

## UNIT – I

### TECHNOLOGY OF CEREALS AND MILLETS

#### RICE PROCESSING

##### PHYSICOCHEMICAL PROPERTIES

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##### **Grain dimension: size and shape**

There exist enormous variations in the size and shape of the grains as they are conditioned by a large number of genes. Grain dimension is expressed as length, breadth and thickness, whereas shape is expressed as the ratio between the length and breadth. These parameters are the major bases for the characterization of rice varieties. Short grain varieties vary in their length from 3 - 6 mm (length-to-breadth ratio, 2.5-3.0) whereas long grain varieties have a length of 6mm and above (length-to-breadth ratio, more than 3.0). There are three major types of rice: long, medium and short-grained, which are classified by the grain shape (length-to-breadth ratio) and tend to have different properties and hence different uses.

##### **Grain colour and translucency**

White and translucent rice is preferred by people in most parts of the world. The colour of the dehusked, unpolished rice is usually pale white, creamy white, brown or red. On polishing, the kernel becomes white, translucent or opaque according to the nature of the pericarp and endosperm colour of the brown rice.

##### **Density**

It ranges from 1.327 to 1.375 g/cm<sup>3</sup> for medium-grain rice, from 1.365 to 1.381 g/cm<sup>3</sup> for long grain rice. Bulk density increases with increase in moisture content.

##### **Cooking/eating quality indicators**

The cooking and processing characteristics of rice are the factors of primary importance in rice-eating areas of the world. Milling, cooking and processing qualities are the fundamental components of quality that determine and establish the economic value of rice. Upon cooking, long-grain rice is dry and fluffy with individual grains, whereas medium and short-grain types are moist and chewy with grains that tend to stick or clump together. Major cooking quality parameters are discussed hereunder.

#### **1. Amylose content**

Amylose content is considered the single most important characteristic for predicting rice cooking and processing behaviour. In rice, it varies roughly from 15-37%. A high amylose content is usually associated with non-sticky cooking characteristics and vice-versa. Glutinous or waxy rice, which has no or very little amylose content, becomes very sticky on cooking.

## **2. Gelatinization temperature**

The gelatinization temperature of starch is the range of temperature within which the starch starts to swell irreversibly in hot water with a simultaneous loss of crystallinity and usually varies from 56<sup>o</sup> to 79<sup>o</sup>C. It is correlated with the extent of disintegration of milled rice in a dilute alkali solution (1.7-2.0% KOH) measured in terms of alkali spread value. Gelatinization temperature is also positively correlated with the cooking time but not with the texture of cooked grains.

## **3. Gel consistency**

The gel consistency test is the index of cooked rice hardness among high amylose rice. Rice is classified on the basis of gel length as soft, medium and hard. Soft to medium gel consistency is preferred to hard gel consistency. Among high amylose rice, intermediate gelatinization temperature and soft gel consistency are preferred by consumers over low gelatinization temperature and hard gel consistency.

### **Milling quality**

Milling quality means the degree to which the endosperm remains intact at the end of milling. Milling quality, indicated by total milling yield or head rice (milled rice kernels that are three quarters or more of the endosperm length) yield, is expressed as a percentage of rough rice. Breakage during milling process is not desirable.

### **Nutritional quality**

Brown rice contains more nutrients (minerals and vitamins) than milled rice. However, status of nutrients is dependent on genetic variability of rice throughout the world.

## **MILLING OF RICE**

### **Conventional rice milling**

Hand-pounding of paddy in a mortar with a pestle is the traditional milling process in remote villages. Pounding the paddy induces upward and downward forces on grain against the grain, removing the husk and bran layers. The pounding also breaks up the fissured grain. The final cleaning is by winnowing in a woven bamboo tray.

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### **Village-level rice mills**

Village-type rice mills can be found in rural communities and are used for service milling paddy of farmers for home consumption.

### **Single pass, single stage mill**

The single pass rice mill is an adaptation of the "Engleberg" coffee huller from the United States, modified for milling rice. In earlier days this type of rice mill was very popular in most rice-growing countries. It is still the mainstay technology for milling parboiled paddy in Bangladesh, and in many African countries. The "iron hullers", or "single pass mills" which all refer to the same mill are notorious for breaking the paddy grain. Because of the high breakage, the total milled rice recovery is 53-55%, and head rice recovery is in the order of 30% of the milled rice. The fine brokens are mixed with the bran and the ground rice hull. This by-product is used for animal feed. In many rural areas, Engleberg mills are used for custom milling the rice requirements of households. The bran produced is left to the miller as the milling fee. The poor performance of the Engleberg mill has led governments to discourage its use and has limited further proliferation. In many Asian countries, Engleberg mills can no longer be licensed to operate as service or commercial mills.

The Micro mill is also a single pass single stage mill, which was designed for local production. All components can be produced by local welding workshops. However, the milling recovery and head rice recovery is quite low and it is therefore only suitable for milling paddy for home consumption in very remote areas where the farmers don't have access to a custom rice mill.

### **Two stage mills (single pass or two pass)**

Two stage milling is either done in compact 2-stage rice mills, or with two separate machines for husking and polishing. Typically they have 0.5 to 1 ton per hour paddy input capacity. They are also used for custom milling services in the rural areas. A typical compact rice mill consists of a 6-inch diameter x 6-inch wide rubber roller husker, and a friction whitener. The friction whitener has a very similar design configuration as the Engleberg except that it has no husking knife. The milling performance of the compact rice mill is superior to the single pass Engleberg huller. Milling recoveries are normally above 60%.

### **Modern rice milling**

The milling process in large commercial mills combines a number of operations that produce better quality and higher yield of white rice from paddy or rough rice.

#### **The modern milling process**

##### **1. Pre-cleaning**

When paddy comes into the mill, it contains foreign materials such as straw, weed seeds, soil, and other inert materials. If these are not removed before hulling, the efficiency of the huller and milling recovery will be reduced. The capacity of the paddy pre-cleaner is normally 1.5 times the milling capacity.

##### **2. Removing the husk (dehusking or dehulling)**

Brown rice is produced by removing the husk from rough paddy rice. The husk is removed by friction as the paddy grains pass between two abrasive surfaces that move at different speeds. After dehusking, the husk is removed by suction and transported to a storage dump outside the mill. Husk accounts for 20% of the paddy weight and an efficient husker should remove 90% of the husk in a single pass.

### 3. Paddy separation

The paddy separator separates unhusked paddy rice from brown rice. The amount of paddy present depends on the efficiency of the husker and should not be more than 10%. Paddy separators work by making use of the differences in specific gravity, buoyancy, and size between paddy and brown rice.

### 4. Whitening or polishing

White rice is produced by removing the bran layer and the germ from the paddy. The bran layer is removed from the kernel through either abrasive or friction polishers. The amount of bran removed is normally between 8 and 10% of the total paddy weight. To reduce the number of broken grains during the whitening process, rice is normally passed through two to four whitening machines connected in series.



*Rubber roller husker*



*Vertical core polisher*

### 5. Separation of white rice

After polishing, white rice is separated into head rice, large and small broken rice, and “brewers” by an oscillating screen sifter. Head rice is normally classified as kernels that are 75–80% or more of a whole kernel. To attain a higher degree of precision for grading and separation a length or indent grader is used.

### 6. Rice mixing

A good rice mill will produce 50–60% head rice (whole kernels), 5–10% large broken and 10–15% small broken kernels. Depending on country standards, rice grades in the market

will contain from 5–25% broken kernels. If rice mixing is to be done properly, then a volumetric mixer is necessary.

### 7. Mist polishing

Mixing a fine mist of water with the dust retained on the whitened rice improves the luster of rice (polishes) without significantly reducing milling yield. A friction type of whitening machine, which delivers a fine mist of water during the final whitening process, is used for “final” polishing before sale.

### 8. Rice weighing

Rice is normally sold in 50 kg sacks which must be accurately weighed and labeled. While most rice mills use a manual mechanical weighing system, very accurate, and fast electronic systems are also available.

## PARBOILING

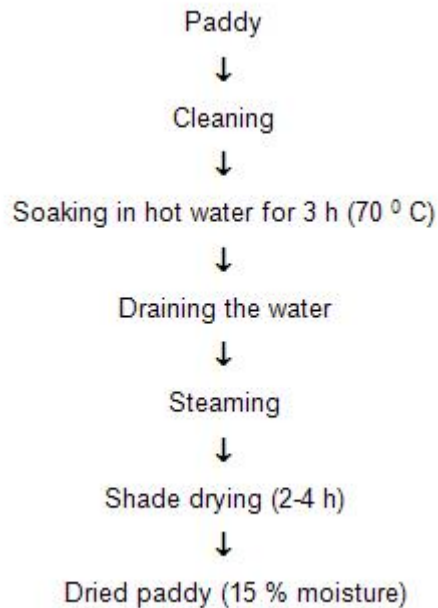
Parboiling is a hydrothermal treatment followed by drying before milling for the production of milled parboiled grain. Parboiling of paddy has been known in the orient for centuries. Nearly 50 per cent of the paddy produced in India at present is parboiled.

In general, the three major steps in parboiling, i.e. soaking, steaming and drying and have a great influence on the final characteristics and quality of parboiled rice.

Parboiling is the latest premilling treatment which improves the quality of rice. The traditional parboiling process in India is carried out in different ways.



## Improved parboiling method of CFTRI, Mysore, India (Batch)



### Advantages of parboiling

- The process imparts a hard texture and a smooth surface finish to the grain as a result which the broken in the milled rice is minimized. While 90 % of the parboiled grains may remain unbroken; the broken in raw rice could be as high as 50 %. The reduction in broken rice results in an increase of 3-5 per cent in the total yield of rice.
- Insects find it more difficult to bite and eat their way through the hard and smooth surface of parboiled rice.
- The loss of solids in the gruel during cooking is also less in parboiled than in raw rice.
- Milled parboiled rice contains more of B-vitamins than milled raw rice.
- Loss of B-vitamins is less in parboiled rice, during washing and cooking, compared to that in raw rice.
- The cooking quality is different from that of raw rice. Parboiled rice is non-sticky and non-glutinous.
- The parboiled paddy on milling produces a bran higher in oil content (about 25-30 % oil) compared to raw rice bran (about 10-20 % oil).
- Parboiled rice bran is relatively stabilized compared to raw rice.

### Disadvantages

- It develops a relatively darker colour compared to raw rice.
- The traditional parboiled process produces an undesirable smell.
- Parboiled rice takes more time to cook to the same degree of softness than raw rice.
- Because of long soaking in traditional process, mycotoxins may develop in parboiled rice and cause health hazards.
- Heat treatment during parboiling destroys some natural antioxidants and hence parboiled rice develops more rancidity than raw rice during storage.
- Shelled parboiled rice requires more power for polishing.

- Parboiled paddy may choke the polisher because of the higher oil content of the bran.
- Parboiling process requires an additional investment of capital.

### **AGEING OF RICE**

Aged rice is nothing but stocked rice which is kept for ageing for more than 6 months. Rice ageing involves changes in the physical and chemical composition of the rice grain. Ageing of rice is an important step in post-harvest processing of paddy, as stored rice is preferred to raw rice owing to the improved flavour. It has better commercial value, higher milling yield, and is preferred by consumers in terms of cooked rice texture, flavour and associated parameters. The process of ageing commences before harvest and continues as an index dependent on time, temperature, and moisture. Rice ageing brings about significant changes in the physicochemical, sensory, cooking and pasting characteristics of rice.

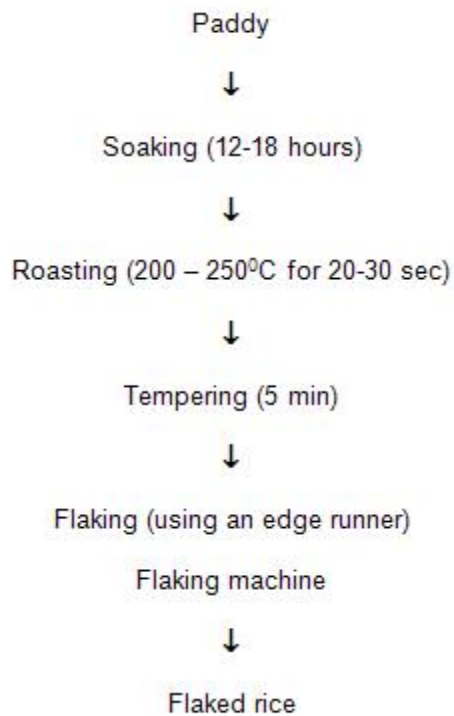
### **Accelerated Aged Rice**

The natural or conventional ageing process requires the rice to be stored for longer and has higher operational and maintenance costs. But artificial accelerated ageing doesn't require as much time and the associated costs are also much lower. Accelerated Aged Rice involves a short duration of thermal treatment and thermal seasoning of the paddy. It induces desirable changes to obtain the best cooking properties and resembles naturally aged rice.

### **FLAKED RICE**

Flaked rice is another important value added product prepared from paddy. Traditionally, it is prepared from soaked paddy, after heat treatment and immediate flattening using a flaking machine (an edge runner).



