

13.7.2 Centrifugation

It is used for removal of juice-insoluble solids. A centrifuge places the juice under high gravimetric force induced by centrifugal action. This is effective in producing a juice that is opaque but free of visible solids. Modern centrifuges are highly automated and run continuously with timed solids ejection. Centrifuges with a high force of gravity are capable of producing clear juice under optimized conditions. Centrifuge must be operated in a manner to minimize the introduction of oxygen in the product. Possible remedies include the use of inert gas.

13.7.3 Pressure filtration devices

13.7.3.1 Filter press

The cost is typically lower than other types of pressure filters. The system can be dismantled easily for inspection and cleaning. Filter cakes can be easily washed from the system once disassembling has progressed. In the filter press, the amount of unfiltered liquid is relatively low once the shutdown process is terminated.

13.7.3.2 Cylindrical element filter

In this system, tubular elements are suspended vertically in a closed tank system. Juice enters from the base of the system and filters through the elements, and the filtrate exits from the top of the system. Wash down and automation of this system are relatively straightforward.

13.7.3.3 Vertical leaf filter

It is a low-cost system because of the inherent simplicity of its design. It offers an easy cake removal system and can be automated. A modified version of the leaf filter is the horizontal tank vertical leaf filter that accommodates a very large area of filtration surface, up to 2000 ft^2 (180 m^2). Filter leaves can easily be removed, inspected, and repaired.

13.7.3.4 Rotating leaf filter

In this filter, the filtration elements are circular leaves suspended on a central axis. The leaves are rotated only during cleaning and discharging, which allows for an automated and rapid cake removal and clean-up system.

13.7.3.5 Horizontal rotating leaf filter

It is essentially identical to the vertical rotating leaf system, except that it is available in much smaller models.

13.8 Clarification of Fruit Juice

Consumers have a strong preference for clear juices. In order to have attractive appearance of finished fruit juice, especially for beverages like fruit juice cordial, clarification of juice is highly essential. Such clarification can be done by the help of centrifugation and use of pectinase followed by decantation. Filter aids such as Infusorial earth, bentonite helps in achieving better clarification of fruit juices. Ultrafiltration (UF) and microfiltration (MF) have been used commercially for the clarification of fruit juices. After extraction, the fruit juice after depectinization is fed to UF unit for clarification. If the juice contains strong colour, microfiltration can be suitable for avoiding colour losses.

Pre-centrifugation (10,000g for 15 min) of juice (especially cherry juice) before clarification is recommended.

13.9 Preservation of Fruit Juices

Traditionally, the shelf-life stability of juices has been achieved by thermal processing. Low temperature long time (LTLT – 63-65°C/30 min) and high temperature short time (HTST – 72-90°C/15-30 sec.) treatments are the most commonly used techniques for juice pasteurization. However, thermal pasteurization tends to reduce the product quality and freshness. Therefore, some non-thermal pasteurization methods have been proposed during the last couple of decades, including high hydrostatic pressure (HHP – pressures up to 1000 MPa with or without heat), pulsed electric field (PEF), etc. These emerging techniques seem to have the potential to provide "fresh-like" and safe fruit juices with prolonged shelf-life.

Apart from thermal pasteurization, some chemical preservatives are also widely used for the extension of the shelf-life of fruit juices and beverages. Two of the most commonly used preservatives are potassium sorbate and sodium benzoate. However, consumer demand for natural origin, safe and environmental friendly food preservatives has been increasing since 1990s. Natural antimicrobials such as bacteriocins, organic acids, essential oils and phenolic compounds have shown considerable promise for use in some food products. Natural antimicrobials such as *bacteriocins, lactoperoxidase*, herb leaves and oils, spices, chitozan and organic acids have shown feasibility for use in some food products. Some of them have been considered as Generally Recognized As Safe (GRAS) additives in foods. Bacteriocins are series of antimicrobial peptides which are readily degraded by proteolytic enzymes in the human body. Among them, nisin is the most commonly used food preservative that has been used to preserve fruit and vegetable juices.

PROCESSING OF SELECTED FRUIT JUICES-I

14.1 Introduction

Fruit are one of the most popular natural food that is highly nutritious and enticing. People are now craving for fruit juices/beverages in „ready-to-drink" form. The shelf life of fruit is limited; they tend to decay with progress of ripening. Concentration of fruit juice, freezing, individual quick freezing, osmotic dehydration, dehydration to obtain fruit powders are some to the methods being used to counteract the limited shelf life of fruit. The fruit as slices/chunks/candied or even as juice/pulps/concentrates are used in food industry viz. ice cream, fruit yoghurt, fruit cakes, fruit bread, etc.

14.1.1 Classification of fruit juices

Food Safety and Standards Act (FSSAI) has laid down specifications for various types of fruit juice beverages including nectars (Figures 14.1 and 14.2).

Table 14.1 FSSAI specifications for various types of fruit beverages.

No.	Name of the product	Fruit juice/puree in the final product (%), Min.	Total Soluble Solids %, Min.	Acidity expressed as citric acid, Max
1.	Squash	25	40	3.5
2.	Crush	25	55	3.5
3.	Fruit Syrup/Fruit Sherbats	25	65	3.5
4.	Cordial	25	30	3.5

14.2 Grapefruit – Botanical name - *Citrus paradise*

Two main varieties include :

1. White grapefruit – „Duncan" and „Marsh". The seedless Marsh is the most popular. The Duncan variety has best flavor.

2. Pink or pigmented grapefruit – „Red blush" and „Star Ruby" – both contains red pigment lycopene.

14.3 Lemon – Botanical name – *Citrus limon* (L).

Two varieties are very popular viz., „Eureka" lemon and „Lisbon" lemon.

Mesero lemon of Italy is best processing lemon in the world.

14.4 Lime – Three types – small fruited one is Citrus aurantifolia, large-fruited one is Citrus latifolia and Sweet lime is *Citrus limettoides*.

Indian lime is sweeter than other limes and popular in India and Pakistan.

Lime is greener in color than lemons, both on the exterior and interior of the fruit.

14.5 Production of Citrus juices
14.6

Washing and Grading of fruit

↓

Extraction of juice using Food Machine Corporation, USA (FMC) or Brown Extractors

↓

Large Reamers (Grapefruit), small Reamers (Lemon/Lime)

Pulp removal in two stages (Pulp content – 20% by volume)
Screening or Finishing
Or
Ultrafiltration to provide clarified product
Pass through Centrifuge – reduce juice pulp by < 3.0%

↓

Pass juice through Evaporator

↓

Oil Extraction
Desludger (8000-10000 rpm)
Separates slurry into 'oil-rich emulsion'
Removes > 90% of oil

↓

Discharge of concentrated oil emulsion

↓

Enzyme treatment, hold in tank for hours
Or
Placed in freezer, store for 30 days

↓

Use De-oiler centrifuge i.e. High speed centrifuge (Polisher)
(16000-18000 rpm, separates pure citrus oil) or partial distillation in vacuum
A Spinning Cone Column may be used

↓

Winterizing
Precipitates dissolved waxes

↓

Evaporation and Pasteurization
85-90°C for 30-40 sec (Grapefruit)
75-85°C/30 sec (Lemon)
90-98°C/60 sec (Orange)
Concentrate (60-65°Brix – Grapefruit)
Gram of equivalent citric acid/lit. of solution – for Lemon or Lime
400 + 5 GPL – 57°Brix

↓

Debittering
Pass fruit juice through a debittering column
Max. 5 ppm Limonin, 600 ppm Naringin (Florida State Department of Citrus)

↓

Single strength Grapefruit juice (1.0-1.5% acid)
Orange juice (< 1.0% citric acid)
Brix/acid = 7-10 (Grapefruit), 13-18 (Orange)

↓

De-aeration
Glucose oxidase can help to reduce oxygen by oxidizing glucose to gluconic acid

Fig. 14.1 Flow chart for preparation of Grapefruit juice

The lemon oil is more valuable than that of orange oil due to high aldehyde (2-4% aldehydes viz., citral – a mixture of neral and geranial) in lemon oil.

Grapefruit oil comprises of terpene thiols and nootkatone, which gives characteristic flavor and aroma to the oil.

FMC system uses Desludger to separate slurry into „oil-rich emulsion", which removes ol from the fruit peel at the juice extractor.

The extent of heat treatment given to juices is important since it should deactivate the pectinase (pectin methyl esterase). Further heating should be avoided to prevent hydrolysis of pectin and sugar, which may result in cloud loss and gelation. If pectic enzyme is inactivated, it avoids separation of two layers viz., pulpy lower one and clear upper one in extracted juice.

14.5.1 Deaeration of juice

Single strength lemon juice even when stored under low temperature undergoes significant degradation, depending on the essential oil content. If oxygen is absorbed in juice during processing, it causes decay, ascorbic acid is oxidized. d-limonene is attacked with the formation of terebenthic taste.

14.5.2 Deoiling of juice

About 5-6% of juice is transformed to vapour at 50°C; there is 80% removal of essential oil plus removal of air. The non-terpenic aromatic fractions are condensed and reintroduced. The oily phase is separated by centrifugation or decantation.

14.6 Orange Juice

The scientific name of Sweet Orange is *Citrus sinensis*. Some varieties of Orange include Sathgudi, Mosambi, Malta; The exotic varieties being Jaffa, Hamlin, Pineapple, Valencia, etc.

14.6.1 BIS Standard: Orange juice shall be obtained by a mechanical process from the endocarp of ripe, sound mandarine or oranges or by reconstituting orange juice. The juice shall have characteristic bitter taste, clean aroma and flavour (free from fermented flavour). The additives permitted include peel oil, orange essence and flavour, sugar, invert sugar and/or liquid glucose. It should be free from preservatives.

Table 14.3 BIS requirements for Orange juice

Particulars	Requirement
Brix of clear sample	Min. 10.0
Acidity	0.25 – 1.0% as anhydrous citric acid
Essential oil	Max. 0.3 ml (based on weight)

14.6.2 Bitterness in juice

Limonin is the main bitter fraction of „Navel‟ oranges. The non bitter mono-lactone of limonic acid gets rapidly converted to bitter tasting dilactone i.e. limonin at pH of about 3.0. Delayed bitterness is due to chemical change i.e. conversion of nonbitter precursor to bitter compounds by the process of extraction of the juice.

14.6.3 Other means to prevent bitterness of orange juice

- During preparation of product, excessive extraction of bitter fractions from the rag and pulp should be avoided.
- Raise the pH to > 4.0 which can prevent the formation of limonin di lactone.
- Use of pectic enzymes. The dispersed colloieds are coagulated by the enzymes and in the subsequent precipitation, they carry the bitter principles with them.
- Stirring the juice with dry polyamide powders and subsequent centrifugation. However, loss of up to 25% of ascorbic acid is reported.

CONCENTRATION AND DRYING OF FRUIT JUICES

16.1 Introduction to Concentration of Fruit Juices

Fruit juices are watery mixtures of most unstable volatile compounds. The solid content of most liquid food is 8-16% and is expensive to pack, store for long periods or to transport to distant places. Hence, it is desirable to remove a part or all of the water from such liquids.

Fruit juice concentrates are valuable semi-finished products for use in the production of: (a) fruit juice, (b) fruit juice beverage, (c) fruit juice powder.

16.1.1 Advantages of concentration

- Provides microbiological stability
- Permits economy in packaging, transportation and distribution of the finished product.

16.1.2 Methods of concentration

The methods used for concentration include the following:

1. Evaporative concentration under vacuum
2. Membrane concentration – Ultrafiltration, Reverse osmosis, Microfiltration
3. Freeze concentration

16.1.2.1 Thermal evaporation under vacuum

This process is commonly adopted since it is economical method of fruit juice concentration. Use of multiple effect vacuum condensing plant is used for the purpose and use of high vacuum (i.e. 29 inches of Hg column) helps in evaporating water from fruit juice at much lower (i.e. 58-60ºC) than its boiling temperature with steam economy too.

Table 16.1 The types of evaporators used for fruit juice concentration are

Concentration method	**Specific type**
Vacuum pan – Tubular	Climbing film Falling film
Recirculation	Single stage and one pass Five stages and single pass
Plate	Three stages and single pass
Agitated film	Single stage
Centrifugal	Single stage

A) *Disadvantages of conventional vacuum concentration*

- Causes loss of much volatile flavouring compounds as well as nutritive value.
- Requires use of fining agents, enzymes and centrifugation for juice clarification
- High temperature promotes oxidation of compounds in the juice, which may result in chemical alteration of the aroma and flavor compounds.

B) *Fouling of evaporators*

When pulpy or cloudy juice is required to be concentrated, the deposition of burnt layer of organic matter on the hot surface of evaporator causes severe problem. The evaporation rate is retarded and it may become difficult to concentrate such fruit juices in a falling film and plate evaporators. In such cases use evaporators having agitators or use „Serum concentration process‟ where the fruit juice is centrifuged to separate the solid phase (pulp) and the liquid phase (serum) is concentrated in an evaporator, before mixing with the pulp.

16.1.2.2 Freeze concentration

Freeze concentration (FC) of fruit juices is a cold, gentle and selective concentration procedure, in which two distinctive steps, viz., ice crystallization and ice separation from the concentrate phase are involved. *a) First stage*

Fruit juice is supercooled below its freezing point to allow water to separate as ice crystals. This uses either (a) Direct contact crystallizer, or (b) Indirect contact crystallizer.

b) Second stage

The ice crystals are separated from the concentrated fruit juices. This takes help of Presses, Filtering centrifuges, Wash columns or a combination of these.

c) Advantages of FC over evaporative methods

- The energy needed to freeze a unit of water is much less.
- The low process temperature prevents undesirable chemical and biochemical reactions (minimum color change, non-enzymatic browning and vitamin losses).
- As vacuum is not involved, the losses of low-boiling flavor and aromatic esters are completely avoided
- The flavor profile is better.

d) Drawbacks of Freeze concentration

- Major problem is the loss of soluble solids of the juice in the separated ice.
- The final concentration of the concentrated juice is as low as 40-55% dry matter, due to steep increase in the viscosity of ice-concentrated mixture.

e) Multi-stage freeze concentration

As the juice concentrates, there is increase in viscosity which retards water crystallization. Multi-stage FC overcomes this to a great extent. In such process, the ice crystals are separated out at the end of each cycle and the remaining concentrate is fed to the succeeding crystallizing compartments. Here, the ice crystals are separated at different levels of concentration and viscosity.

16.1.2.2

Membrane processing

In the fruit juice industry, membrane technology is used mainly to clarify the juice by means of ultrafiltration and microfiltration and to concentrate it by means of nanofiltration and reverse osmosis.

a) ***Ultrafiltration (UF)***

These membrane processes can perform clarification and fractionation over and above concentrating.

i) Advantages of UF

- Produces juice of desirable quality at low cost of operation and with greater speed.
- In a single step, it performs juice clarification and fining.
- Lower energy consumption (i.e. 20-30 BTU/lb. of water removed vs. 300 BTU for triple effect vacuum condensing plant)
- Increased flavor and aroma retention

b) Reverse osmosis (RO)

It is basically a concentration process. Pressure is applied to fruit juice that is greater than its osmotic pressure. This pressure forces the water out of the juice.

i) Advantages of RO

- Considerable amount of aroma retention at a cost competitive with evaporation, without undue loss of solids.

- Concentration without phase change or thermal damage.

ii) Drawback of RO

It limits the upper concentration level at about 28^{o}Brix.

16.1.2.4 Combined UF and RO

Initially, the fruit juice is passed through UF system to remove suspended solids. The UF permeate is directed to an RO system to simultaneously concentrate the flavor and aroma compounds, sugars and amino acids for eventual reconstitution to single strength juice. This allows for concentration of orange juice to levels of ~ 42^{o}Brix. On commercial scale up to 45-55^{o}Brix can be achieved.

16.2 Drying of Fruit Juices

Fruits and vegetables are dried to enhance storage stability, minimize packaging requirements and reduce transport weight. Preservation of fruits and vegetables using solar drying techniques can lead to poor quality and product contamination. Energy consumption and quality of dried products are critical parameters in the selection of drying processes. New drying technologies are being considered to have minimal drying time, economy with less nutrition loss; these includes osmotic drying, vacuum drying, freeze drying, superheated steam drying, heat pump drying and spray drying.

Fruit may be dried as a whole (e.g., grapes, various berries, apricot, plum, etc.), in sliced form (e.g., banana, mango, papaya, kiwi, etc.), in puree form (e.g., mango, apricot, etc.), as leather, or as a powder by spray or drum drying. Depending on the physical form of the fruit (e.g., whole, paste, slices), different types of dryers must be used for drying.
The advantages of fruit and vegetable drying are compensated by some negative changes that occur during drying, for example „heat damage‟ of heat-sensitive constituents (vitamins, enzymes, etc.); browning, shrinkage, and „case hardening‟; irreversible loss of ability to rehydrate; loss of volatile constituents; and changes in moisture distribution within the product.

16.2.1 Methods of drying fruit juices

There are several methods of drying the fruit and vegetables, solar drying being the oldest one. The type of dryers is listed below:

- Fluidized bed dryers – includes Vibrofluidized, Pulse fluidized or Spouted bed dryers.

- Spray dryers
- Contact dryers
- Foam drying
- Vacuum and freeze drying

The fluidized bed dryers give good mass transfer due to enhanced air turbulence in such dryers. The description of some important drying techniques is given below:

16.2.2.1 Spray drying

Some fruit or vegetable powders are produced from juices, concentrates, or pulps by using a spray drying technique. Dry powders can be directly used as important constituents of dry soups, yogurt, etc. The drying is achieved by spraying of the slurry into an airstream at a temperature of 138°C to 150°C and introducing cold dry air either into the outlet end of the dryer or to the dryer walls to cool them to 38°C– 50°C. The most commonly used atomizers are rotary wheel and single-fluid pressure nozzle. A wide range of fruit and vegetable powders can be dried, agglomerated, and instantized in spray drying units, specially equipped with an internal static fluidized bed, integral filter, or external vibrofluidizer. Bananas, peaches, apricots, and to a lesser extent citrus powders are examples of products dried by such techniques.

Spray drying of soluble fruit powders and convective drying of fruit and vegetables reduces the thermoplasticity of particles and product hygroscopicity. They also eliminate the need for adding stabilizers which may adversely affect the sensory properties of the final product.

16.2.2.2 Foam drying

Foam mat and foam spray drying are two foam drying methods. Foam mat dried fruit or vegetable powders have fewer heat-induced changes in color and flavor than conventional spray dried or drum dried products. It yields product with lower density than that of a conventional dryer. The product density is about equal to the density of instantized or agglomerated powder.
A stable gas-liquid foam is a prerequisite. Glycerol monostearate, solubilized soya protein, and propylene glycol monostearate are the typical additives for the fruit and vegetable foam formulation from juice or pulp. Foam mat drying involves drying a thin layer (0.1–0.5 mm) of the stabilized foam in air at 65°C–70°C for a few minutes, as the foam structure decreases drying time to about one-third. The foam is spread on perforated floor craters as the airstream is forced through the bed. A continuous belt tray dryer or a modified spray dryer can be used.

Good quality tomato, apple, grape, orange, and pineapple powders can be produced by this technique. Optimal initial concentration of feed solids is in the range of 30% for tomato and 55% for orange.

16.3 Other Methods of Fruit Dehydration

Though these methods cannot be employed for fruit juice dehydration, the fruit pieces can be subjected to following methods for dehydration as detailed below:

16.3.1 Osmotic dehydration of fruits

Osmotic dehydration is one of the processes used to reduce or avoid detrimental phenomena in fruit and vegetables without a sensorial and nutritional quality loss.Osmotic dehydration, consists of placing fruit pieces in contact with sugar syrup to remove 30-50% of water by weight, before conventional drying methods, that inhibits the action of polyphenol oxidase and prevents loss of volatile flavour constituents during dehydration. The process involves immersion of the fruit and vegetables (reduced to 3-10 mm pieces), in a concentrated solution of sugar syrup and ascorbic acid to effect partial dehydration (from ~ 6-8 to 1.0-1.5 kg moisture/kg dry matter). Most fruits are suitable for osmotic dehydration, except tomatoes and citrus fruits. The technique is currently largely used in the production of semi-candied fruits.

The factors affecting the osmotic drying process include size and shape, type of osmotic agent, concentration of the osmotic solution, temperature, food to solution ratio, duration, pressure, agitation of the osmotic medium and food pieces, Ca fortification of fruits and vegetables, etc. The osmotic agents used were a saturated glucose or sucrose solution, 60^{o}Brix glucose or isomerized glucose-fructose syrups, sucrose (70%)-glycerol (65%) 1:1 and ethanol. The temperatures of about 25 -43^{o}C have been successfully used.

The recent technologies that have been used to enhance osmotic drying include blanching, freeze-thawing, pulsed vacuum osmotic drying, ultrasound, pulsed electric fields, high pressures, supercritical CO_2, etc.

Osmotic drying has been used as a pretreatment prior to another drying process while use of osmotic drying for production of intermediate moisture foods.

16.3.2 Freeze-drying of fruits

There are two main stages in the freeze drying process: (a) freezing of the food, when most of the water is converted into ice, and (b) sublimation, when the bulk or all of the ice is transferred into vapor under very low pressure or high vacuum. In some cases, additional final drying, in the same or other equipment, is necessary. Cabinet or tunnel batch-type dryers are typically used with pressures in the range 13.5–270 Pa. Bananas, oranges, strawberries, peaches, plums, tomato, fruit juices and flavors, asparagus, beans, cabbage, cauliflower, celery, mushrooms, onions, peas, parsley and chives are processed by freeze drying.

The advantage of freeze drying over other methods of drying is the superior quality of the product. Little or no shrinkage occurs. The dry product has a porous structure and a color almost as fresh as that of the raw material. The only disadvantage of this process is the high equipment and operational cost.

Freeze-drying includes fluidized bed processes, spray-drying, continuous processes, foam drying processes, slush freezing and the thermal shock processes.

16.4 Preservation of fruit juices

Especially for low pH fruit juices (like lime, lemon juices) mild pasteurization is sufficient to have the desired shelf life. However, for higher pH fruit juices over and above stringent pasteurization, chemical preservatives (i.e. salts of sorbic acid or benzoic acids) may be used, where permitted by laws. The main purpose is to prevent fermentation from occurring during the refrigerated or even ambient temperature storage.