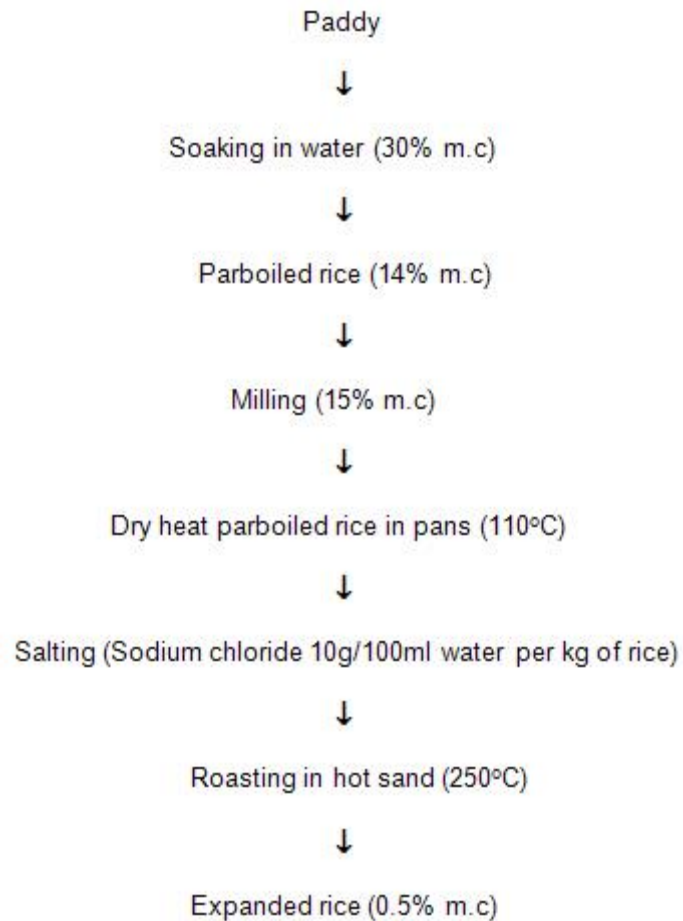


## **PUFFED RICE**

Expanded rice (murmura, pori, muri) is a traditional convenience food widely consumed in India either as such or with Jaggery, roasted Bengal gram and shredded vegetables and spices. The product is mostly produced in home or cottage sector by skilled artisans.

In the traditional process, the paddy is soaked in water preferably over night until saturation, drained and then either steamed or dry roasted in sand for parboiling. The parboiled paddy is milled, salted and again roasted in sand for expansion.





## **BYPRODUCTS OF RICE**

The main by-products of rice are rice husk or hull, rice bran, and brewer's rice.

- Rice husks or hulls are generated during the first stage of rice milling, when rough rice or paddy rice is husked.
- Rice bran is generated when brown rice moves through the whiteners and polishers. When paddy is hand-pounded or milled in a one-pass Engleberg steel huller, rice bran is not produced separately but mixed with rice hulls.
- Brewer's rice is separated produced when milled rice is sifted.

One hundred kilogram (100 kg) of paddy rice will generate approximately 5–10 kg of bran. Rice bran is a mixture of substances, including protein, fat, ash, and crude fiber. In many cases, bran contains tiny fractions of rice hull, which increases the ash content of bran. Bran composition is largely dependent on the milling process.

In modern rice mills, several different kinds of bran are produced: coarse bran (from the first whitening step), fine bran (from second whitening step) and polish (from the polishing step). Polish consists of part of the endosperm and is often referred to as meal.

Rice bran has a high nutritive value. Besides proteins, rice bran is an excellent source of vitamins B and E. Bran also contains small amounts of antioxidants, which are considered to lower cholesterol in humans. Rice bran contains 10–23% bran oil. The oily nature makes bran an excellent binder for animal feeds. Bran oil, once stabilized and extracted, is a high-quality vegetable oil for cooking or eating. The conventional use of rice bran is as an ingredient for animal feeds, in particular ruminants and poultry. In recent years however, advances in stabilization techniques have been made which has led to new uses for bran and its derivatives, most notably bran oil for cooking and waxes for cosmetic products. In the developing countries, rice bran is underutilized due to a lack of suitable stabilization techniques.

Brewer's rice is often used as an ingredient for beer brewing, hence the name. In rural areas, brewer's rice has a variety of uses including ingredients for rice flour and rice noodles.

## **PROCESSING OF WHEAT**

Wheat is one of the most important cereal crops in the World, with an estimated annual production of 540 - 580 million metric tonnes. Wheat belongs to the genus *Triticum* of the grass family Gramineae. Common wheat (*Triticum aestivum*) and durum wheat (*Triticum durum*) are the two major wheat groups grown for food use now. Wheat is the most valuable of all food grains and is widely used in all its stages, from whole to finely milled and sifted. In the bakery, wheat flour is the most important ingredient, which provides bulk and structure to most bakery products, including breads, cakes, cookies, and pastries.

### **TYPES OF WHEAT**

Wheat is classified into two groups: hard and soft. Hard wheat is higher in protein compared to soft wheat. It yields stronger flour, which forms more elastic dough, and is better for bread making when strong elastic dough is essential for high-leavened volume. Soft wheat is lower in protein, which forms weaker dough or batter, and is better for cake making.

### **WHEAT PROCESSING**

#### **Storage**

The quality of wheat is to be preserved while moving from the field to storage and subsequently to the processing mill. If not properly stored; insects, moisture damage, molds or other conditions may cause losses. Moisture content must be less than 20% before harvesting, and wheat is then carefully dried to moisture below 12.5%, a level which is regarded as safe for storage. The desired moisture content is achieved in kiln or in modern driers taking care of the temperature of the grain does not exceed 50°C.

#### **Milling**

The objective of wheat milling is to grind cleaned and tempered wheat by separating the outer husk from the internal endosperm. Early processing of wheat was accomplished by means of hand grinding, grinding stones, or mortar and pestle. Later on, wheat was milled between two

circular millstones, one fixed and the other mobile and rotating. Recent technology in wheat milling involves metal cylinders or rollers for milling purposes.

### **Cleaning**

Wheat received at mill may contain certain impurities entering from field, during storage and transportation, or accidentally. Frequently encountered impurities include: straws, chaff, sticks, weed seeds, other cereal grains, shrunken and broken kernels, infected kernels, mud, dust, stones, metal objects, etc. Wheat cleaning operation makes use of certain characteristics of impurities which are different from those of wheat e.g. size (length and width), shape, terminal velocity in the air currents, specific gravity, magnetic and electrostatic properties, colour, surface roughness, etc.

The grain is initially passed through a series of screens of selected apertures that removes matter either smaller or larger in size than the wheat kernel. Gross foreign material is removed over a set of sieves (rubble separator).

In gravity separator, impurities which are similar to wheat in size but different in specific gravity are separated out. Wheat grains are then moved on tilted screen, through which adjusted air currents are drawn. Heavier materials such as stones are separated and remain closer to screen, while lighter impurities and wheat floats down the screen.

After gravity separation, series of rotating discs separators remove impurities that are similar in diameter but different in shape from the wheat. This rotating discs with indentations pick-up only those wheat kernels that fit into the pockets and allow other grains such as oats, barley to pass through.

Dry scouring of wheat kernel removes any dirt adhering to it. In the scorer wheat kernel is bounced against a wall, which may be of a perforated sheet metal, a steel wire woven screen or any emery surface.

Magnetic separators separate foreign materials such as nails, pieces of metal that could damage equipments or generate spark, which could cause a dust explosion.

In final cleaning operation, wheat is washed by water. Wheat is immersed in water and then conveyed by means of a worm to a centrifugal machine called whizzer, where it is vigorously agitated and spun dried. Washing of wheat removes crease dust.

### **Conditioning / Tempering**

Conditioning of wheat is carried out primarily to improve the physical state of grain for milling. In conditioning moisture content of wheat kernel is adjusted. This includes heating and cooling of the grain for definite period of time, in order to obtain the desired moisture content and distribution. At this adjusted moisture level of wheat before milling, wheat endosperm becomes mellow and bran becomes tough. Bran that absorbs proper amount of moisture becomes elastic and will not splinter during grinding to contaminate the flour with fine particles, and thus flour becomes whiter in colour. The endosperm becomes mellow and more friable, thereby reducing the amount of power required to grind it.

Several methods are employed to condition the wheat. Heating the wheat, application of warm water, application of live steam, or just intensive mixing of wheat and water are some of the methods used to increase the amount and rate of water penetration into kernel.

Three factors affect the rate and level of water penetration into the kernel: temperature, amount of water (% moisture content) and time. The ideal water and wheat temperature for tempering condition is 25<sup>0</sup>C. Higher temperature will increase the rate of penetration into the kernel. Temperature above 50<sup>0</sup>C will change endosperm starch and protein characteristics.

Typical moisture contents of tempered wheat and tempering times are as follow:

#### **Typical moisture contents of tempered wheat and tempering times**

<b>Type of wheat</b>	<b>Optimum moisture content of tempered wheat</b>	<b>Tempering time (Hrs)</b>
Hard spring wheat	16 - 17%	36
Hard red winter wheat	15.5 - 16.5%	24
Soft wheat	14.5 - 15.5%	10
Durum wheat	16 - 17.5%	6

#### **Milling / Separation of flour**

Objective of wheat milling is to separate the branny cover and germ of the wheat kernel from the endosperm.

Wheat flour milling is a process that consists of controlled breaking, reduction and separation, Wheat flour milling involves three basic processes:

- i). Grinding: Fragmenting the grain or its parts
- ii). Sieving: Classifying mixtures of particles based on its particle size
- iii). Purifying: Separating bran from endosperm particles based on their terminal velocity, by means of air currents.

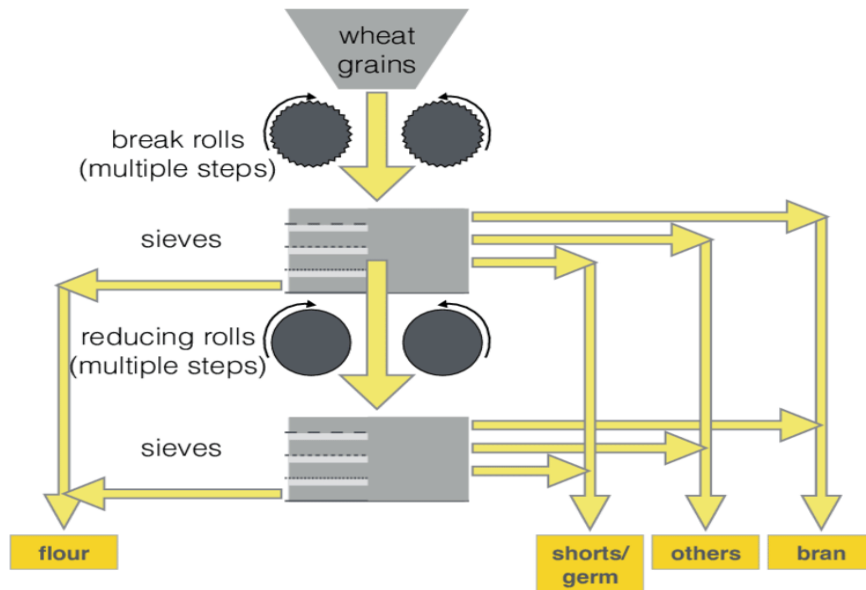


Diagram to show the basic layout of a roller mill.

Grinding of the wheat occurs between two cast rolls (break rolls) that rotate against each other. These rollers are fluted and they are not in contact with each other. The upper roller rotates two and a half times for each rotation of the lower one. Hence, the grain is engaged between fluted serrations of the rolls and broken or cut by the faster roll as it is held back by the slower roll. This initial stage in milling process is referred as breaks. The breaks are used in the grinding steps to separate the bran, germ and endosperm from each other. The grist coming out from the rolls is sifted through a plansifter. The plansifter is a machine consisting of a vertical nest of horizontal sieves, the whole assembly gyrating in a horizontal plane. A single plansifter consist of four or five different mesh sizes may yield five or six fractions of different particle size.

The series of break rolls and sieves converts the grain into semolina, which is small granule made up of endosperm. The outer husk is collected separately as bran. The semolina is separated into three grades: fine, medium, coarse in an operation called gradual reduction system. Here the rolls are smooth and one rotates only one and a quarter times for each rotation of the other.

The number of parts of flour by weight produced per 100 parts of wheat milled is known as the flour yield, or percentage extraction rate. The wheat grain contains 82% of white starchy endosperm, but it is never possible to separate it out fully from the bran. Extraction rates of different flours are as follow:

### Extraction rates of different flours

Sr. No.	Flour	Extraction rate (%)
1	Wholemeal flour	95
2	Brownish flour	85
3	Creamy flour	80
4	White flour	70

### FLOUR GRADE

Different grades of flour can be obtained by milling wheat.