Sterilization of the fruit juice by In-can (retort) or by Ultra high treatment (UHT) followed by aseptic packaging can help in extending the shelf life for months even under ambient storage conditions.

ROLE OF SUGAR AND OTHER INGREDIENTS IN FRUIT PRESERVATION

17.1. Introduction

The fruit are perishable in nature and so are the juices expressed out of them. Preparation of sugar preserves like Jams, Jellies, Marmalades, Conserves, etc. are one means to extend the shelf life of fruit juice at the same time enable the consumers to enjoy the body and texture of a gel – a mouthfeel that is relished by all. The high osmotic pressure of sugar creates conditions that are unfavourable for the growth and reproduction of most species of bacteria, yeasts and molds.

17.2 Preservation of Fruit Solids by Sugar

Food preservation if the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by microorganisms. A sugar concentration of about 60% in finished or processed fruit product generally increases their preservation. Preservation is not only determined by the osmotic pressure of sugar solutions, but also by water activity in the liquid phase, which can be lowered by sugar addition and by evaporation down to 0.848 aw. This value however, does not protect the products from mould and osmophilic yeasts. Maximum saccharose concentration that can be achieved in liquid phase of product is about 67.89%.

In the case of jellies and preserves, the water is withdrawn from the microorganisms toward the concentrated sugar syrup through osmotic gradient. The microorganisms become dehydrated and incapacitated, and are unable to multiply and bring about food spoilage. In jellies, jams and preserves, a concentrated sugar solution of at least 65% is necessary to perform this function. Since the sugar content naturally present in fruits and their juices is less than 65%, it is essential to add sugar to raise it to this concentration in jellies and preserves.

17.3 Fruit Products Based on Sugar Preservation

17.3.1 Preserves

They are whole fruits or large pieces of fruit in thick sugar syrup, often slightly jellied. Preserves are made from practically all fruits including peaches, pears, plums, aonla, strawberries, grapes, muscadines, quinces and tomatoes.The fruit for preserving should be in a firm-ripe rather than a soft-ripe stage. By using up to 25% of firm-ripe fruit, the tartness is increased and less pectin is required in the formula. The fruit should be uniform in size or uniform pieces so as to cook evenly. Examples include fig preserve, watermelon rind preserve, etc.

17.3.2 Jam

It is essentially a gel or semi-solid mass containing pulped or whole fruit, made by boiling the fruit pulp with sugar solution. It is made from crushed or macerated (ground) fruit and generally is less firm than jelly. They may be made from a single fruit or mixture of fruits. It may contain small particles of fruit as against preserves, which may contain whole or large pieces of fruit.

17.3.3 Jelly

It is made from fruit juice. A perfect fruit jelly has a clear colour and a flavor characteristic of the fruit used. It is transparent and sparkles, quivers but does not flow when removed from its mould. The jelly should be tender enough to cut easily and is so firm that angles produced retain their shape.

17.3.4 Conserves

Conserves are similar to jams with chopped nuts (pecans, walnuts or others) and raisins added for texture and flavour. Conserves are mixtures of two or more fruits usually including citrus fruits. The chief ingredient in specific conserves being figs, peaches, pears, plums, oranges or carrots.

Conserves contain higher proportion of fruit than preserves or marmalades.

17.3.5 Marmalades

They have the characteristics of jellies and preserves combined. It is a semi-viscous jelly which contains the fruit pulp and may contain the peels suspended evenly throughout the jellied juice. They are made from under ripe fruit, rich in pectin and acid, chiefly citrus fruits – alone or in combination with other fruits. Popular marmalades are combination citrus, orange-peach, orange-pear, ginger-pear, pearpineapple and grape. The pectin and acid contents of the marmalades should be kept slightly higher than what has been recommended for jellies.

17.4 Prerequisites for Preparing Gelled Fruit Products

17.4.1 Selection of fruits

They maybe from under ripe, undersize and off-grade fruit or even from peels, cores and wind-fall fruit. The fruit should be sufficiently ripe (not overripe); mixture of under-ripe and ripe fruits is advantageous. Combining fruits rich in acid with those rich in pectin is less expensive than using acid or commercial pectin to supplement the deficiency. The juices of different fruits may be mixed.

17.4.2 Principle

The preparation is based on the gel making power of pectins which are present naturally in the products or added to them. Fruits that are low in pectin and acid components can be used to make jams and jellies, provided the pectin and acid content is adjusted to levels that make them gel.

17.4.3 Pectin in jelly formation

Protopectin is a component of the cementing material between plant cell walls; also a part of cell walls themselves. These are most abundant during the immature stage of fruit and are converted to pectin as the fruit matures. The chemical structure of pectin is shown in Figure 17.1.

When fruit are heated, the protopectin that has not turned to pectin is partially hydrolyzed or converted to pectin. To increase the amount of pectin extracted, some acid has to be added to the extraction solution and heat has to be applied.

When fruit are very ripe, other enzymes break up the pectin into pectic acid and alcohol. Pectic acid does not form a gel, except in the presence of added calcium molecules.

Jellies made with additional commercial pectin are usually bright and more transparent with no lessening of colour.

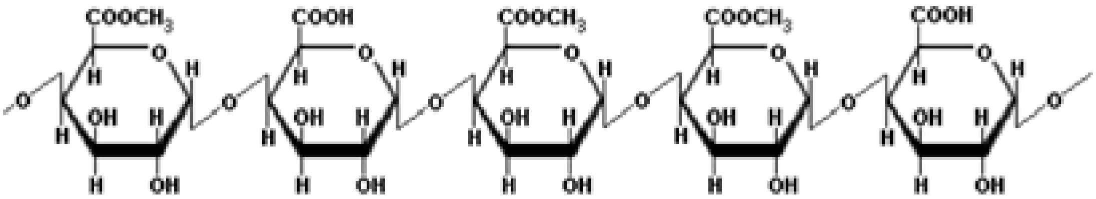


Fig. 17.1 Chemical structure of Pectin

17.5 Commercial Production of Pectin

Plant materials are used. Most frequently culled or rejected apples, apple pomace or the pulp (together with peel and core wastes) remaining after apple juice extraction are used. Lemon rejects are also a good source. Extract all pectin substances including protopectin, pectinic acid, pectic acids and pectin related compounds.

17.5.1 Pectins are classified into two groups:

(a) those with a high methoxyl content (HMP) ~ 11% methoxyl (b) those with low methoxyl content (LMP)

HMP is extracted with higher temperature, acidic solutions. Pectins with high methoxyl content forms gels in presence of high sugar and acid concentration. Most commercial pectins are HMP.

LMP containing pectic acids are extracted with lower temperatures with less acidic solutions, but in presence of other chemical compounds. LMP are pectin derivatives which do not need sugar to gel. If used, they need to react with a calcium salt (dicalcium phosphate), which has to be added during jam making.

17.5.2 Pectin extraction method

The fresh fruit tissue or separated parts, including the peel and core are heated in 95% alcohol or 0.05N HCl (pH 2.0) for 10-20 min at 70°C to inactivate pectic enzymes. After the pretreatment, the materials is ground in an electric blender and placed in water. Versene or Na-EDTA is added at 2.0%. The pH is adjusted to 6.0. The mixture is heated for about an hour at 90-95°C. The slurry formed is rapidly filtered and the pectin is precipitated from the solution using acidified alcohol. The precipitate is centrifuged and repeatedly washed with 70% alcohol. Acetone is used for dehydration and the pectin produced is vacuum-dried. It may also be dried in a hot-air oven at 50°C for 4 h.

17.5.3 Household extraction of pectin

A pectin solution of maximum strength can be obtained with about 30 min of boiling. When this period is divided into two, each of 15 min period of extraction, maximum amount of pectin can be extracted.

Other jellying agents include agar, arrow root, tapioca flour or cassava starch.

17.6 Other Ingredients

Successful jelly formation requires correct proportion of sugar, acid and pectin.

17.6.1 Sugar

Pectin-sugar gel formation occurs as a result of the precipitation of a part of pectin present in solution. Precipitation takes place in such a way so as to develop high binding forces at the surface. These hold the solution of other ingredients with sufficient strength to confer on the whole system the rigidity and texture associated with a jelly.

The addition of sugar is essential to produce an ideal jelly texture, appearance, flavour and yield. The sugar reduces the stability of the system by removing water from the pectin particles and affects the strength of the acidity.

The sugar content influences (a) the pH optimum or maximum acidity, and (b) maximum gel strength.

A sugar content of between 60-65% is usually preferable. The proportion of sugar added to extract should be appropriate to pectin concentration; depends on the acid present in the extract.

Smaller percentage of sugar gives lower jelly strength at all acidity levels. This may be made up by use of larger amount of pectin or acid or both.

Too little sugar added when pectin is over-concentrated results in tough jelly.

The principal cause for failure in gel formation is addition of too much sugar.

17.6.1.1 Inversion of sugar

The maximum solubility of sucrose at 86^{o}F is 68.7 %.

Inversion is desirable since (a) it lowers the concentration of sucrose, and (b) it reduces the possibility of sugar crystallization.

$$\text{Sucrose} \xrightarrow{\text{Heat + Acid}} \text{Glucose + Fructose}$$

The degree of inversion depends on:

(i) Hydrogen ion-concentration

(ii) Duration of boiling

For sufficient inversion, boil the pectin extract for 10 min at pH 3.0 or for 30 min at pH 3.5 (i.e. boil sugar with
0.05% H_2SO_4 for 15 min).

In the finished jelly, 30-50% invert sugar/glucose should be present.

If < 30% invert sugar – chances of crystallization.
If > 50% invert sugar - development of a honey-like mass.

17.7 Estimation of Pectin Strength of Fruit Extract

The following methods can be employed to determine the pectin in fruit juices:

1. Testing amount of pectin by precipitating it with alcohol or methylated spirit.
2. Finding the viscosity of pectin solution using a jelmeter. The temperature of pectin solution should be between 70-100oF. Close the bottom end and fill juice in the tube; allow dripping for 1 min. and close the bottom. The figure (i.e. 11/4, 1, ¾, ½ etchings) nearest (< or >) the level of the juice in the tube of jelmeter is noted. The data shows the cups or parts of cups of sugar to be added to each cup or part of the juice extract.
3. Making actual test jellies from the fruit extract.

17.7.1 Alcohol test

Place 1 teaspoon (5 ml) of liquid in a saucer. Allow it to thoroughly cool down. Three teaspoonfuls (15 ml) of alcohol (95%) are added and the mixture is gently shaken and allowed to stand for 3-5 minutes (Table 17.1). **Table 17.1 Alcohol test to estimate the pectin strength of fruit extract**

Observation	Inference	Quantity of sugar
A firm jelly-like mass forms	Extract is rich in pectin	¾ - 1 cup of sugar to 1 cup of fruit extract.
Pectin precipitates in form of several lumps	Extract is medium in pectin	½-2/3 of a cup of sugar to 1 cup of extract.
Few small stringy lumps	Low pectin concentration	Extract should be concentrated.