#### Patent flours

Patent flours are from the more refined streams and vary considerably in the percentage of the total flours represented. Characteristics of these flours are determined by the percentage of separation. The manner in which the particles of endosperm are separated is called 'separation' whereas extraction, refers to the percentage of flour which has been extracted from wheat kernel. The following are approximate percentages of patent flours:

First patent: 70 per cent of total flour, used for cakes

Short patent: 80 per cent of total flour, is used for bread.

Medium patent (also called cut off flour): 90 per cent of total flour, used for breads.

Long or standard patent: 95 per cent of total flour

#### Clear flours

The flour remaining after the patent is removed is called clear flour and it may be separated in to different grades. It is also called low grade flour. This flour which comes from the tail end of the breaks and reduction system is dark in colour. Clear flours are strong and are suitable for rye and other dark breads. Clear flour has more good quality proteins. Flour made from soft wheat's is used for cakes, pastries and biscuits. Hard wheat varieties are used for the production of yeast leavened breads. Amber durum wheat's are used for the production of noodles, macaroni etc.

#### Red dog flours

The last reduction flour is called red dog. It is dark in colour and contains large amounts of bran and germ. It is usually sold as animal feed.

#### Wheat shorts

This is another fraction obtained in rolled milling of wheat. It is found mixed with bran and germ in the milled feed.

#### Germ

In the process of roller flour milling, germ is eliminated along with mill feeds. It can be

separated and used for the production of wheat germ oil. The residual solvent extracted wheat germ is in proteins and B- vitamins and can be used in the preparation of weaning foods.

## **FLOUR TREATMENTS**

### **Bleaching agents**

Flour contains a yellowish pigment, of which about 95% consists of xanthophyll or its esters. Bleaching of the natural pigment occurs very slowly when the flour is stored in bulk. Hence, to accelerate the bleaching process chemical bleaching agents are used. Nitrogen peroxide, chlorine, chlorine dioxide, nitrogen trichloride, benzoyl peroxide and acetone peroxide are the principal agents used for bleaching of wheat flour.

### **Maturing or improving agents**

The bread making quality of wheat flour improves during storage for a period of 1 - 2 months. This change in baking quality is known as maturation or ageing. Chemical improver accelerates the maturing process by modifying the physical properties of gluten during fermentation. The stickiness in dough gets reduced and hence improved handling properties, increased tolerance in the dough to varied conditions of fermentation, and in producing loaves of larger volume and more finely textured crumb.

The action of improvers is believed to be an oxidation of the sulphydral or thiol (SH) groups present in wheat gluten. Hence, the thiols are not available for participation in exchange reactions with disulphide (S:S) bonds. This reaction is considered to release the stress in dough and consequently the dough tightened. Potassium bromated, ascorbic acid, azodicarbonamide, stearyl lactylates, ammonium/potassium per sulfate, acid calcium phosphate, acid sodium pyrophosphate are widely used maturing agents in wheat flour.

Chlorine, chlorine dioxide and acetone peroxide acts as both bleaching as well as maturing agents.

### **Biological additives**

Enzymes such as amylases, proteases and oxidases are added to improve mixing, fermentation, flavour development, texture and storage properties of the baked products. Amylases break down starch molecules into glucose which is used by yeast to liberate carbon dioxide gas. Glucose oxidase enzyme is used to replace the chemical maturing agents such as potassium bromate which is banned in certain countries. Proteases are usually used in biscuit dough to reduce the mixing time. Lipoxigenase is used in bread dough as bleaching and maturing agent.

### **Emulsifiers**

Emulsifier reduces surface tension and thus facilitates mixing of fat and aqueous phases. Emulsifiers are widely used in biscuit dough, icings, cakes, etc. where it helps in improvement of the texture. Mono/diglycerides, lecithin, polyglycerol esters,

calcium stearoyl lactylate, polysorbates, sodium stearoyl lactylate are some of the widely used surfactants in manufacture of baked food products. Emulsifiers with low HLB (Hydrophilic Lipophilic Balance) value such as mono/diglyceride, lecithin are suitable for high fat products, while emulsifiers with higher HLB values (sodium stearoyl lactylate) are best suited for low fat high moisture foods.

### **Antimicrobial agents**

Bakery products are susceptible to microbial contamination especially with molds and rope formers owing to its high moisture and nutrient rich composition. Products get contaminated generally during processing steps such as cooling, slicing and wrapping. So wheat flour is usually added with certain mold inhibitors such as calcium/sodium propionate, sorbic acid or its calcium/potassium salts, acetic acid, lactic acid, acid calcium phosphate, sodium diacetate.

### **Vitamins and minerals**

Wheat milling involves removal of bran, germ and aleurone layers. These layers are rich in vitamins and minerals. Hence, to meet the deficit of these nutrients, wheat flour is usually enriched with vitamins and minerals. Even lysine which is an essential amino acid is substantially lost during processes such as milling and baking. So, the flour is enriched with lysine too.

### **BY-PRODUCTS**

The by-products from wheat milling process are known as wheatfeed. The common by-product feeds of wheat milling are wheat bran, middlings, mill run, shorts, red dog, screenings, germ meal, and germ oil. Wheat bran is a common wheat by-product. It is produced from break rolls. Nutritionally, in comparison to the other wheat millfeeds wheat bran contains the highest fiber content. Another relatively common wheat milling by-product is wheat middlings or wheat midds. Wheat middlings have a higher digestible energy content than wheat bran. Wheat shorts have a similar appearance to wheat middlings but with fine bran particles. Red dog is a minor millfeed. It is flour rich bran particles mostly aleurone layer.

### **CORN MILLING**

Corn or Maize (*Zea mays*, L) is used for animal feeding, for human consumption and for the manufacture of starch, corn syrup solids, sugar, beer, industrial spirit, etc. The products of milling include maize grits, meal, flour, and protein and corn steep liquor. Corn is consumed as human food in many forms. In its harvested wet form, it is consumed as vegetable. The ready-to-eat breakfast cereal corn flakes is made from maize grits. Popcorn the first snack food is undoubtedly the oldest snack food. The majority of corn consumed as human food has undergone milling and is consumed as a specific or modified fraction of the original cereal grain. Like other cereal grains, corn is milled to remove hulls and germ.

### **Corn Classification**

Maize or corn is classified commercially into four main classes as follows:

1. Dent varieties, which, when mature have a pronounced depression or dent at the top of the kernel. These have hard patches of densely packed endosperm cells at the outer edges of their endosperm and soft, opaque cells toward their center. Their shapes vary from long and narrow to wide and shallow.
2. Flint varieties, which have a continuous hard layer surrounding the endosperm. When these kernels dry, they dry evenly and therefore do not form a dent.
3. Flour or soft varieties, which are almost entirely opaque and soft. It is the soft maize varieties that are normally used to make corn flour.
4. Waxy maize varieties that have a waxy appearance especially when broken. The starch consists of very little amylose and is effectively 100% amylopectin (maize starch is normally about 30% amylose and 70% amylopectin).

## **CORN PROCESSING**

Maize is processed by dry or wet milling. Dry milling may or may not include de-germing as a preliminary step. Non-de-germing dry milling is carried out on a local basis in small grist mills or in modern roller mills using sifters and purifiers. The maize is ground to make coarse wholemeal of 85 - 95% extraction rate. This wholemeal is highly susceptible to the rancidity as the germ is retained which has a high oil content. Wet milling and dry milling involving de-germing are carried out in large commercial mills.

### **Dry milling**

- Two different systems are used for dry milling of corn.
- The non-degerming system grinds corn into mill with hardly any separation of germ. This corn meal has comparatively shorter shelf-life, as the germ is retained, which contains 32 - 35% oil. This oil in presence of oxygen and lipolytic enzymes is prone to oxidative and hydrolytic rancidity.
- Hence, it is necessary to remove the germ from corn to produce corn products with much lower fat content and greater shelf-life.
- Tempering and degerming system remove most of the germ and hull and leave the endosperm as free of oil and fiber as possible to recover maximum yield of endosperm and germ as large clean particles.
- Corn is cleaned to remove dirt, stones, insects, tramp iron, broken kernels and extraneous plant materials.
- The corn is then conditioned by adding water to increase the moisture content to 21%, and the moistened corn is allowed to equilibrate for 1 - 3 hrs. The objective of conditioning is to loosen the germ and toughen the bran and to mellow the endosperm so as to obtain a maximum yield of grits and a minimum yield of flour in the subsequent milling.
- Degerming and dehulling is carried out in one of the three ways:

1. Beall de-germinator (De-germer and corn huller)
  2. With roller mills and sifters
  3. With impact machines such as entoleters and gravity separators
- Once the germ and hull are removed, the endosperm is reduced in size to grits with roller mills. A complex array of additional roller mills and particle size separating equipment is used to purify and size endosperm particles. All products must be dried prior to packaging or bulk storage.

### **Wet milling**

- Wet milling of corn is achieved by a combination of chemical and mechanical means. Wet milling begins with steeping of cleaned corn for 30 - 48 hours with water. Sulfur dioxide is added to the water at the rate of 0.1 - 0.2% and the solution is heated to about 50°C. This condition prevents growth of putrefying microorganisms.
- During steeping, the kernel absorb solution and swell, activating enzymes native to the kernel to assist in breaking down the structure; the bisulfite ion reduces disulfide bonds in the protein matrix, increasing protein solubility and diminishing interactions between starch and protein; the lactic acid and/or exogenous enzymes produced by the lactobacilli help soften the endosperm.
- After steeping corn is ready for grinding and fractionating in disc attrition mill. The ground slurry is then pumped to hydroclones (liquid cyclones) to separate lighter-weight germs. The germs are dried and processed for oil and meal. The heavier underflow from the hydroclones is screened, and larger particles are finely reground with an impact mill to free the starch, protein, and fiber from each other.
- Fiber is separated and washed over series of screens.
- The remaining stream of starch and protein is passed through disc nozzle type centrifuges, where heavier starch is separated from the protein.
- The protein is dewatered using additional centrifuges and vacuum filters. The remaining starch slurry is washed and passed through hydroclones. Centrifuges and/or vacuum filter dewater the purified starch.

### **PROCESSING OF MALT**

The process of malting involves three main steps. The first is soaking the barley - also known as steeping - to awaken the dormant grain. Next, the grain is allowed to germinate and sprout. Finally, heating or kilning the barley produces its final color and flavor. In the production of malt based beverages and malted milk food, barley grain is first converted into malt. The malting process commence with the steeping of barley in water at a temperature of about 12°C for 36 hours with frequent aeration, to achieve a moisture level sufficient to activate metabolism in the embryonic and aleurone tissues, leading in turn to the development of hydrolytic enzymes. The wet barley is germinated around 14°C for a period of about 144 hours.

During germination, enzymes migrate through the starchy endosperm, progressing from the embryo end of the kernel to the distal end. In this mobilization phase, generally referred as “modification”, the cell wall and protein matrix of the starchy endosperm are degraded, exposing the starch granules. After a period of germination, the green malt is kilned at a temperature not exceeding 85<sup>0</sup>C, to arrest germination and stabilize the malt by lowering the moisture levels, typically to less than 5%. In the process, undesirable raw flavours are removed and pleasant malty notes are introduced. The kilning process is also responsible for developing the colour of the malt.

### **Step 1: Steeping**

The first and very critical step in creating quality malt is steeping. This is when the grain kernel is cleaned and brought to life with water and oxygen. This is done by immersing or “steeping” the grain in water, followed by an air rest period that allows the water content of the grain to increase. The absorbed water activates naturally existing enzymes and stimulates the grain to develop new enzymes. The water temperature and aeration are vital for producing high-quality malt. The steeping process can vary with grain type and size but typically occurs over a period of 24-48 hours. Air rests serve the added role of removing carbon dioxide and ethanol, which are the products of respiratory metabolism and may inhibit germination. Steeping is complete when the barley has reached a sufficient moisture level to allow a uniform breakdown of starches and proteins.

### **Step 2: Germinating**

The second step is to continue the germination process that started in steeping. Here, growth and modification of the grain occurs. From the outside of the grain, rootlets emerge from the kernel, and within the outer husk a shoot - or acrospire - grows. Modification is the breakdown of protein and carbohydrates and results in the opening up of the seeds’ starch reserves. This process typically takes 4-6 days and results in what is called “Green Malt.” To achieve a high quality and consistent germination process, our maltster controls temperature and moisture levels with regulated airflow and uniform water spray. To avoid grain clumping, non-uniform heating, and varying rates of germination, the grains are separated with periodic rotation. Even with modern equipment and this structured approach, the degree of modification is still gauged by our craft malster with his eyes, his sense of smell, and with his hands. Malting truly is part art and part science.

### **Step 3: Kilning**

The third and final step in the malting process is kilning. Convection heat treatment dries the green malt to prevent further germination. If germination continued, the kernel would keep growing and all of the starch reserves needed by the brewer would be used by the growing plant. For most malts, moisture is initially removed from the germinated grain - this is called Withering. Additional drying further reduces the moisture content and prepares the malt for flavor and color development. Other important results achieved during the kilning process include enzymatic activity and friability. It is the controlled variations in this step that produces the wide range of malt colors and flavors used by brewers in crafting their unique and distinctive ales and lagers.

## UNIT – II

### TECHNOLOGY OF PULSES

Pulses are defined as dried edible seeds of cultivated legumes. Pulses occupy important place in human diet. They serve as major sources of dietary protein and energy. Bengal gram/Chick pea (chana), pigeon pea (tur/arhar), cow pea (lobia), black gram (urad), green gram (moong), lentils (masur), peas (matar) are some of the major pulses grown in India.

#### PROCESSING OF PULSES

Processing of pulses is of primary importance in improving their nutritive value. The processing methods used are soaking, germination decortications, cooking and fermentation.

**Soaking:** Soaking in water is the first step in most methods of preparing pulses for consumption. As indicated above, soaking reduces the oligosaccharides of the raffinose family. Soaking also reduces the amount of phytic acid in pulses.

**Germination:** Germination improves the nutritive value of food pulses. The ascorbic acid content of pulses increases manifold after 48 hours of germination. Germinated and sprouted pulses have been used to prevent and cure scurvy. The riboflavin, niacin, choline and biotin contents of all pulses increase during germination. The germination process reduces and/or eliminates most of the antinutritional and toxic factors in several pulses.

**Decortication:** A simple method is to soak the seeds for a short time in water; the husk takes up more water than the seeds and may be easily separated by rubbing while still moist. In the alternative, the soaked grains may be dried and the husk removed by pounding and winnowing. Roasting also renders the husk easier to separate. Roasted legumes like those of Bengal gram and peas are widely used in India.

**Cooking:** Cooking destroys the enzyme inhibitors and thus improve the nutritional quality of food pulses. Cooking also improves the palatability.

**Fermentation:** The processing of food pulses by fermentation increases their digestibility, palatability and nutritive value. Fermentation process improves the availability of essential amino acids and, thus, the nutritional quality of protein of the blend. In general, the nutritive value of the legume based fermented foods has been shown to be higher than their raw counterparts.

#### MILLING OF PULSES

Pulses are consumed in its dehusked and split form which is termed as dal. Pulse milling (dal milling) is accomplished in three major steps namely: loosening of husk, dehusking and

splitting of pulses. Pulses are generally consumed in the form of Dal. Traditional methods for processing of pulses were labour intensive, time consuming and incurred losses. Modern technologies for processing of pulses have replaced old age methods and thus avoid losses and saves time. Processing of pulses involves two basic steps:

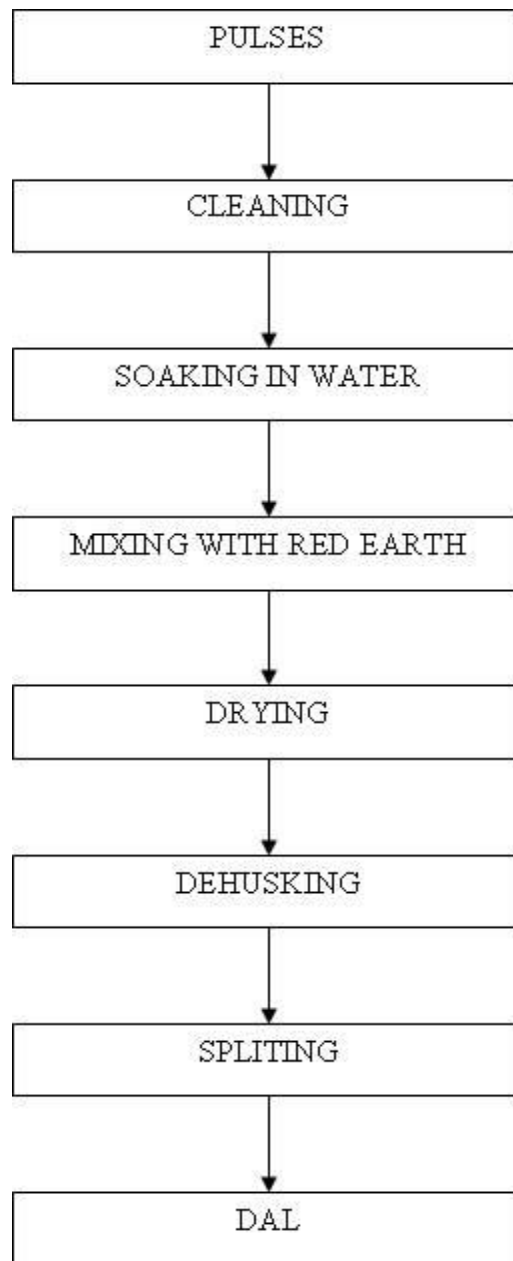
- (i) seed coat/husk loosening and its removal and
- (ii) conversion of seed grain into splits and grinding into flour depending upon its end-use. Various methods are employed for pulse/dal milling. Pulses undergo some basic unit operations during pulse milling such as cleaning and grading, drying, loosening of husk, dehusking, splitting and polishing.

### **Wet milling of pulses**

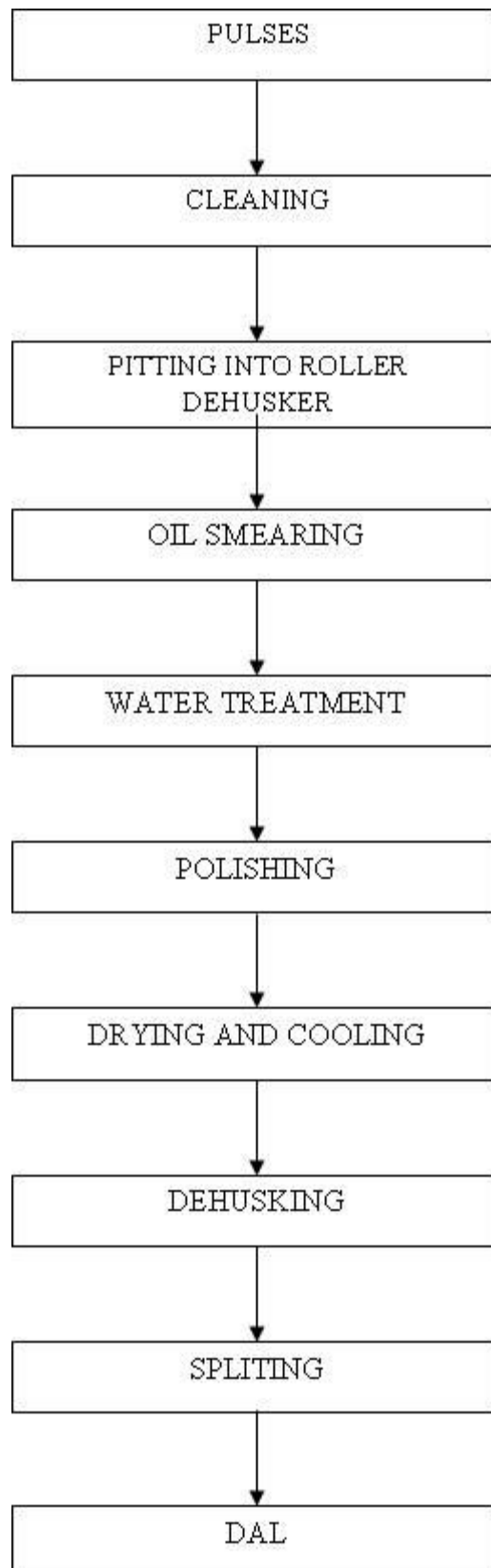
Wet method of pulse processing involves cleaning to remove dust, dirt, chaff, stone pieces, immature grains and other seeds. The easy-to-dehusk pulses are then soaked into water for a period of 2 - 8 hrs whereas difficult-to-dehusk type of pulses (pigeonpea, black gram, green gram) are often treated with red earth. The pulses are subsequently dried and then subjected to dehusking and splitting to obtain Dal.

### **Dry method of pulse milling**

In the case of the dry method of pulse milling, the pulses after cleaning are fed into a roller de-husker where a scratch, dent and crack are formed on the outer seed coat. Pitted pulses are then stored for 1 day to 3 days after applying oil on the surface. Generally, 150 - 250 gm oil per 100 kg pulses is applied. The oil diffuses between husk and cotyledon and thus facilitates the loosening of the husk. Water treatment (2.5 - 3.5 kg water/100 kg pulses for the overnight period) helps in further loosening the husk. Then the pulses are subjected to drying and cooling. Now, the dried pulses are de-husked and split to obtain dal.



**Wet milling of pulses**



**Dry milling of pulses**

## UNIT – III

### TECHNOLOGY OF OIL SEEDS

#### PROCESSING OF NUTS AND OIL SEEDS

The major role of edible oils and fats in our diet is to supply energy. Fat provides 9-kilo calories for each gram consumed. Fat contains polyunsaturated fatty acids (PUFA) which reduce blood cholesterol and is important in the prevention of coronary heart diseases. They also contain essential fatty acids (EFA) which are required for the maintenance of normal growth, reproduction and skin permeability. Apart from these fatty acids, fats are the only source of fat-soluble vitamins such as Vitamin A, D, E and K in our diet.

World's five major annual edible oilseeds are soybean (*Glycine max* (L.) Merr.), cottonseed (*Gossypium hirsutum* L.), rapeseed/canola (*Brassica napus* L. *B. rapa* L. and *B. juncea* L.), sunflower seed (*Helianthus annuus* L. var. *marcocarplus* DC.) and peanut/groundnut (*Arachis hypogaea* L.) Almost all oilseeds are processed commercially by oil expellers. Oilseeds are made up of tiny particles called cells. Oil glands are embedded in each cell which liberates oil on rupturing. Thus, the primary object of oilseed processing is to rupture the gland and cell wall which gives more yield of oil during processing. Recovery of oil (primarily triglycerides and phospholipids) from oilseeds is facilitated by rupturing the cell wall by heat and pressure during flaking, and by optional extrusion with an expander, followed by pressing or solvent extraction.

#### EXTRACTION OF OIL FROM OILSEEDS

##### Cleaning

Oilseeds received at the mill may contain certain impurities entering from the field, during storage and transportation, or accidentally. Frequently encountered impurities include straws, chaff, sticks, weed seeds, other grains, shrunken and broken seeds, infected seeds, mud, dust, stones, metal objects, etc. Cleaning of oilseeds comprises the removal of all the impurities mentioned above.

##### Conditioning/Tempering

The ground or flaked oilseeds are heated with live steam to about 90°C. The purpose of tempering is to facilitate oil recovery. The heat treatment ruptures all the cells, partly denatures the proteins and inactivates most of the enzymes. It is very essential to maintain the optimum temperature to avoid the formation of undesirable colouring compounds and aromas. After conditioning and moisture adjustment to about 3%, the oil is obtained by pressing and/or solvent extraction.

## Pressing

The oil is removed by pressure from an expeller or screw press. The residual oil in the resultant oilseed meal is about 4 - 7%. It is, however, more economical to apply lower pressures and to leave 15-20% of the oil in the flakes, and then to remove this oil by a solvent extraction process (prepress solvent extraction process).

### Oil extraction methods

Sr. No.	Method of oil extraction	Employed for	% residual oil in meal/cake	Remarks
1	Solvent extraction	Low oil seeds (less than 30% oil)	0.5 - 1.0%	<i>Oil is solubilized by solvent (n-hexane).</i>
2	Full/Hard pressing	High oil seeds (greater than 30% oil)	4.5 - 7.5%	<i>Seeds are passed through continuous screw press.</i>
3	Prepress-solvent extraction	High oil seeds (greater than 30% oil)	0.75 - 1.25%	<i>16 - 20% oil is extracted by screw press and the cake is then treated with solvent to achieve further extraction.</i>

## Extraction

The ground seeds are rolled into thin flakes by passing them between smooth steel rollers. The extraction is then performed using non-polar solvents such as food-grade hexane, as a solvent (boiling point 60-70°C). In addition to n-hexane, it contains 2- and 3-methyl pentane and 2,3-dimethylbutane and is free of aromatic compounds. Solvent removal from the raw oil-solvent mixture, called miscella, is achieved by distillation. The maximum amount of solvent remaining in the oil is 0.1%. The oil-free flakes are then steamed to remove the solvent (*desolventizing*) and, after dry heating (*toasting*), cooled and sold as protein-rich feed for cattle. The crude oil obtained either by pressing or solvent extraction contains suspended plant debris, protein and mucous substances. These impurities are removed by filtration.