17.8 Acid

For any given pectin-sugar combination under given conditions of temperature, there is a maximum hydrogenion-concentration or acidity which just permits the completion of jelly formation within the time limit of the system.

The acid concentration affects the final structure through the alteration of the rate of setting, but does not show an optimum when the setting time is made sufficiently long by diminishing the sugar content.

Given a certain proportion for a particular pectin level, the sugar and acidity controls the strength of the jelly formed; the sugar through its dehydration of the pectin particles, and the acid by its own destabilizing action and its effect on the speed at which sugar-pectin equilibrium is attained.

High quality product is associated with a sugar content of ~ 65% and this is related to a pH of 3.4 - 3.1. The rheology of jelly as influenced by the acidity of the system is depicted in Table 17.2.

Table 17.2 Rheology of jelly based on the acidity of system

Quantum of acid	Rheology of jelly
Small amount of acid	Weak fibrillar structure, unable to support sugar solution adequately
At higher acidity or lower pH	Jelly is somewhat stiffer.
Acidity further increases	Acid tends to hydrolyze pectin fibrils. Fibrils lose elasticity and jelly becomes syrupy. Syneresis is likely to occur.
Less acid (sugar normal)	Add more pectin.

The final jelly should contain a minimum of 0.5% (preferably 0.75%) total acidity and not exceeding 1.0% acidity.

Weak jellies can be improved by adding a little acid.

When fruit extracts are deficient in acid, either characteristically or because they are obtained from over-ripe fruit, it is possible to improve their jellying capacity by addition of acids viz., citric, tartaric or malic acids (usually found in fruits); tartaric acid gives best results. Lemon juice may be added, or other fruit juices which are sour can be blended with them.

The acid should be added near the finishing point. If external pectin is used, acid should be added just before the jellies are poured into containers.

17.8.1 Proportion of ingredients

The desired proportion of ingredients required to obtain good jelly is as follows:

Table 17.3 Desired proportions of ingredients for jelly making

Pectin	Sugar	Fruit acid	Water
1.0	60-65	1.0	33-38

17.9 Acid

For jelly containing 1.0% pectin, the optimum pH and sugar requirement is as follows:

Table 17.4 pH of jelly mass based on the sugar content used

Optimum pH	3.0	3.2	3.4
Sugar (%)	60	65	70

17.10 Theory of Jelly Formation

17.10.1 Fibril theory

When sugar is added to pectin solution, it destabilizes the pectin-water equilibrium and pectin conglomerates forming a network of fibrils through the jelly. The network of fibrils holds the sugar solution in the interfibrillar spaces.

The firmness of network depends on (a) the concentration of sugar, and (b) acidity.

The fibrils of pectin become tough in presence of acids. Small amount of acid gives a weak fibrillar structure. Large amount of acid tends to hydrolyze pectin; the fibrils lose elasticity and the jelly becomes syrupy.

17.10.2 Spencer"s theory

Sugar acts as a precipitating agent; the presence of acid helps it. Greater the quantity of acid, lower is the sugar requirement.

17.10.3 Olsen"s theory

Sugar acts as a dehydrating agent which disturbs the equilibrium existing between water and pectin. The negative charge on pectin is reduced with help of hydrogen-ion-concentration. Pectin precipitates and coalesces in the form of a fine network of insoluble fibres, provided sugar is present in sufficient concentration. As the system reaches equilibrium, the jelly strength becomes the maximum.

17.11 Pectin – A Prized Ingredient in Jam/Jelly making

17.11.1 Raw materials for Pectin

Apple pomace and Citrus peel (Lime, lemon and orange) serves as raw material for extraction of pectin

.

17.11.2 Types of Pectin

High methoxyl (HM) pectins are defined as those with a Degree of Esterification (DE) above 50, while low methoxyl (LM) pectins have a DE of less than 50. LM pectins can be acid or alkali-treated. LM pectins can be either amidated (LMA) or non-amidated (LM).

17.11.3 Pectin in jelly formation

Protopectin is a component of the cementing material between plant cell walls; also a part of cell walls themselves. These are most abundant during the immature stage of fruit and are converted to pectin as the fruit matures.

When fruit are heated, the protopectin that has not turned to pectin is partially hydrolyzed or converted to pectin. To increase the amount of pectin extracted, some acid has to be added to the extraction solution and heat has to be applied.

When fruit are very ripe, other enzymes break up the pectin into pectic acid and alcohol. Pectic acid does not form a gel, except in the presence of added calcium molecules.

Jellies made with additional commercial pectin are usually bright and more transparent with no lessening of colour.

17.5 Concentration of Pectin and Jelly characteristics

1.0% pectin	Firm and tough jelly
< 0.5% pectin	Jelly fails to set

17.11.4 Commercial production of pectin

Plant materials are used. Most frequently culled or rejected apples, apple pomace or the pulp (together with peel and core wastes) remaining after apple juice extraction are used. Lemon rejects are also a good source. Extract all pectin substances including protopectin, pectinic acid, pectic acids and pectin related compounds.

Pectins are classified into two groups:

(a) those with a high methoxyl content (HMP) ~ 11% methoxyl content
(b) those with low methoxyl content (LMP) – lower methoxyl than mentioned above

HMP is extracted with higher temperature, acidic solutions. Pectins with high methoxyl content forms gels in presence of high sugar and acid concentration. Most commercial pectins are HMP.

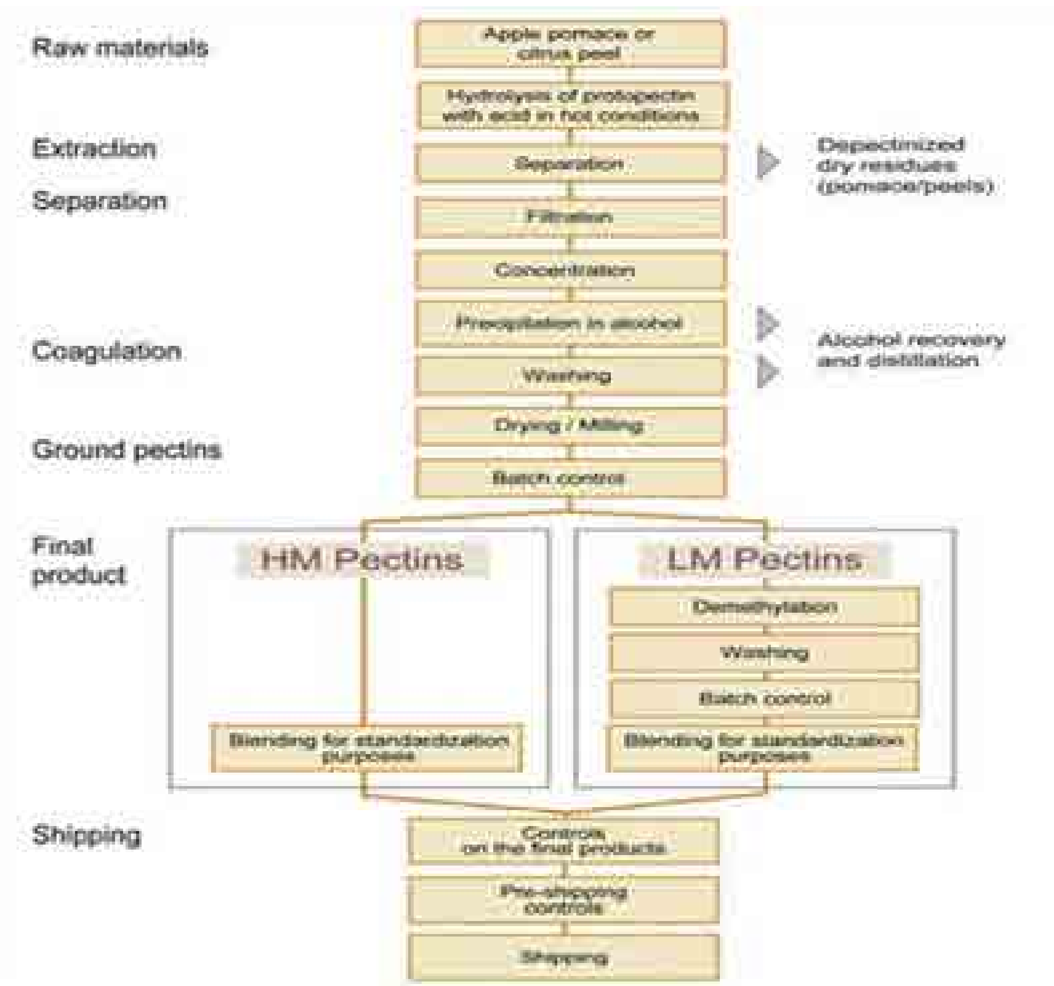
LMP containing pectic acids are extracted with lower temperatures with less acidic solutions, but in presence of other chemical compounds. LMP are pectin derivatives which do not need sugar to gel. If used, they need to react with a calcium salt (dicalcium phosphate) which has to be added during jam making.

17.11.5 Pectin extraction method

The fresh fruit tissue or separated parts, including the peel and core are heated in 95% alcohol or 0.05N HCl (pH 2.0) for 10-20 min at 70ºC to inactivate pectic enzymes. After the pretreatment, the materials is ground in an electric blender and placed in water. Versene or Na-EDTA is added at 2.0%. The pH is adjusted to 6.0. The mixture is heated for about an hour at 90-95ºC. The slurry formed is rapidly filtered and the pectin is precipitated from the solution using acidified alcohol. The precipitate is centrifuged and repeatedly washed with 70% alcohol. Acetone is used for dehydration and the pectin produced is vacuum-dried. It may also be dried in a hot-air oven at 50ºC for 4 h.

17.11.6 Household extraction of pectin

A pectin solution of maximum strength can be obtained with about 30 min of boiling. When this period is divided into two, each of 15 min period of extraction, maximum amount of pectin can be extracted. Other jellying agents include agar, arrow root, tapioca flour or cassava starch.



TEA

28.1 Introduction

Tea is one of the most popular beverages in the world. It also provides valuable source of income to many tea producer countries. It is a capital earning industry. To promote its development, the Govt. of India has set up

Tea Board under the Ministry of Commerce. Tea Taster‟s academy has recently come up in Coonoor in theNilgiris.

Tea is a perennial plant having a lifespan extending 100 years.

The popularity of tea is due to:

- Its sensory properties
- Relatively low retail price
- Apparent health benefits

28.2 History

The history of tea production in India spans more than 160 years. In 1838, the first consignment of tea from Assam was shipped to England.

The word *'Chai'* is derived from a Cantonese word *'Chah'*. Plantations in Darjeeling, Tarai and Dooars regions of northern Bengal and Nilgiris and other regions of South India.

28.3 Origin and Distribution

Centre of origin – Southeast China

Later it spread to Southern portion of China, parts of India, Myanmar, Thailand, Laos and Vietnam

Early part of 19th Century – An unsuccessful attempt was made to establish Chinese tea in India. Only when the native „wild‟ tea plants found in Assam were used, the tea production in India became successful.

Tea industries in India are there in Assam, West Bengal, Kerala, Karnataka, Tamilnadu and to some extent in Tripura and Himachal Pradesh.