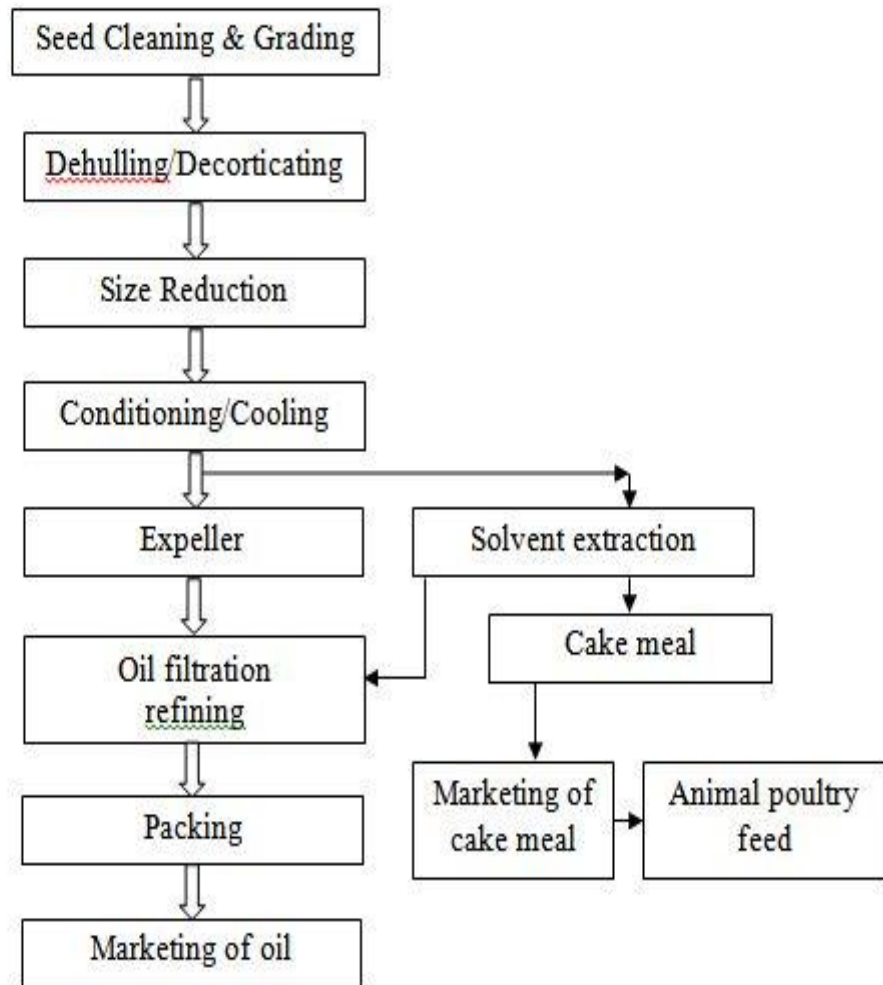
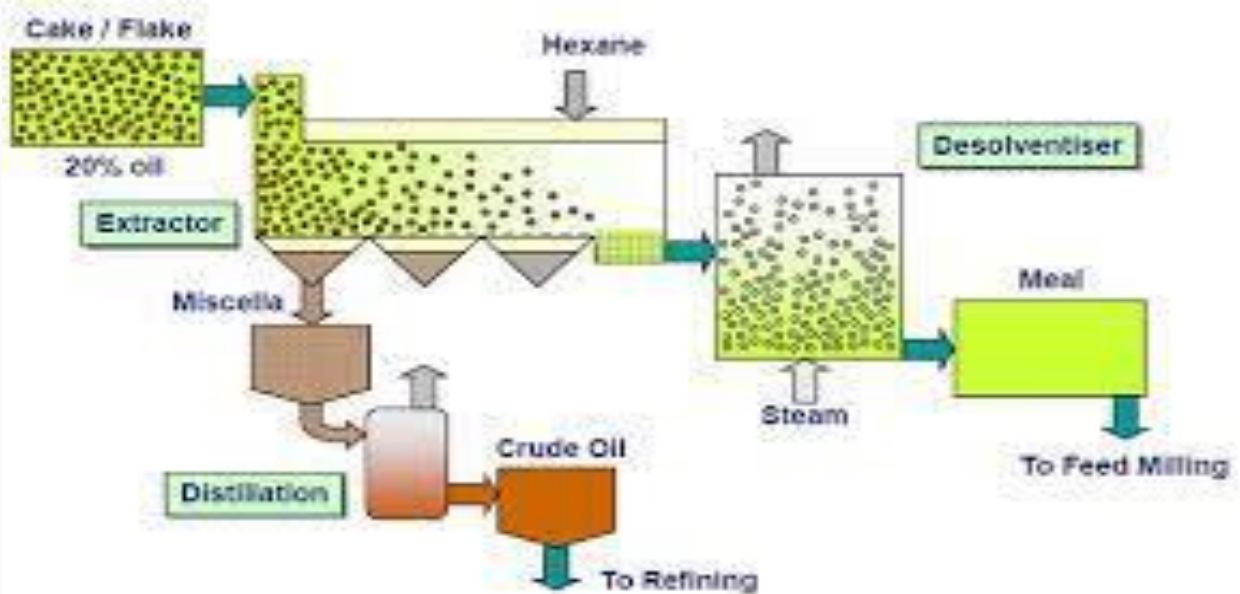


Fig. 7.1 Process flow chart of oil seeds processing



## **PROCESS OF OIL REFINING**

In many local markets, further refining is not required as the complexes of unrefined oils are preferred. International markets tend to prefer lighter less intense oils for cooking which means further processing of the oil. There is a series of refining processes that can be carried out after the oil has been filtered.

### **i) De-odorising**

Volatile compounds that produce bad odours can be eliminated through the process of sparging, i.e. bubbling steam through the oil, under a vacuum.

### **ii) Wintering**

Allowing the oil to stand for a time at low temperatures so that glycerides, which naturally occur in the oil, with higher melting points solidify and can then be removed from the oil by filtering. Over time glycerides can degrade releasing fatty acids into the oil increasing the acidity levels and reducing the quality.

### **iii) Neutralisation**

Fatty acids can be neutralized by adding a sodium hydroxide solution, also known as caustic soda, or by stripping, which is a similar process to de-odorising.

### **iv) Bleaching**

Some oils have a very dark colour to them that is unpopular with consumers. The appearance of oil can be lightened by bleaching.

### **v) De-gumming**

De-gumming is a way of treating seeds that have high phosphatide content. The phosphatide, which makes a gummy residue, is removed by mixing the oil with 2 to 3% water. This hydrated phosphatide can then be removed by settling, filtering or centrifuging.

## **RANCIDITY**

The change that a lipid undergoes, leading to an undesirable flavour and odour development is known as rancidity. This is brought about in two ways: hydrolysis and oxidation giving rise to hydrolytic rancidity and oxidative rancidity.

### **I) Hydrolytic rancidity**

Hydrolytic rancidity occurs when the fat is broken up into free fatty acids and glycerol in the presence of water. Hydrolysis is catalyzed by acid, bases, enzymes or thermal effects. When base is the hydrolyzing agent, the liberated fatty acids are converted into their salts (soaps) and the hydrolysis is termed "saponification". The other agents release free fatty acids and the reactions brought about by them are collectively known as lipolysis, or "hydrolytic rancidity". The presence of the enzyme lipoprotein lipase (LPL) quickens this process.

Rancidity in foods may be very slight, indicated by a loss of freshness to very severe, indicated by objectionable odours and flavours.

## **II) Oxidative rancidity**

Rancidity may also be caused by oxidative processes (Oxidative rancidity). Oxidation at the double bonds on the unsaturated glycerides may form peroxides which then decompose by hydrolysis to form aldehydes, ketones and acids of smaller carbon chain causing objectionable odor and taste. This process is called oxidative rancidity. It is greatly increased by exposure to light. Nearly all natural fats are oxidized when exposed to air, light and moisture. It has been observed that highly refined fats and distilled fatty acids or their esters begin to absorb atmospheric oxygen almost immediately upon exposure to it, whereas natural fats often exhibit an “induction period” of variable duration before oxidation begins. This oxidation of unsaturated glycerides are prevented by substances which are called “antioxidants”.

### **Antioxidants-preventing the deteriorative changes in fat and oils:**

Antioxidants are those compounds that prevent the oxidation of fat.  $\alpha$  Tocopherol is the natural antioxidant present in plant and animal tissues. The addition of minute amounts of certain synthetic compounds also prevents oxidation and they are called synthetic antioxidants.

e.g. Propyl gallate, Isoamyl gallate, BHT, BHA, Nordiguaretic acid, ethoxyquin, Tertiary Butylhydroquinone

Certain compounds induce oxidation by their presence and they are called as pro-oxidants e.g. iron, copper and other metal ions.

Some compounds increase the antioxidant activity of the antioxidants and they are called as synergies e.g. ascorbic acid, citric acid and phosphoric acids.

## **PROTEIN CONCENTRATES AND ISOLATES**

The major purpose of the preparation of concentrates and isolates from a protein source is to increase the concentration of proteins by the removal of non-protein ingredients from the source so that the smaller amounts can be used in the formulation to impart nutritional as well as functional properties. The methods utilized for the removal of non-protein ingredients should be such that they should not affect the nutritional and functional properties of the protein to a great extent.

### **Protein Concentrates and isolates**

The process for the production of protein isolate from soya beans and ground nuts consists of the following steps

1. solvent extraction of edible soya bean or peanut meal
2. extraction of proteins with dilute sodium hydroxide at pH 8.
3. precipitation of protein and pH 4.5 from the extract by the addition of hydrochloric acid.
4. filtration of proteins and washing with water.

5. Solubilize the wet protein in water by adjusting pH 7 and spray drying.

### **Solvent-extracted soya bean or ground meal**

Soyabean dhal (decuticled soybean) or decuticled groundnut is expressed in a screw press to remove oil. The cake is extracted with food grade hexane, desolventized and powdered.

### **Extraction of proteins**

The soya bean or ground nut cake flour (one part) is suspended in 15 parts of the weight of water. Concentrated sodium hydroxide solution is added while stirring till pH increases to about 8. The extract is separated using a basket centrifuge.

### **Precipitation of proteins**

The proteins in extract are precipitated by adjusting pH of the extract to 4.5 by the addition of hydrochloric acid. The proteins are separated using basket centrifuge and washed with water.

### **Solubilization of proteins and drying**

The wet proteins are suspended in four times the weight of water. The pH is adjusted to 7 by addition of sodium hydroxide. The resulting protein is spray dried.

### **Uses**

Protein isolate from soya bean or ground cake can be used in the production of vegetable toned milk, infant foods, protein enriched biscuits and bread.

## UNIT – IV

### FRUITS PROCESSING

#### PRINCIPLES OF FRUIT AND VEGETABLE PRESERVATION

All food preservation methods are based upon the general principle of preventing or retarding the causes of spoilage caused by microbial decomposition, enzymatic and non-enzymatic reaction, chemical or oxidative reactions and damage from mechanical causes, insects and rodents etc. Food preservation operates according to three principles, namely:

##### **Prevention or delay of microbial decomposition brought out by**

1. Keeping out microorganisms or asepsis
2. Removal of microorganisms e.g. washing, filtration etc.
3. Hindering the growth and activity of microorganisms by controlling the conditions required for the growth and activity of microorganisms by use of low temperature, drying, maintenance of anaerobic conditions or chemicals
4. Killing microorganisms by heat or irradiation

##### **Prevention or delay of self-decomposition of foods by**

1. Destroying or inactivating food enzymes e.g. blanching, low temperature storage, chemical preservation, drying etc.
2. Preventing or delay of chemical reactions e.g. prevention of oxidation with the use of antioxidants as oxygen speeds up decomposition of food and antioxidants deprives food from oxygen.

##### **Prevention of damage because of external factors such as insects, rodents, dust, odour, fumes, and mechanical, fire, heat or water damage.**

**Eg.** Use of boxes, cartons, and shock absorbing materials, sealed tight, vacuum-packaging etc.

#### PROCESSING OF JAMS

As per FSSAI, Jam means a product prepared from sound, ripe, fresh, dehydrated, frozen or previously packed fruits including fruit juices, fruit pulp, fruit juice concentrate or dry fruit by boiling its pieces or pulp or puree with nutritive sweeteners namely sugar, dextrose, invert sugar or liquid glucose to a suitable consistency. It may also contain fruit pieces and any other ingredients suitable to the products. It may be prepared from any of the suitable fruits, singly or in combination. It shall have the flavor of the original fruit(s) and shall be free from burnt or objectionable flavors and crystallization.

##### **The specific requirements for Jam are as follows:**

Total soluble solids (m/m) - Min. 65.0 %

The product shall be manufactured from a minimum of 45.0% by weight, of originally prepared, fruit, exclusive of any added sugar or optional ingredients of a finished product, except for Strawberry or Raspberry fruit, where it shall contain a minimum of 25.0% fruit.

As per FSSAI, Fruit cheese means the product prepared from pulp/puree of sound, ripe fruit (s), whether fresh, frozen, or previously preserved or dry fruits, by cooking with salt, and

nutritive sweeteners to attain a thick consistency so that it sets on cooling. The fruit cheese shall be neither too soft nor too hard to chew. It may be prepared from any of the suitable fruits, singly or in combination. It shall have the flavor of the original fruit(s) and shall be free from burnt objectionable flavors and crystallization.

The specific requirements of Fruit cheese are the same as specified for Fruit Jam.

### **Salient characteristics of jam**

The amount of pectin in the gel is quite small (< 1.0% of the weight of jam); sugar content is very high (60-70%). Of the remainder, the bulk is water with a small amount of fibrous matter and seeds.

For a chunky texture, some pieces of fruit are added about 5 minutes before the cooking is finished. If a stiffer or sweeter jam is desired, more thickener or pectin, honey or sugar may be added.

### **Fruit or fruit combinations**

Some fruits such as lemons and bitter oranges are rich in both acid and pectin and can be easily made into jam.

Some popular combinations include: pineapple, orange, banana, apple and plum.

### **Sugar**

55 parts of sugar is required for every 45 parts of fruit. With excess sugar, the jam becomes gummy and sticky.

The finished jam should have 30-50% invert sugar / glucose to avoid crystallization of cane sugar during storage.

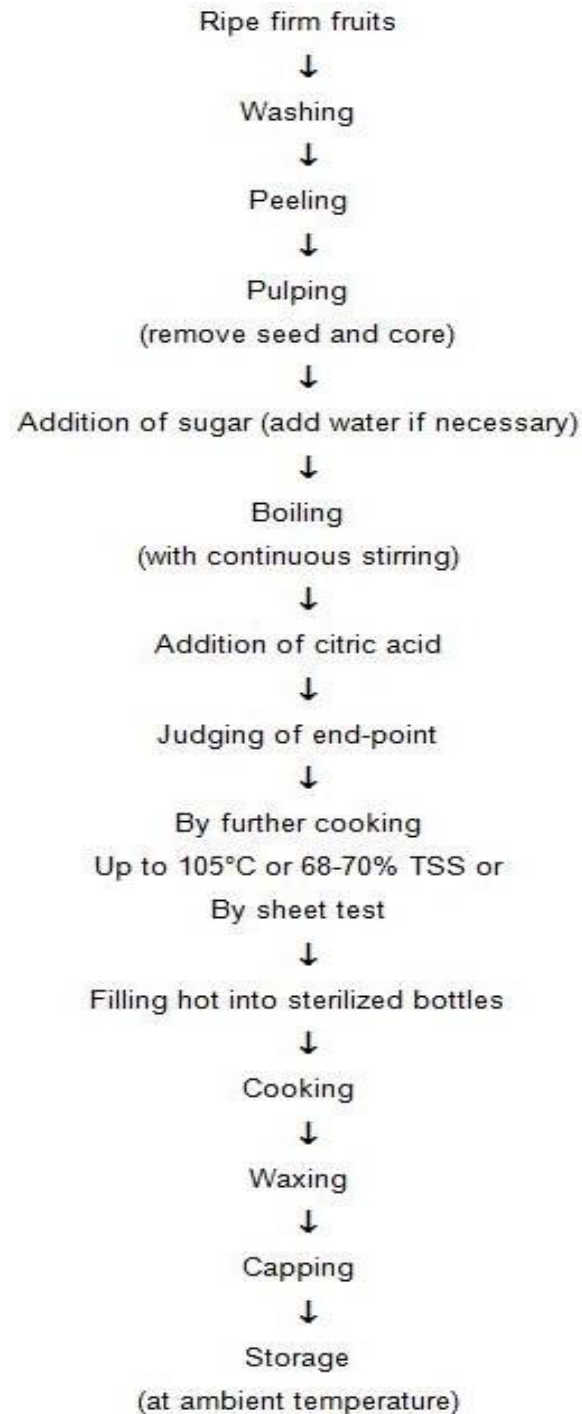
### **Acid**

Acidity can be supplemented by use of citric, tartaric or malic acid. The pH influences inversion of sugar and setting of the jam.

For pectin jam, pH of 3.3 gives a good set. For Apple and Plum jam, the pH range of 3.2-3.5 is desirable; optimum being 3.35.

### **Preparation of jam**

The process for preparing Fruit Jam is depicted in Fig.



### **Judging the end-point or point at which boiling is stopped**

#### **Determining the boiling point with a thermometer**

Thermometers or thermocouples are used to indicate the temperature which should be approximately the boiling point of a 65% sugar solution (103.9-105°C), when the process is complete. A 65% solid boils at 104.8°C at sea level. It should be 8-9°C higher than the boiling point of water at that place.

## **Hydrometers**

They help in determining the specific gravity of the material.

## **Refractometer**

We can determine the percentage solids i.e. TSS read directly on the scale. Use Abe or Zeiss type refractometers and for dark-colored jams/jelly, use projection type refractometers.

## **Sheeting or ladle test**

### *a) Cold plate test*

A drop of boiling liquid from the pan is placed on a plate and allowed to cool. If the jelly is about to set, it will crinkle when pushed with a finger.

### *b) Sheet or Flake test*

Some portion of a gel is taken in a large spoon or wooden ladle and cooled slightly. When dropped, if it falls in the form of flake or sheet, the end point is reached. If the jelly drips like syrup, it is required to further concentrate.

## **Weighing**

The boiling pan is weighed before and after putting the fruit extract and sugar in it. The weight of the finished gel should be 1.5 times the weight of sugar used. Industry uses specific gravity method, which gives a reliable indication of the point of readiness.

## **Storage of jam**

The surface of jam is susceptible to mold growth; yeast cannot grow or thrive. There is risk of mold development and fermentation, with alteration in the taste. Permitted preservatives may be used at levels sufficient to inhibit the growth of yeast and molds.

Jam should be stored in a fairly cool place or else some moisture evaporates resulting in surface graining and shrinkage of jam. It should be stored in a place having RH of ~ 80%.

## **PROCESSING OF JELLIES**

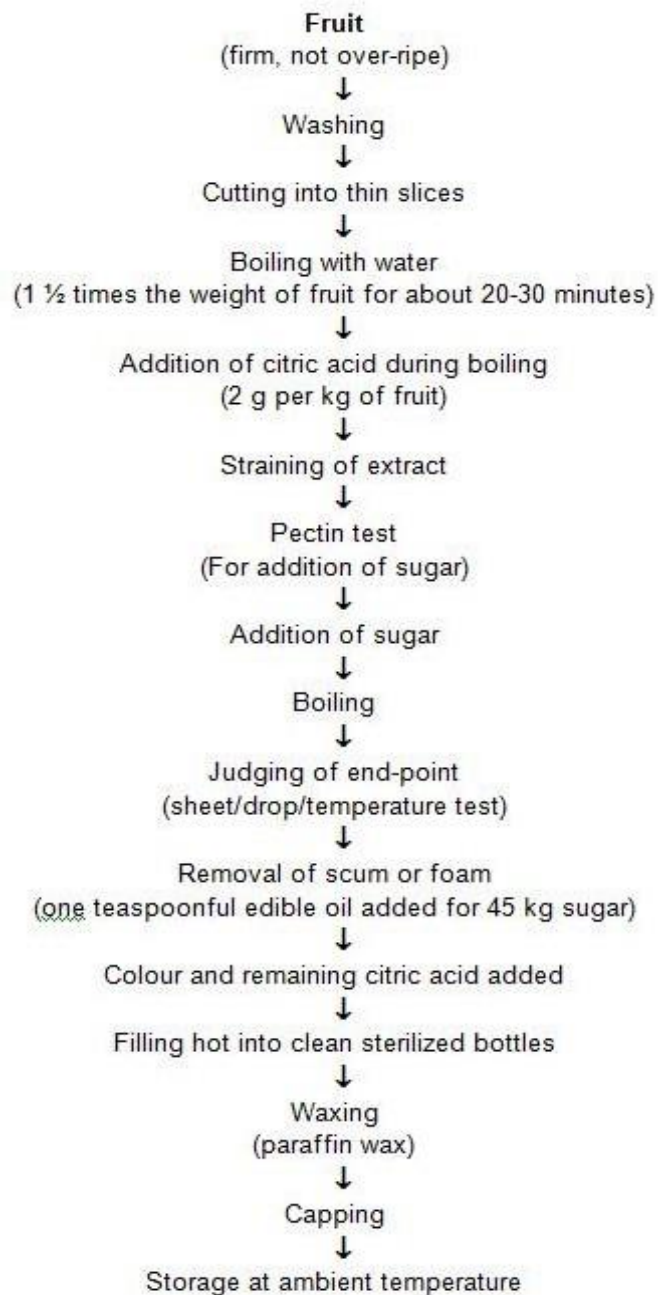
As per FSSAI, Fruit Jelly means the product prepared by boiling fruit juice or fruit(s) of sound quality, with or without water, expressing and straining the juice, adding nutritive sweeteners, and concentrating to such a consistency that gelatinization takes place on cooling. The product shall not be syrupy, sticky or gummy and shall be clear, sparkling and transparent.

The specific requirements are as shown below:

Total soluble solids (m/m) - Min. 65.0 %

The product shall be manufactured from minimum 45.0%, by weight, of original prepared fruit, exclusive of any added sugar or optional ingredients of the finished product.

## Flow chart for preparation of jelly



## Defects in jelly

### Crystals in Jelly

Sugar crystallization may result from:

- (a) Too much sugar

(b) Too little acid

(c) Overcooking of jelly

(d) Too long a delay in sealing the container of jelly.

Crystals may sometimes be found in jelly because during the boiling, syrup spatters on the side of the pan and dries up. In subsequent pouring of the finished product, these crystals (act as seed material) are carried into the glasses of jelly.

### **Cloudy jelly**

Usually occurs with the red juices. It is caused by imperfect straining. Restraining of juice without pressure brings a lower yield, but ensures a clear product.

### **Failure to gel**

#### *a) Causative factors*

Improper balance of pectin, acid, sugar and mineral salts, which may come about in several ways:

- Fruit used may lack sufficient pectin or acid or both
- Overcooking may destroy so much pectin that a gummy mass is formed
- Undercooking, due to insufficient concentration
- Too much water used for extraction of juice, so that the proportion of sugar is too great for the pectin and the long time required for evaporation may destroy some of the pectin.

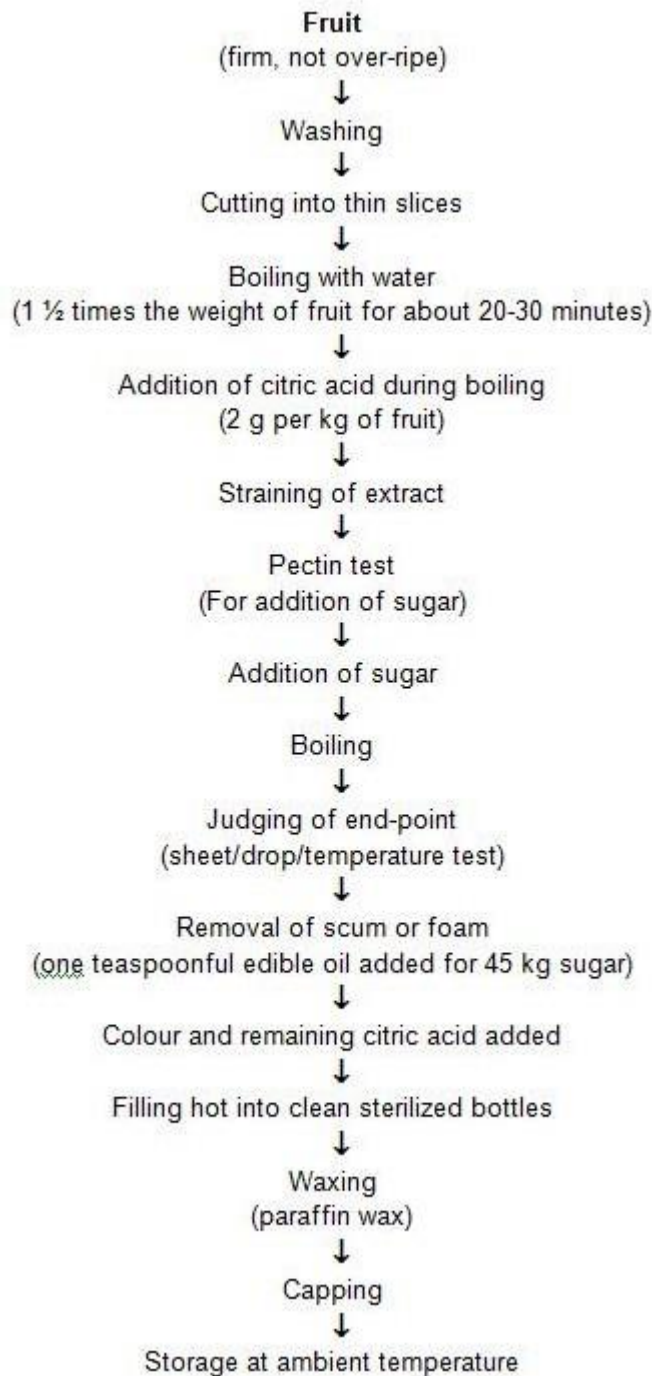
### **Tough Jelly**

The jelly becomes tough or stringy when too little sugar is used for the quantity of fruit juice used or when boiling is continued after the jelling point has been reached.

## **PROCESSING OF MARMALADE**

As per FSSAI, Marmalade means a product prepared by boiling sound fruits with peel, pulp and juice, with or without water, added nutritive sweeteners, and concentrating to such a consistency that gelatinization takes place on the cooling of the product. It shall not be syrupy, sticky or gummy and shall be clear and transparent.