28.4 FSSAI Definition of Tea

Tea means tea other than Kangra tea obtained by acceptable processes, exclusively from the leaves, buds and tender stems of plant of the *Camellia sinensis* (L) O.Kuntze. It may be in the form of black or oolong tea. The product shall have characteristic flavour free from any off odour, taint and mustiness. It shall be free from living insects, moulds, dead insects, insect fragments and rodent contamination. The product shall be free from extraneous matter, added colouring matter and harmful substances.

Tea may contain „natural flavours" and „natural flavouring substances" which are flavour preparations and single substance respectively, acceptable for human consumption, obtained exclusively by physical processes from materials of plant origin either in their natural state or after processing for human consumption in packaged tea only. Tea containing added flavour shall bear proper label declaration. Tea used in the manufacture of flavoured tea shall conform to the standards of tea. The flavoured tea manufacturers shall register themselves with the Tea Board before marketing flavoured tea. The product shall conform to the following requirements expressed on basis of material oven-dried at 103±2ºC. The specifications for tea are furnished in Table 28.1.

Table 28.1 Specific requirements of Tea by FSSAI

Parameters	**Requirements**
Total ash (w/w)	Min. 4.0% and Max. 8.0%
Water soluble ash	Min. 45% of total ash
Alkalinity of water soluble ash expressed as KOH (w/w)	Min. 1.0% and Max. 3.0%
Acid insoluble ash (w/w)	Max. 1.0%
Water extract (w/w)	Min. 32.0%
Crude fibre (w/w)	Max. 16.5%

28.4.1 Kangra tea

It is derived exclusively from leaves, buds and stems of plants of the *Camellia sinensis* grown in Kangra and Mandi valleys of Himachal Pradesh.

Tea for domestic market may contain added vanillin flavour up to a maximum extent of 0.5% by weight and other flavours as depicted in Table 28.2.

Table 28.2 Permitted flavors for inclusion in tea by FSSAI

Flavours	**Per cent by weight (Max.)**
Cardamom	2.8
Ginger	1.0
Bergamot	2.0
Lemon	1.6
Cinnamon	2.0
Mixture of above flavours	The level of each individual flavour shall not exceed the quantity specified above

28.4.2 Green tea

It means the product derived solely and exclusively, and produced by acceptable processes, notably enzyme inactivation, rolling or comminution and drying, from the leaves, buds and tender stems of varieties of the species *Camellia sinensis* (L) O. Kuntze, known to be suitable for making tea for consumption as a beverage. The product shall have characteristic flavour free from any off odour, and rodent contamination visible to the naked eye. The product shall be free from extraneous matter, added colouring matter and harmful substances. The other specifications for such tea are same as for Tea, except for total catechins which should be min. 9.0 and max. 19.0% w/w.

28.5 Health Benefits of Tea

Black tea leaf contains significant amounts of vitamin E & K. Vitamin C is present in green tea, but only traces are found in black tea. The phenolic constituents (referred to as vitamin P) strengthen the walls of capillary blood vessels. Tea also contains vitamin A (carotenoids) and vitamin B. It is too low in Fe, Cu and Fluoride.

5 cups of tea supplies 25% and 10% of the daily requirements of minerals like Mn and Zn respectively.

Catechins (viz., epigallocatechin gallate) have antimicrobial and anticancer properties. The black tea polyphenols absorb metals from the diet i.e. lead from contaminated water. Moderate amount of caffeine present in a cup of tea is mildly stimulating whilst provoking minimal irritability.

Decaffeinated teas have already appeared in the market.

28.6 Adulteration

Common adulterant is „spent" or „used" tea plus some colouring substances unfit for human consumption.

28.7 Health hazards

Caffeine is toxic to cardiovascular and nervous systems, when consumed excessively. Tea contains tannin which interferes with Fe absorption. Thus, it is prudent to avoid tea either before or after meals.

28.8 Caffeine in tea

It is an important pharmacological agent.

Mild stimulating action – central nervous system is almost indiscriminately stimulated from the top downwards; helps enhancing work efficiency by overcoming fatigue.

Caffeine often prescribed for migraine headache. It induces secretion of catecholamines in mammalian tissue.

Increases the level of serum lipids, but this effect is almost nullified by antilipidemic activity of high levels of polyphenols in tea. It is effective as a respiratory stimulant; produces peripheral vasodilation and increased circulation in kidneys and brain; increases the number of active glomeruli in the kidney and has a diuretic action.

Caffeine causes secretion of both acid and pepsin in the stomach and can aggravate peptic ulcer.

28.9 Classification of Teas

Tea plant *Camellia sinensis* (L) O. Kuntze is the only important economic species of the family Theaceae.

The two botanical varieties are recognized

28.9.1 China Tea (*Camellia sinensis* var. sinensis)

It is a variety found in more temperatate producing regions such as China, Japan, USSR< Turkey, Iran and Northern, higher altitude growing areas of India. It produces delicately flavoured tea.

28.9.2 Assam Tea (*Camellia sinensis* var. *assamica*)

It can survive only at high altitudes near the Equator. It is less resistant to cold than China type and much higher yielding plant, but produces less delicately flavouredbeverage.

28.10 Types of Processed Tea

28.10.1 Fermented or black tea

They contribute a major proportion of tea consumed in Western hemisphere. They are produced by full fermentation and roughly classified as „Plain‟ or „Flavoury‟.

28.10.2 Plain black tea

The taste characteristics are associated with the phenolic substances produced during fermentation e.g. Assam tea.

28.10.3 Flavoury black tea

They are sold on the basis of their aroma characteristics e.g. Darjeeling tea.

28.10.4 Green tea

There is no fermentation; the leaf remains green. When infused, the liquors are greenish, pale primrose or lemon-yellow in colour with no trace of red or brown. They are produced and consumed mainly in China and Japan. Green tea constitutes ~ 20% of total production.

28.10.5 Partially fermented tea

These are partially oxidized so that their appearance is somewhat intermediate between that of green and black tea. They are manufactured primarily in China e.g. Oolong, Pouchong teas. Oolong or Ponchong or Red Tea forms only 2% of total tea production.

28.10.6 Flavoured tea

Teas are sometimes scented with various plant essential oils such as lemon, bergamot, rose and fragrant olive which impart sweet floral attributes to enhance the natural flavour of tea.

Other teas are blended with flower petals, spices or dried leaf such as Rosemary, Peppermint, Camomile and Chrysanthemum.

28.10.7 Brick tea

These are tea (black or green) which are compressed in the form of bricks or cakes. Portions of bricks are broken off for use and are sometimes cooked with butter or other fats.

28.10.8 Instant tea

It is the water soluble extract of tea leaf, usually marketed as a powder, flake or granule, either pure or as a part of flavoured mixes.

Most Instant tea is made from black tea, but some is made from green tea. Iced lemon teas are popular example in USA.

28.10.9 Products promoted on health grounds

„Decaffeinated tea" is promoted on health grounds. Tea is decaffeinated with methylene chloride or other chlorinated solvents and supercritical CO_2.

Flavours

The flavours used include chocolate, jasmine, mandarin orange peel, Bergamot and other sweet herbs. In India, cardamom, ginger, lemon, bergamot and mint are popular flavoured teas.

TEA LEAF PROCESSING

29.1 Introduction

The production of orthodox and CTC tea accounts for 52.0 and 48.0% of black tea production respectively. India is the largest producer of Black tea while China is the largest producer of Green tea in the world.

Most of the teas we buy are blends, mixed from different pure teas so as to ensure same flavour from year to year.

Leaf is more popular in northern India and Dust in Southern parts. Central India – equal consumption of both dust and leaf varieties.

29.2 Chemistry of Tea Leaves

The fresh tea leaf is characterized by large quantities of methylxanthines and polyphenols. The composition of unprocessed tea leaf and young shoot of Assam tea is presented in Table 29.1 and Table 29.2 respectively.

Table 29.1 Composition of unprocessed tea leaf

Constituents	Percentage
Protein	20
Carbohydrates	30
Lipids	2
Polyphenols	33
Caffeine	5
Vitamins and minerals	7

Table 29.2 Chemical composition of young shoot of Assam tea

Components	Dry weight (%)
A. Soluble in water	
Phenolics	30
Flavanols*	18-32
Flavonol glycosides	3-4
Proanthocyanidins	2-3
Phenolic acids	
- Caffeine	3-4
Amino acids	
- Theanine	2
- Others	2

Carbohydrates	4
Organic acids	0.5
B. Partially soluble in water	
Starch	2-5
Other polysaccharides	12
Protein	15
Ash	5
C. Insoluble in water	
Cellulose	7
Lignin	6
Lipids	3
Pigments	0.5
Volatiles	0.01-0.02

* Flavanols comprise of Epigallocatechin gallate: 9-13%,

Catechin: 1-2% **29.2.1 Methylxanthines**

Caffeine – a purine alkaloid. Its content in fresh leaf is about 3-4% (dry weight basis) which cannot be significantly reduced by conventional tea processing. High caffeine levels leads to good „cream‟ formation in the liquor. Caffeine reacts with theaflavins and imparts „briskness‟ to tea infusion.

29.3 Enzyme action

Polyphenol oxidase enzyme in tea leaf plays a key role in fermentation. Other enzymes include peroxidase, amylase, □-glucosidase, peptidase, chlorophyllase, phosphatase and leucine transaminase.

Gallocatechin $\xrightarrow[\text{Enzymatic oxidation}]{\text{Catechins \& Polyphenol oxidase}}$ Theaflavins and Thearubigins

Theaflavins and Thearubigins are the two groups of polyphenolic compounds unique to black tea. Theaflavins account for 0.3-1.8% of dry weight of black tea. They are bright red pigments which gives the liquor the highly sought-after characteristics (i.e. „brightness‟ and „briskness‟

(keen/sharp flavour)). Thearubigins comprise between 9-19% of the dry weight of black tea. They are phenolic brown pigments with acidic properties. Aroma forms during fermentation.

29.3.1 Polyphenols and Polyphenol oxidase activity

29.3.1.1 Green tea

The most important biochemical changes to occur during steaming or roasting are inactivation of the enzyme polyphenol oxidase so that the catechins remainunoxidized, preserving the green colour of the leaf.

29.3.1.2 Black tea

Fermentation is the most important stage in „black tea" manufacture, which results in the formation of taste and aroma products, responsible for character of black tea. Fermentation is a misnomer, since microorganisms are not involved.

29.4 Tea Leaf Processing

The processing of tea leaves starts just after harvesting. The sequence of steps is as detailed below:

29.4.1 Harvesting/Plucking

This involves manual or mechanical removal of terminal young tender portions of peripheral shoots. The standard method is to pluck „two leaves and a bud".

The quality of final product deteriorates with an increase in mature leaf content.

Hand plucking is preferred. The mechanical harvesting involves use of modified hedge trimmers and motorized machine pluckers.

29.5 Black Tea Processing

29.5.1 Withering

The change which occurs in green leaf from the time it is detached from the plant to the time of maceration or rolling is collectively referred to as „Withering".

Air temperature, atmospheric vapour pressure, air velocity and air direction affects the rate and degree of physical wither.

Green leaves are spread over mesh in specially made wooden troughs with a bed thickness of 20 – 45 cm. A cross flow of heated air (temperature raised by 3-5°C by an electric fan) or ambient air during favourable atmospheric condition is maintained during entire stage (16-19 hours). This process reduces the moisture content from 80% to 50-60%.