### **Flowchart for processing of marmalade**



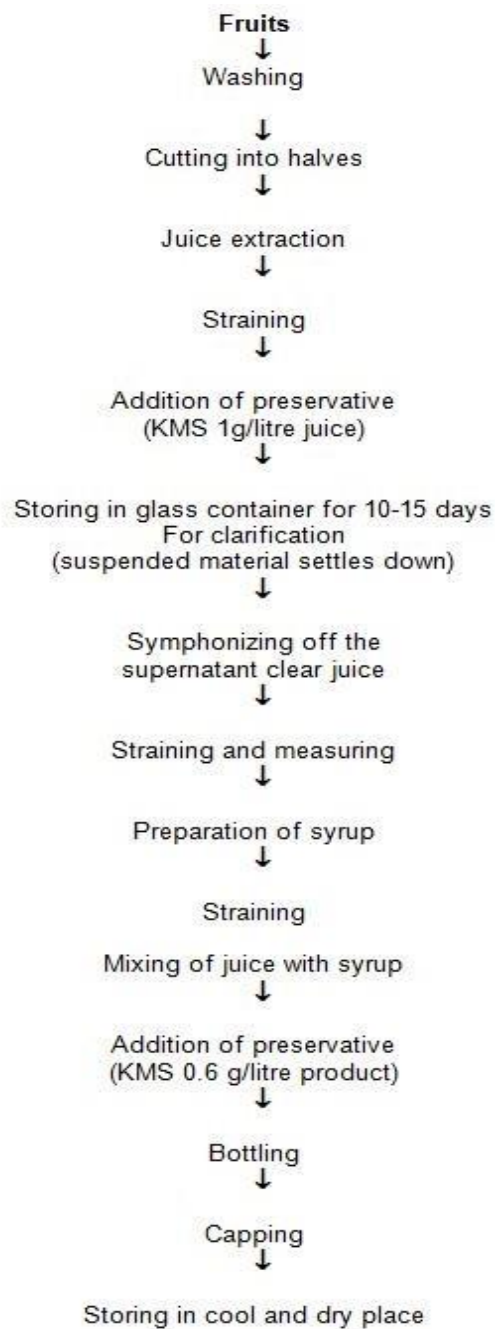
## PROCESSING OF CORDIAL

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<sup>o</sup> Brix. The acidity of the cordial should not be more than 3.5 per cent as anhydrous citric acid. The maximum permissible limit of preservatives 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 is generally consumed by mixing it with alcoholic beverages like gin.

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

### Flowchart for processing of cordial



## **PROCESSING OF SQUASHES AND CRUSHES**

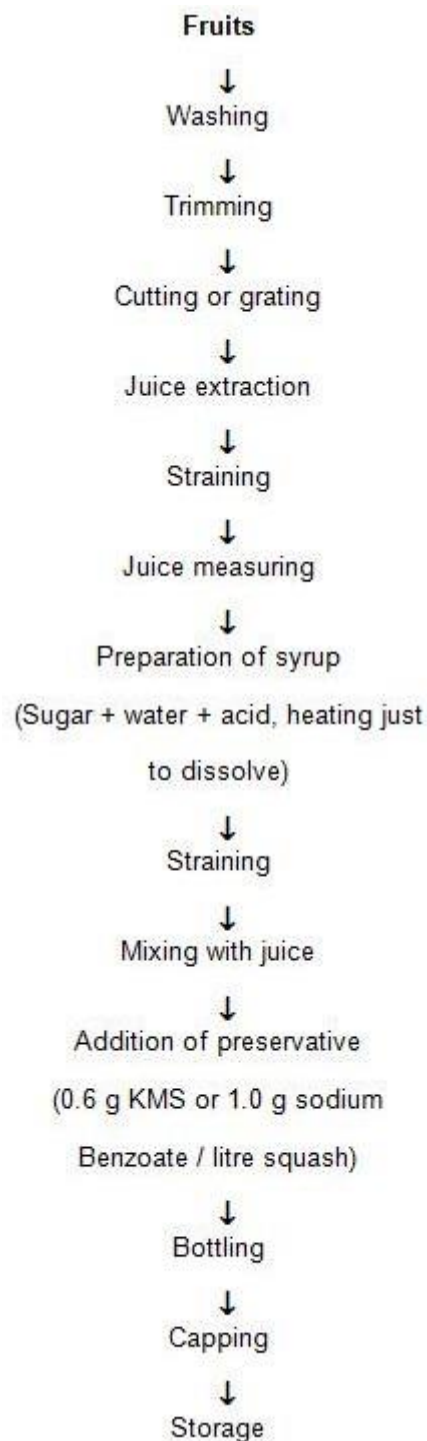
Squash is the product, which is prepared by mixing of calculated quantity of fruit juice or pulp, with sugar, acid and other ingredients. As per FSSAI specifications, squash should contain not less than 25 per cent fruit content in finished product and the total soluble solids content should not be less 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.

## Flowchart for processing of squash



## PROCESSING OF 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° 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 de-esterification 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.

### **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<sup>0</sup>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<sup>0</sup>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.

### **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<sup>0</sup>C. The pasteurization conditions are 80-85<sup>0</sup>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.

### **Hot fill operation**

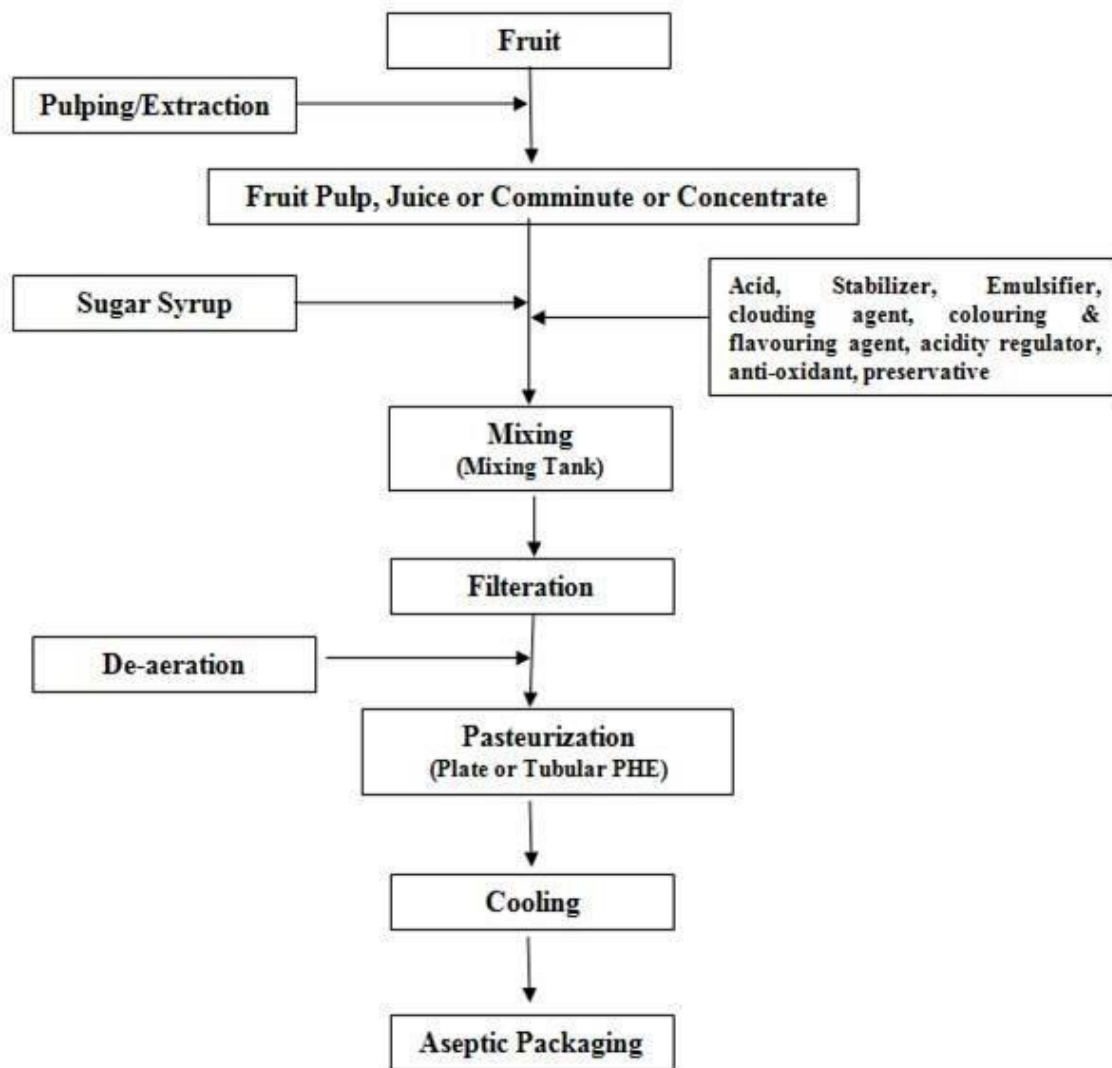
Hot filling offer a simpler mean of ensuring microbial integrity of the nectars. The bulk product is heated to a pre-determined temperature then filled hot (70-85<sup>0</sup>C) in packs and sealed immediately. In case of glass bottle they should be pre-heated to minimize thermal shock. The packs are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

## **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.

### Ingredients used in dilutable beverages

<b>S. No.</b>	<b>Ingredient</b>	<b>Remark</b>
<b>1</b>	<b>Fruit Components</b>	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.
<b>2</b>	<b>Syrup</b>	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 sterilization.
<b>3</b>	<b>Acid</b>	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.
<b>4</b>	<b>Preservatives</b>	Mainly added to prevent growth of fungi, yeast, lactic acid bacteria. Permitted are sulphur dioxide, benzoic acid and sorbic acid.
<b>5</b>	<b>Flavourings</b>	Mostly natural or natural identical flavourings are used. Must improve the flavour of beverages without affecting other properties.
<b>6</b>	<b>Colourings</b>	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.
<b>7</b>	<b>Other Additives</b>	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.



### Process flow diagram for the manufacture of dilutable beverages

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

## EFFECT OF PROCESSING ON PIGMENTS

### Chlorophyll

All green leaves and green colour vegetables like beans and peas contain chlorophyll. The complex structure and conjugation of proteins make chlorophyll very susceptible to chemical changes in cooking and consequently, the pleasant green color is difficult to retain.

**Effect of putting in hot water** - When greens are put in boiling water, the green color becomes brighter. This is due to the greater translucency of plant tissue due to the expulsion of intercellular air collapse of the intercellular space.

**Solubility in water** – Hydrolysis of ester linkages yields a compound chlorophyllide which is water soluble. A limited amount of chlorophyllide produced during the storage of certain green vegetables prior to cooking accounts for the light green tint of the cooking water.

**Effect of prolonged cooking and acid** – Destruction of chlorophyll increases with cooking time. Chlorophyll – a is more readily converted to pheophytin than chlorophyll-b. Green vegetables should be cooked for a very short time, less than 7 minutes to retain the color. Magnesium present in the structure of chlorophyll is rather easily displaced by hydrogen molecule when it is heated in the presence of organic acid. A pale greenish grey compound known as pheophytin- a or an olive- green pheophytin-b results.

**Effect of Sodium bicarbonate** -When sodium bicarbonate reacts with chlorophyll the phetyl and methyl groups are displaced and a bright green water-soluble chlorophyllin is formed.

**Effect of calcium salts** – The addition of a small amount of calcium acetate or other calcium salt prevents the mushiness by blocking the breakdown of the hemicelluloses.

### **Carotenoids**

Ordinary cooking conditions have little effect on the colour or the nutritive value of carotenoid. The colour is little affected by acid, alkali and the volume of the water. The nutritive value is protected during cooking by the insolubility in water.

- **Effect of heat and oxidation:** the high degree of unsaturation of the carotenoids makes them susceptible to oxidation with the resulting loss of color after the food containing them has been dried. The loss in intensity of color is not only due to oxidation of the unsaturation of carotene but also shift from trans form to cis form.
- **Effect of cooking in fat:** an appreciable amount and enough to affect the color will dissolve in ghee when carrot kheer or halwa is made.

### **Anthocyanins**

As the pH changes the colour of the anthocyanins changes. At an acidic pH of 3 it maintains red colour. As the pH increases to a weak acid or neutral solution the quinone has a violet color.

### **Betalains**

An acidic medium promotes a reddish colour where as a neutral or somewhat alkaline pH brings out brownish blue of the pigment.

### **Anthoxanthins**

The colour of the vegetables will be whiter if little acid such as lime juice or vinegar is added during cooking. If the water in which cauliflower is cooked is slightly alkaline, it will have a distinctly yellow colour to it. They turn yellow or orange in the presence of alkali. This is used as a confirmatory test.

## Phenolic content

Method of processing has no effect on phenolic content in spinach and other vegetables like onion and tomato. Boiling, pressure cooking and microwave cooking significantly decreased phenolic content in amaranth. In brinjal there is a significant increase by all the methods as compared to the raw brinjals. In French beans processing increased phenolic content.