It is a physical process wherein (a) moisture loss leads to changes in cell membrane permeability; the stomata on the lower surface of the leaf begin to shut gradually, (b) it preconditions the leaf for „maceration" or „rolling".

29.5.1.1 Two-stage withering

The leaf is stored in a holding tank with minimal moisture loss for about 6 h to achieve chemical wither. The leaf is then spread on withering troughs or a moving beltwitherer and moisture is rapidly reduced by use of warm air.

Other methods include Drum withering, Tunnel withering, etc.

29.5.2 Maceration / Rolling

29.5.2.1 Orthodox method

The physically withered leaf is subjected to rolling. The leaf gets damaged, become twisted and the semipermeable membrane of leaf gets distorted allowing the cell juices to be expelled to cover the leaf surface. This allows the juice to mix with cellular enzyme in presence of oxygen and the chemical reactions necessary for fermentation commences.

29.5.3.1 Cruch, Tea and Curl (CTC) method

The withered leaves are passed through CTC machine, causing severe rupturing of leaf cells. Machine consists of two steel engraved rollers rotating at different speeds in opposite direction (70 and 700 rpm). The leaves are allowed to consecutively pass through 2-3 such machines to achieve rupturing of cells and desired size.

The CTC machine has 3 sets of rollers: (a) first cut (coarse), (b) second cut (fine) and (c) third cut (super fine), after which the leaves are completely rolled. The capacity of CTC machine ranges from 750 to 1000 kg/h.

Other maceration methods include Legg-cut, Rotorvane, Triturator. A modern factory uses Rotorvane plus three CTC machines in series.

29.5.3.1.1 Advantage of CTC over Orthodox process

- Leaf distortion is much greater
- Fermentation is faster
- Liquoring properties are improved
- CTC and Lawrie Tea Processor (LTP – a modern CTC machine) teas have higher levels of theaflavins and thearubigins and therefore have more colour and are brighter and brisker than orthodox teas.

29.5.3 Fermentation

The liquor characteristics of black tea can be determined by control of temperature and time of fermentation (chemical transformation). The rolled leaf mass is placed on floor in thin layers at room temperature and with increased humidity (90-95% RH) using humidifiers. Fermentation is continued till the colour of leaf mass turns golden brown (1-2 hours).

Batch method uses troughs or trolleys, while *Continuous method* uses perforated moving belt fermentation machines through which air is passed.

The fermentors are connected to air supply by a duct, which can be humidified, if necessary, to reduce the temperature of fermenting tea (dhool).

The enzymatic oxidation, originally termed as „fermentation" since it affects liquor quality and cuppage of tea. Such operation influences the colour, brightness and briskness of liquor. It also imparted mellowness to brew. After fermentation, the colour of leaf mass changes from green to bright coppery red. Generally, the lower the fermentation temperature, the better is the black tea.

29.5.4 Firing/Drying

Once optimum fermentation is achieved, it is necessary to destroy enzymes. The „dhool" is fed to the driers by conveyors at a temperature of 90-120°C for 12-15 minutes. This process reduces the moisture content of fermented tea from ~ 60% to < 4%. It terminates fermentation by inactivating the enzymes. It makes the product fit for sorting and packaging.
In driers the inlet and outlet temperature may range from 82-98°C and 45-55°C respectively. Fluidized bed driers are being used recently. In this the blown hot air moves the dhool by process of fluidization. The disadvantage of firing is loss of considerable amount of volatile aroma compounds.

29.5.5 Grading and Sorting

Tea after firing is a mixture of particles of different sizes, ranging from „dust" to „leaf" of about 5 cm long and 1.3 cm wide. They are sorted into uniform grades acceptable to the buyers. The grading and sorting of tea is carried out using mechanically oscillatory sieves fitted with meshes of many different sizes. Winnowing in some form or other is routinely employed and according to the size and density of the particles, separates

„fannings" and „dust", carrying away the fibrous residues which is of no commercial value as a grade.

29.5.6 Packaging and Storage

For bulk transport, Tea chests are used to contain 60 kg tea. Chest is made up of plywood, lined inside with Aluminium foil. Other packaging material includesmultiwalled paper sacks – 2 plies of Kraft paper with an additional layer of Aluminium foil on the inside.

29.6 Green Tea Processing

It is manufactured from fresh leaf which has not been fermented. It depends on arresting the enzyme activity in green leaf. The different methods of green tea production are depicted in Fig. 29.1 and 29.2. **29.6.1 Chinese process of Green Tea manufacture**

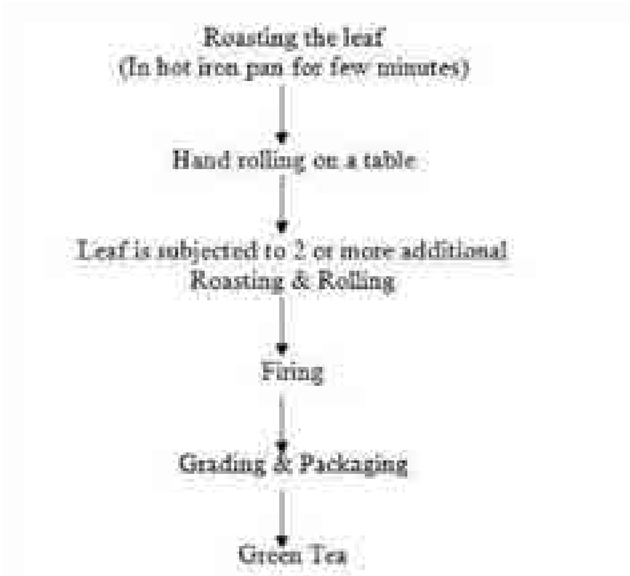


Fig. 29.1 Green tea processing by Chinese process

29.6.2 Japanese process of Green tea manufacture

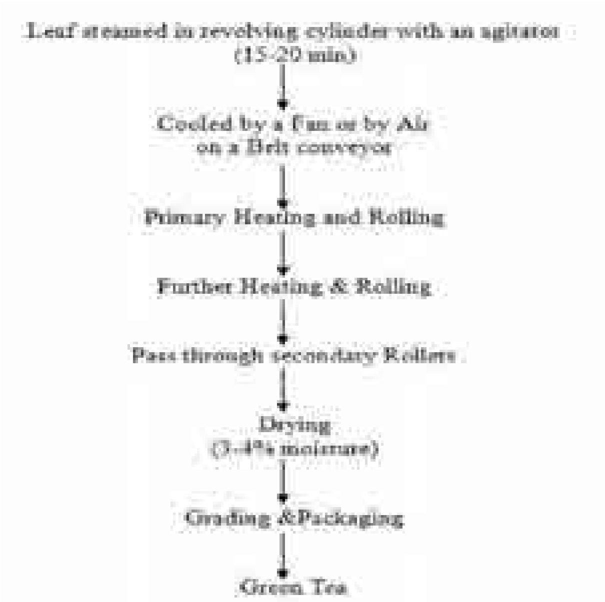


Fig. 29.2 Green tea processing by Japanese process

29.7 Processing for Partially Fermented Tea

The typical processing method adopted for preparing partially fermented tea is shown in Figure 29.3.

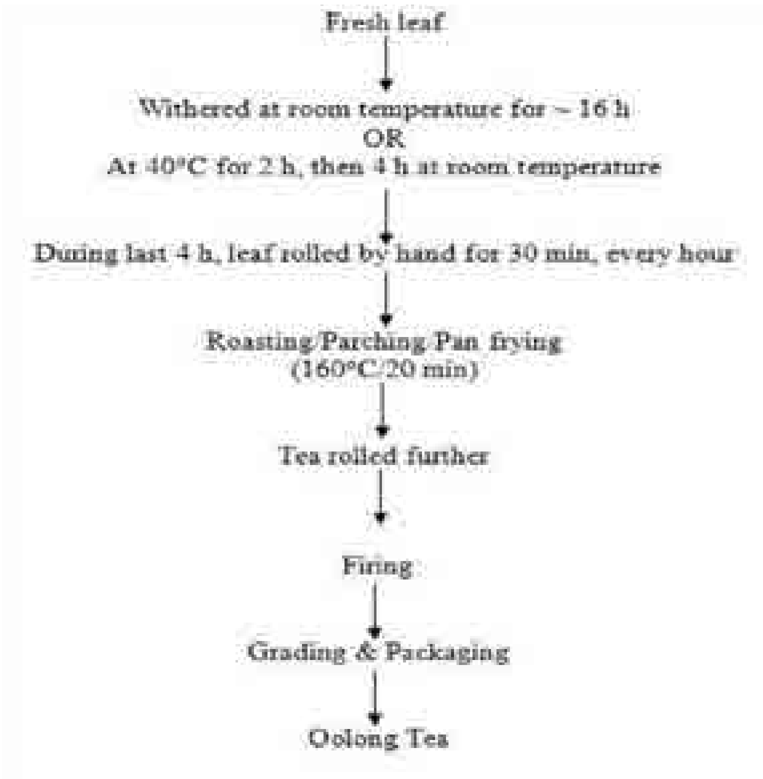


Figure 29.3Tea processing for partially fermented tea.

SPECIALTY TEA PRODUCTS

30.1 Introduction

Value addition to tea has been a reality and since people are fond of stimulating beverages, there has been introduction of an array of specialty tea products. Some of the examples of such specialty tea products are discussed herein.

30.2 Flavoured Tea

Teas are sometimes scented with various plant essential oils such as lemon, bergamot, rose and fragrant olive which impart sweet floral attributes to enhance the natural flavour of tea.

Other teas are blended with flower petals, spices or dried leaf such as Rosemary, Peppermint, Camomile and Chrysanthemum.

30.2.1 Flavours

The flavours that have been used include chocolate, jasmine, mandarin orange peel, Bergamot and other sweet herbs. In India, cardamom, ginger, lemon, bergamot and mint are popular flavoured teas.

30.3 Brick Tea

These are tea (black or green) which are compressed in the form of bricks or cakes. Portions of bricks are broken off for use and are sometimes cooked with butter or other fats.

30.4 Herbal Tea

This type of tea can be made using dried rosemary herb. Prepare dark out of optimum level of concentration of Rosemary herb. Blend black tea and rosemary; combination of other herbs like basil, mint, lemongrass, thyme, chamomile with rosemary.

30.5 Tea Bag

The first tea bags were hand-sewn silk bags and tea bag patents dated as early as 1903. First appearing commercially around 1904, tea bags were successfully marketed by the tea and coffee shop merchant Thomas Sullivan from New York, who shipped his tea bags around the world. Modern tea bags are usually made of paper fibre. The heat-sealed paper fiber tea bag was invented by William Hermanson, one of the founders of Technical Papers Corporation of Boston. The rectangular tea bag was invented in 1944. Prior to this tea bags resembled small sacks.

The tea bag is referred to as „Cinderella‟ of tea industry – now dressed in paper instead of silken gown.

A tea bag is a small, porous sealed bag containing tea leaves and used for brewing tea. Tea bags are commonly made of paper, silk or plastic. The bag contains the tea leaves while the tea is brewed, making it easier to dispose of the leaves, and performs the same function as a tea infuser. Some tea bags have an attached piece of string with a paper label at the top that assists in removing the bag while also identifying the variety of tea.

A broad variety of teas, including herbal teas, are available in tea bags. Typically, tea bags use fannings, the left-overs after larger leaf pieces are gathered for sale as loose tea, but some companies such as Honest Tea sells teabags containing whole-leaf tea.

30.6 Products Promoted on Health Grounds

30.6.1 Decaffeinated tea

This type of tea is promoted on health grounds. Chloroform or methylene chloride is an effective solvent for isolating caffeine from tea leaf. However, it is not widely accepted by consumers because of its toxicity. Decaffeination using supercritical carbon dioxide is effective and leaves no solvent residues, but it needs expensive equipment. Sawdust lingo-cellulose columns can be used to separate caffeine from tea extracts, but they are difficult to use for decaffeination of tea leaf.

30.6.1.1 Hot water treatment – an alternate safe method

When fresh tea leaf was decaffeinated with a ratio of tea leaf to water of 1:20 (w/v) at 100°C for 3 min, caffeine concentration was decreased from 23.7 to 4.0 mg/g, while total tea catechins decreased from 134.5 to 127.6 mg/g; 83% of caffeine was removed and 95% of total catechins was retained in the decaffeinated leaf. Hence, hot water treatment can be considered to be a safe and inexpensive method for decaffeinating green tea. However, a large percentage of tea catechins were lost if rolled leaf and dry tea were decaffeinated by such treatment and so this process is not suitable for processing black tea.

30.7 Aseptic Packaging Tea Concentrates

These are produced from top quality tea leaf (*Camellia sinensis*) through hot water extraction and Reverse Osmosis (RO) concentration at low temperature. It is then subjected to Ultra High Temperature (UHT) treatment and aseptically packaged. The products include Green tea, Jasmine tea, Oolong tea and Black tea.

The liquid concentrates look crystal clear and retain the flavor characteristics of tea leaf and are ideally suitable for making iced tea mixes and Ready-to-Drink (RTD) tea beverage.

30.8 Instant Tea

It is the water soluble extract of tea leaf, usually marketed as a powder, flake or granule, either pure or as a part of flavoured mixes.

Most Instant tea is made from black tea, but some is made from green tea. These are produced especially in USA and UK. Iced lemon teas are popular example in USA.
Instant tea is presently manufactured by spray/freeze drying of the concentrated brew of processed tea leaves/dust. A new technique has been developed for the production of instant/soluble tea powder from the expressed juice of green leaves. After plucking, the leaves are crushed and juice pressed out. The juice is then subjected to fermentation under specified conditions. The fermented juice is steamed, centrifuged and freezedried to get instant tea powder. At the same time, the pressed leaf residue is subjected to fermentation and drying for preparation of tea granules. The instant tea produced is of good liquoring characteristics. The theaflavin to thearubigin ratio was 10.71 for instant tea and 12.12 for tea granules. The caffeine content was 40.4 mg and 96 mg per cup for instant tea and tea granules respectively. There is considerable savings in the economy as the juice and residue are converted into value-added products using this method.

30.8.1 Manufacturing process for instant tea

The processing in tea processing plant includes extraction, separation of waste, evaporation and spray drying. The plant size varies from 5 kg/h to 1000 kg/h of instant tea.

The processing steps are as outlined below:

- Instant tea is manufactured from black tea by extracting the brew from processed leaves, tea wastes or undried fermented leaves.
- The extract is concentrated under low pressure, and dried to a powder by any of the processes including freezing, drying, spray-drying and vacuum-drying.
- Low temperature is used to minimize the loss of flavor and aroma.

The flow chart for production of Instant tea is furnished in Fig. 30.1.

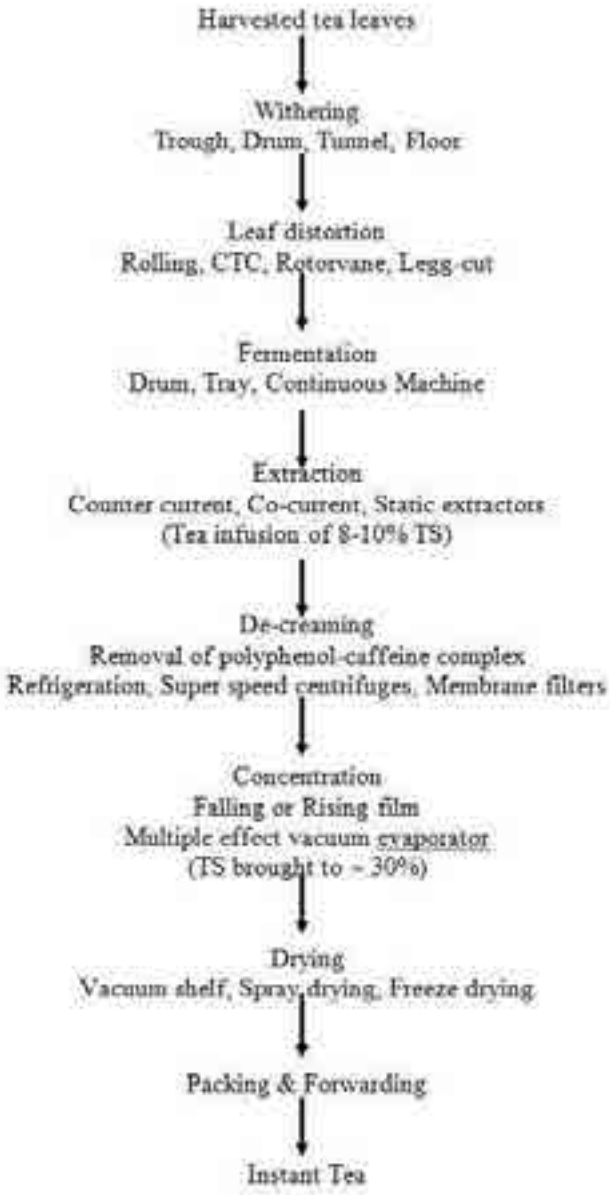


Fig. 30.1 Process flow-chart for production of Instant Tea

COFFEE

31.1 Introduction

Coffee was allegedly born before 1,000 A.D. when legend has it that a shepherd named Kaldi, in Caffa, Ethiopia noticed that his sheep became hyperactive after grazing on some red berries. Coffee was first introduced in Turkey during the Ottoman Empire around A.D. 1453 and coffee shops opened to the public. Coffee came to India via Mysore in Karnataka, brought secretly by a Sufi Saint from Meccan named Baba Budan.

Coffee is pleasure. Its taste, flavour, aroma and refreshing effect makes it unique.

Green coffee – A green coffee bean is a commercial term which designates the dried seed of the coffee plant. It has about 10.0% moisture. Coffee plant or tree belongs to Coffea genus.

31.2 Classification of Green Coffee Beans

Two species are commercially important for green coffee: *Coffea canephora* (also referred to as *C. robusta*) *Coffea arabica L.*

Arabica accounts for 75% of global coffee production.
Arabica coffee bush bears about 5 kg fruit per year which corresponds to 300-400g of Instant coffee. Robusta bushes yield slightly higher.

31.3 Comparison of *C. robusta* with *C. arabica*

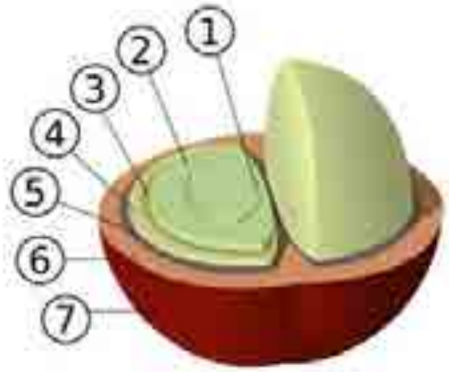
- Flavour quality (roasted and brewed) is generally considered to be inferior for *C. robusta.*
- Less expensive per unit weight of green coffee.
- Characteristics found favourable in manufacture of some instant coffees.
- Often features in Espresso coffee.
- Consumed as regular brewed coffee.

Arabica has more aroma. Robusta contains more caffeine and is consequently slightly bitter.

Indian coffee is the most extraordinary of beverages, offering intriguing subtlety and stimulating intensity. India is the only country that grows all of its coffee under shade. Typically mild and not too acidic, these coffees possess an exotic full-bodied taste and a fine aroma.

India‟s coffee growing regions have diverse climatic conditions, which are well suited for cultivation of different varieties of coffee. Some regions with high elevations are ideally suited for growing Arabicas of mild quality, while those with warm humid conditions are best suited for Robusta‟s.

31.4 Structure of coffee bean



1. center cut
2. bean (endosperm)
3. silver skin (testa, epidermis)
4. parchment (hull, endocarp)
5. pectin layer
6. pulp (mesocarp)
7. outer skin (pericarp, exocarp)

When the fruit is ripe, it is almost always handpicked, using either „selective picking‟, where only the ripe fruit is removed or „strip-picking‟, where all of the fruit is removed from a branch all at once. Because a tree can have both ripe and unripe berries at the same time, one area of crop has to be picked several times, making harvesting the most labor intensive process of coffee bean production.

There are two methods of processing the coffee berries. The first method is „wet processing‟, which is usually carried out in Central America and areas of Africa. The flesh of the berries is separated from the seeds and then the beans are fermented – soaked in water for about 2 days. This dissolves any pulp or sticky residue that may still be attached to the beans. The beans are then washed and dried in the sun, or, in the case of commercial manufacturers, in drying machines.

The „dry processing‟ method is cheaper and simpler, used for lower quality beans in Brazil and much of Africa. Twigs and other foreign objects are separated from the berries and the fruit is then spread out in the sun on cement or brick for 2–3 weeks, turned regularly for even drying. The dried pulp is removed from the beans afterward.

After processing has taken place, the husks are removed and the beans are roasted, which gives them their varying brown color, and they can then be sorted for bagging.

31.5 Organic Coffee

Organic coffee are those produced by such management practices which help to conserve or enhance soil structure, resilience and fertility by applying cultivation practices that use only non-synthetic nutrients and plant protection methods. Further, there has to be credible certification by an accredited certification agency.

Organic coffee is being produced by about 40 countries in the world with major production share coming from Peru, Ethiopia and Mexico. Organic coffee is chiefly consumed in the Europe, US and Japan. Organic coffee products are now marketed in the form of regular, decaffeinated, flavoured and instant coffee as well as in other foods like ice creams, yoghurt, sodas, candies and chocolate covered beans, etc.

31.6 Green Bean Processing

Green bean itself has no comestible value for humans and must be roasted before use as a flavourful and stimulant aqueous beverage.

Green coffee beans are dried, cleaned and packed usually in 60 kg bags and stored before they are roasted.

COFFEE PROCESSING

32.1 Introduction

The previous lesson dealt with origin and classification of coffee. In this lesson the processing of coffee bean will be discussed. The green bean has no comestible value for humans and must be roasted before use for developing the desired colour and flavor, enjoyed as a stimulant beverage.

32.2 Green Bean Processing

32.2.1 Roasting process

It is a time-temperature dependent process, whereby chemical changes are induced by pyrolysis within the coffee beans, together with marked physical changes in their internal structure. The required change takes place with a bean temperature from 190^{o}C upwards; bean temperature up to 240^{o}C may be reached in less than 12 minutes.

Batch operated horizontal rotating drum roaster with either solid or perforated walls, in which hot air from a furnace/burner passes through the tumbling green coffee beans. Green coffee beans under movement are subjected to heat by conduction from hot metal surfaces, or convection from hot air, or more generally a mixture of both methods of heat transfer, together with contribution by radiation.

A typically sized roaster holds 240 kg of green coffee, with an outturn (charging to discharging) of 15 min. The furnace or burner will be either oil or gas fired.

Other roasters include:

Vertical static drum with blades

Vertical rotating bowl

Fluidized bed

Pressure roasting

The latest roasters have shorter roast times i.e. of the order of 3-5 min. Fast-roasted coffee is advantageous because of lower bulk density and „high yield" on brewing.

The degree of roast may vary from „Very light to very dark".

Consumer preference is usually „medium roast".

32.2.1.1 Physico-Chemical Changes in Coffee

32.2.1.1.1 Chemical changes

The chemical changes include Maillard type reactions and caramelization of sucrose. The composition of roasted coffee is furnished in Table 32.1.

Volatile complex comprising of furan derivatives, pyrazines, pyridines, benzenoid aromatics, aliphatics, alicyclics and various sulphur compounds. These are important for the flavour/aroma in medium-roast Arabica coffee.

Some compounds are generated by straight pyrolysis of single compounds e.g. chlorogenic acids in generating phenols; there is overall 40% residual content for a medium roast. The change in chlorogenic acid content is used as analytical measure of **„degree of roast"**.

Similarly, coffee oil leads to formation of small amounts of aldehydes and hyrdrocarbons. The coffee oil is practically unaffected, as is the caffeine content.

Newly formed residuum of ~ 25% by weight of roasted coffee is melanoidins/humic acids. The loss of mass is
2-3% on dry basis for **„Light roast"**, whereas it is up to 12% on dry basis for **„Very dark roast"**. The beans lose 15-20% of their weight, but increases up to 25% in size.

32.2.1.1.2 Physical changes

The physical changes that occur include:

Change in colour.

Formation of cavities/cracking of surface.

Void volume is 47% of **„medium roast bean"** vs. 0% in green bean.

32.2.2 Cooling

In batch operation, the roasted beans have to be quickly discharged at the end of required roasting period into a cooling car, or vessel, allowing upward passage of cold air.

Component	**Typical average content for (%)**	
	Arabica	**Robusta**
Alkaloids (caffeine)	1.3	2.4
Trigonelline (including roasted byproducts)	1.0	0.7
Proteinaceous		
„Protein"	7.5	7.5
Free amino acids	0	0
Lipids (Coffee oil with unsaponifiable)	17.0	11.0
Sugars:		
Sucrose	0	0
Reducing sugars	0.3	0.3
Polysaccharides (unchanged from green)	33.0	37.0
Lignin	3.0	3.0
Pectins	2.0	2.0
Acids		
Residual chlorogenic	2.5	3.8
Quinic	0.8	1.0
Aliphatic	1.6	1.6

Minerals (oxide ash)	4.5	4.7
Caramelized/condensation products (Melanoidins, etc.)	25.5	25.5
Total	100.0	100.0

In addition, water may be sprayed from within the rotating drum, just before the end of the roast – so called **„Water quenching"**.

32.2.2.1 Advantages of water quenching

- Assists in necessary cooling.
- Adds a small percentage of water by weight to roasted beans, thereby assists uniformity of particle size in subsequent grinding.

3.2.3 Grinding

Multistage twin horizontal rollers up to 4 stages may be used to ensure more uniform particle size distribution.

1st and 2nd stages – Essentially performs cracking or crushing the beans into smaller units.

3rd and 4th stages – Leads to progressively finer grinding.

The grind size required is related to subsequent method of brewing to be adopted and whether for home use or subsequent large scale extraction i.e. coarse, medium, fine, very fine. The ground size of roasted and ground coffee beans for different applications is presented in Table 32.2.

Table 32.2. Grind size of roasted and ground coffee beans

Grind size	Actual size (µm)
Fine grind	430 (Europe), 800 (USA)
Coarse grind*	850 (Europe), 1130 (USA)

* for household percolators

The number of different screen sizes numbered by aperture size within the range of 1400 µm to 250 µm. Newer method performs sizing by laser beams.

32.2.4 Packaging

Roasted and ground (R & G) coffee releases substantial quantities of entrapped CO_2 gas which develops high internal pressure, leading to bursting of package.

The usual packaging material is laminates.

32.2.4.1 Packaging under vacuum

It allows a low percentage of oxygen content in headspace to be established within the package and accommodate release of CO_2. Alternatively CO_2 scavenger may be used.

32.2.4.2 Degas over a sufficient time period

The R & G coffee is allowed in bulk to degas over a sufficient time period to a low level, followed by gas purging whilst individual packages are being filled.

Gas purging is used to ensure that the residual oxygen in headspace is below 1.0%.

In Europe, use of plastic packages to which a non-return valve is securely attached allows release of excess CO_2, when internal pressure exceeds a certain predetermined level.

32.3 A Glance at the Processing Steps

32.3.1 Green bean treatment

Cleaning

Blending

Storage

32.3.2 Roasting

32.3.2.1 Roast bean treatment

Storage

Grinding

Conditioning

32.3.2.2 Extraction

Fast instant coffee extractors (FIC)

Conventional batch percolators

Continuous counter current extractors (CONTEX)

- *FIC extraction unit*

It reduces extraction time by 50% compared to batch percolators. Water is directed through the ground coffee in two stages. The process results in two completely separated extract fractions viz., aroma and hydrolysis. After extraction, the extract is filtered and centrifuged.

- *Clarification*

It is a system consisting of filters and centrifuges to separate insoluble parts from the extract to achieve international standards.

32.3.2.4 Concentration

Falling film and plate evaporators

Freeze concentration

Membrane filtration systems

- *Concentration*: It serves to increase the solids content in extract prior to freeze or spray drying.

a) **Thermal concentration** – Multistage non-recirculating evaporators operating under vacuum in a plug flow mode.

b) **Membrane filtration** – The aroma fraction of the extract can be pre-concentrated using „reverse osmosis" in a membrane filtration system.

c) **Freeze concentration** – By cooling the extract to subzero temperatures, excess water is removed as ice crystals.

Freeze and thermal concentration, membrane filtration, Falling film and plate evaporators are used for the purpose of concentration.

32.3.2.5 Drying

Nozzle Tower spray dryer

Fluidized bed spray dryer

Continuous freeze dryers (CONRAD)

Batch freeze dryers (RAY)

32.3.2.6 Agglomeration

Rewet agglomerators (RWA)

32.3.2.7 Packing

32.4 Domestic and Catering Methods of Brewing

Brewing is extraction of soluble substances contributing to the basic taste plus of volatile substances for overall flavour. Roast coffee must be ground before brewing.

The two main mechanical principles are:

32.4.1 Steeping/Slurrying of R & G coffee with water, with or without agitation, followed by sedimentation or filtration or both.

32.4.2 Percolation in fixed beds of R & G coffee held in an open or closed container. Water may be passed through either in a single pass under gravity or under pressure (including steam, as in Espresso making), or in a multipass.

32.5 Extraction

Extraction of coffee solids can be carried out by

Fast instant coffee extraction.

Conventional batch percolators.

Continuous countercurrent extractors.

32.6 Factors in Brewing

Coffee-to-water weight ratio

The appliance used for brewing.

The temperature employed.

Of the components of roasted coffee, only some will be extracted completely with variable amounts of the others to reach ~ 28% w/w total maximum and 21% optimum under household brewing conditions, by hot or boiling water – so called „yield‟.

Mechanical operation involved is a means of separating the undesired so-called „Spent coffee grounds‟ from the required brew formed by sufficient contact with water. The brew should contain as little of spent ground particles as possible and must be presented hot (i.e. 50-55^{o}C).

32.7 Flavour Quality of Coffee Brew

The factors determining flavour quality of brew include:

The choice of blend used.

The degree of roast.

Brewing conditions.

Choice of grind.

32.8 Filter coffee

South Indian Coffee, also known as Filter Coffee is a sweet milky coffee made from dark roasted coffee beans (70-80%) and chicory (20-30%), especially popular in the southern states of Tamil Nadu and Karnataka. The most commonly used coffee beans are Arabica and Robusta.

Outside India, a coffee drink prepared using a filter may be known as Filter Coffee or as Drip Coffee as the water passes through the grounds solely by gravity and not under pressure or in longer-term contact.

Fig. 32.1 South Indian metal based coffee filter

32.9 Aromatization of Coffee

It is a term applied to a process, whereby essentially the headspace coffee aroma volatiles are made available by plating coffee aroma oil, prepared by expression methods from roast coffee, or other sources onto the soluble coffee, usually at the packing stage. This is a treatment imparted to improve the flavour and aroma. The powder lacks full flavour and aroma of freshly brewed coffee. The flavour and aroma constituents are trapped and recovered during roasting, grinding and extraction and from oils pressed from coffee bean. The cold CO_2 does not damage the flavour and aroma compounds in coffee oil and it is easily separated from extracted oil for recompression and reuse.

After CO_2 removal of the oil, the „Roasted and Ground coffee" is still highly suitable for extraction of water soluble solids in the regular extraction battery operation.

32.9.1 Aroma recovery

The extract fractions are stripped of their volatiles in an aroma recovery unit. After being stripped from the concentrate in a flash evaporator, the aroma is recovered in a 2-stage condenser system.

INSTANT COFFEE

33.1 Introduction to Instant Coffee

Instant coffee, also called **soluble coffee** and **coffee powder**, is a beverage derived from brewed coffee beans. It is the dried soluble portion of roasted coffee, which can be presented to the consumer in either powder or granule form for immediate make-up in hot water. Instant coffee is commercially prepared by either freezedrying or spray drying, after which it can be rehydrated.

Instant coffee was invented in 1901 by Satori Kato, a Japanese scientist working in Chicago.

Historically, most instant or soluble coffees first contained added carbohydrates (~ 50% w/w) such as corn syrup solids, as simple aqueous extract of roasted coffee, extracted under atmospheric conditions (100^{o}C). However, it could not be spray dried to a satisfactorily free-flowing low-hygroscopic powder.

In 1950, Instant coffee of 100% pure coffee solids became commercially available. In 1965, Instant coffee in soluble form, somewhat darker in colour and improved retention of aromatics became available.

The manufacture of instant coffee is accompanied by some slight hydrolysis of the polysaccharides in the roasted coffee (by further aqueous extraction at temperatures up to 175^{o}C and addition to the simple extract before drying), which is reflected in the slightly increased reducing sugar content (i.e. arabinose, mannose and galactose) and probably assists solubilization of these polysaccharides, not otherwise easily possible at 100^{o}C. This provides a powder of satisfactory physical properties.

Advantages of instant coffee include speed of preparation (instant coffee dissolves instantly in hot water), lower shipping weight and volume than beans or ground coffee (to prepare the same amount of beverage), and long shelf life.

About 20% of all processed coffee beans are used for making Instant coffee. The capacity of the plant available is up to 500 kg of Instant coffee per hour.