## Sulphur containing vegetables

The eye irritating substance in onion is an acid derived specifically from (+) –S-(prop-1-enyl) –L-Cysteine sulfoxide as a result of the action of an enzyme. The irritant is propenylsulphenic acid, which decomposes rather rapidly. This compound and many of the sulphur compounds contributing flavours to various members of the allium genus are quite volatile and escapes during cooking unless the cooking time is short. When onions are chilled in the refrigerator or in a bowl of cold water the enzymes in the onion slow down at a molecular levels and watering of eyes is reduced.

## Loss of nutrients during cooking

- Losses begin from pre-preparation onwards, like peeling the vitamins presents under the skin may be lost.
- Carrots have a valuable layer of nutrients under the skin so they should be scraped but not peeled thick.
- Throwing away outer leaves of cabbage can result in loss of carotene.
- Beet root, carrot and cauliflower leaves are very nutritious, hence discarding these leaves results in loss of nutrients.

**Solvent action of water:** Water soluble nutrients may be dissolved in the cooking water and the nutrients may be lost. Losses by solution can be reduced by the following methods:

- Cut the vegetable into bigger pieces so that the exposure of the vitamins to water is less. When carrots are cut in crosswise the loss of ascorbic acid is greater than that when they are cut lengthwise.
- Soaking or washing time should be reduced. So that enough time is not given for the water soluble nutrients to get dissolved in water.
- Wash the vegetables with the skin and later should be peeled and cut.
- Use as small quantity of water as possible so that there is no extra water at all.
- Cook for a short time. As period of cooking increases more and more of ascorbic acid leaches into the water.
- Cook the vegetables by steaming and pressure cooking, where no additional water is added.
- Cover the vessel with a lid to hasten the cooking process.
- Cook the vegetables with the skin so that the leaching of vitamins into the water would be less.
- Leached water can be used in cooking.

## Oxidation and chemical decomposition

- Losses of nutrients can occur by chemical decomposition which may be caused by the reaction of the cooking water or by heat.
- Vitamin C is readily oxidisable and if this proceeds beyond the stage of dehydro- ascorbic acid, all vitamin activity is permanently lost.

- Oxidation may be accelerated by enzymatic action, by heat, by an alkaline medium by traces of copper and by free access to atmospheric oxygen.
- Vitamin A gets oxidized by dehydration or application of dry heat.

### **Prevention of losses by oxidation or chemical decomposition**

- Cut the vegetables into bigger pieces so that the exposure is less.
- Cut and use it immediately. By grinding, the losses will be more due to greater atmospheric exposure. By extraction of juice the losses are greater.
- Start cooking with boiling water. The greatest destruction of ascorbic acid occurs during the first minute or two of the cooking period. This destruction is the result of the presence of both oxygen and of oxidizing enzymes in the plant tissue. Water should be boiling when the vegetable is put to cook to expel oxygen from the tissues which catalyses the oxidation of ascorbic acid.
- Cover the pan so that there is no direct contact with the atmospheric oxygen.
- Use a sharp knife. When sharp knife is used to cut cabbage bruising is avoided and loss of ascorbic acid is reduced.
- The more alkaline the solution, the faster is the rate of destruction especially temperature and time of heating are increased. Ascorbic acid is protected to some extent when heated in the natural acids of certain foods such as tomatoes, vinegar, tamarind and lime juices. The use of baking soda increases the loss of thiamine and vitamin C.
- After cooking, the food has to be consumed immediately; even if it is kept in the refrigerator, the losses continue to occur.

Riboflavin and niacin are stable even at 100<sup>0</sup>C. Riboflavin is sensitive to light. Foods which are exposed to sunlight before cooking causes riboflavin loss. Minerals are not destroyed by cooking.

There is maximum retention in steaming and pressure cooking because there are less losses due to leaching. The richer the vitamin C in the raw vegetable, the more is the retention in steaming and pressure cooking.

### **Addition of baking soda**

Sometimes, baking soda is added to vegetables to improve the colour or to hasten cooking process. At alkaline PH, thiamine are unstable and vitamin C. Alkaline medium increases losses due to heat. Folic acid is also lost in alkaline medium.

## UNIT – V

### BEVERAGES

A Beverage is composed chiefly of water used as a drink for the purpose of relieving thirst and introducing fluid to the body, nourishing the body, and stimulating or soothing the individual.

#### CLASSIFICATION

Beverages may be classified as alcoholic or non-alcoholic.

**Alcoholic beverages** - These are of two types fermented and distilled. Fermented beverages are made with grains and fruits.

Example: Beer, wine Perry, Cider.

The fermentation takes place in the presence of yeast in which sugars are converted into ethyl alcohol liberating carbon dioxide and water.

Distilled beverages are obtained from alcoholic fermentation and distillation of substrates such as grains and fruits.

Example: Whisky, Brandy, Vodka, Rum

**Non-alcoholic beverages** - Non-alcoholic beverages are classified according to their function in the body. A particular beverage may have more than one function.

Refreshing – A refreshing beverage makes one feel energetic and cool after consumption.

Example: Buttermilk, lemon water

Nourishing - Nourishing beverages are those that are high in energy and protein.

Example: milk, fruit juices, milkshakes

Stimulating - Stimulating beverages have caffeine that stimulates the central nervous system

Example: coffee, tea

Soothing - Soothing beverages reduces pain or discomfort

Example: warm milk, hot

Appetizing - Beverages that increase appetite

Example: soups, fruit juice

#### PROCESSING OF BEER

Barley beers can be divided into two broad groups: top-fermented beers and bottom-fermented beers. This distinction is based on whether the yeast remains at the top of the brew (top-fermented beers) or sediments at the bottom (bottom-fermented beers) at the end of the fermentation.

## **Raw materials for brewing**

The raw materials used in brewing are barley, malt, adjuncts, yeasts, hops, and water.

### **a) Brewer's yeasts**

Yeasts in general will produce alcohol from sugars under anaerobic conditions, but not all yeasts are necessarily suitable for brewing. Brewing yeasts besides producing alcohol, are able to produce from wort sugars and proteins in a balanced proportion of esters, acids, higher alcohols, and ketones which contribute to the peculiar flavor of the beer.

### **b) Brewery Processes**

The processes involved in the conversion of barley malt to beer may be divided into the following:

1. Malting
2. Cleaning and milling of the malt
3. Mashing
4. Mash operation
5. Wort boiling treatment
6. Fermentation
7. Storage or lagering
8. Packaging

#### **1. Malting**

The purpose of malting is to develop amylases and proteases in the grain. These enzymes are produced by the germinated barley to enable it to break down the carbohydrates and proteins in the grain to nourish the germinated seedling before its photosynthetic systems are developed enough to support the plant.

#### **2. Cleaning and milling of malt**

The purpose of milling is to expose particles of the malt to the hydrolytic effects of malt enzymes during the mashing process. The finer the particles, the greater the extract from the malt.

#### **3. Mashing**

Mashing is the central part of brewing. It determines the nature of the wort, hence the nature of the nutrients available to the yeasts and therefore the type of beer produced. The purpose of mashing is to extract as much as possible of the soluble portion of the malt and to enzymatically hydrolyze insoluble portions of the malt and adjuncts. The aqueous solution resulting from mashing is known as wort. The wort is boiled for 1-1½ hours in a stainless steel kettle. When corn syrup or sucrose is used as an adjunct it is added at the beginning of the boiling. Hops are

also added, some before and some at the end of the boiling. Hops are the dried cone-shaped female flower of the hop plant - *Humulus lupulus*. The importance of hops in brewing lies in its resins which provide the precursors of the bitter principles in beer and the essential (volatile) oils which provide the hop aroma.

The purpose of boiling is as follows.

- (a) To *concentrate* the wort,
- (b) To *sterilize* the wort
- (c) To *inactivate* any enzymes
- (d) To *extract* soluble materials from the hops
- (e) To precipitate protein, which forms large flocs because of heat denaturation and complexing with tannins extracted from the hops and malt husks. Unprecipitated proteins form hazes in the beer, but too little protein leads to poor foam head formation.
- (f) To develop color in the beer; some of the color in beer comes from malting but the bulk develops during wort boiling. Color is formed by several chemical reactions including caramelization of sugars, oxidation of phenolic compounds, and reactions between amino acids and reducing sugars.
- (g) Removal of volatile compounds: volatile compounds such as fatty acids which could lead to rancidity in the beer are removed.

#### **4. Fermentation**

The cooled wort is pumped or allowed to flow by gravity into fermentation tanks and yeast is inoculated or 'pitched in' at a rate of  $7-15 \times 10^6$  yeast cells/ml, usually collected from a previous brew. The progress of fermentation is followed by wort-specific gravity. During fermentation, the gravity of the wort gradually decreases because yeasts are using up the extract. However, alcohol is also being formed. As alcohol has a lower gravity than wort the reading of the special hydrometer (known as a saccharometer) is even lower. °Brix is used in the sugar industry, whereas Balling (United States) and °Plato (continental Europe) are used in the brewing industry.

#### **5. Lagering**

During lagering secondary fermentation occurs. Yeasts are sometimes added to induce this secondary fermentation, utilizing some sugars in the green beer. The secondary fermentation saturates the beer with CO<sub>2</sub>.

#### **Packaging**

The beer is transferred to pressure tanks from where it is distributed to cans, bottles, and other containers. The beer is not allowed to come in contact with oxygen during this operation; it is also not allowed to lose CO<sub>2</sub> or become contaminated with microorganisms. To achieve these objectives, the beer is added to the tanks under a CO<sub>2</sub> atmosphere, bottled under a counter pressure of CO<sub>2</sub>, and all the equipment is cleaned and disinfected regularly.

## Beer defects

The most important beer defect is the presence of haze or turbidity, which can be of biological or physicochemical origin. Biological turbidity is caused by spoilage organisms and arises because of poor brewery hygiene (i.e. poorly washed pipes) and poor pasteurization. Spoilage organisms in beer must be able to survive the following stringent conditions found in beer: low pH, the antiseptic substances in hops, pasteurization of beer, and anaerobic conditions.

Yeasts and certain bacteria are responsible for biological spoilage because they can withstand these. Wild or unwanted yeasts which have been identified in beer spoilage are spread into many genera including *Kloeckera*, *Hansenula*, and *Brettanomyces*, but *Saccharomyces* spp appear to be commonest, particularly in top-fermented beers. These include *Sacch. cerevisiae* var. *turbidans*, and *Sacch. diastaticus*. The latter is important because of its ability to grow on dextrans in beer, thereby causing hazes and off-flavors. Among the bacteria, *Acetobacter*, and the lactic acid bacteria, *Lactobacillus* and *Streptococcus* are the most important. The latter are tolerant of low pH and hop antiseptics and are microaerophilic hence they grow well in beer. *Acetobacter* is an acetic acid bacterium and produces acetic acid from alcohol thereby giving rise to sourness in beer. *Lactobacillus pastorianus* is the typical beer spoiling lactobacilli, in top-fermented beers, where it produces sourness and a silky type of turbidity. *Streptococcus damnosus* (*Pediococcus damnosus*, *Pediococcus cerevisiae*) is known as 'beer sarcina' and gives rise to 'sarcina sickness' of beer which is characterized by a honey-like odor.

## PROCESSING OF WINE

Wine is by common usage defined as a product of the "normal alcoholic fermentation of the juice of sound ripe grapes". Nevertheless, any fruit with a good proportion of sugar may be used for wine production. If the term is not qualified then it is regarded as being derived from grapes, *Vitis vinifera*. The production of wine is simpler than that of beer in that no need exists for malting since sugars are already present in the fruit juice being used. This however exposes wine-making to greater contamination hazards

### Processes in wine making

#### a. Crushing of grapes

Selected ripe grapes are crushed to release the juice which is known as 'must', after the stalks which support the fruits have been removed. These stalks contain tannins which would give the wine a harsh taste if left in the must. The skin contains most of the materials which give wine its aroma and color. Grape juice has an acidity of 0.60-0.65% and a pH of 3.0-4.0 due mainly to malic and tartaric acids with a little citric acid.

#### b. Fermentation

(i) **Yeast used:** The grapes themselves harbor a natural flora of microorganisms (the bloom) which in previous times brought about the fermentation and contributed to the special characters of various wines. Yeasts are then inoculated into the must. The yeast which is used is *Saccaromyces cerevisiae* var. *ellipsoideus* (synonyms: *Sacch. cerevisiae*, *Sacch. ellipsoideus*, *Sacch. vini*).

Wine yeasts have the following characteristics: (a) growth at the relatively high acidity (i.e., low pH) of grape juice; (b) resistance to the high alcohol content (higher than 10%); (c) resistance to sulfite.

### c. Control of fermentation

(a) **Temperature:** Heat is released during the fermentation. It has been calculated the temperature of a must containing 22% sugar would rise 52°F (11°C) if all the heat were stopped from escaping. If the initial temperature were 60°F (16°C) the temperature would be 100°F (38°C) and fermentation would halt while only 5% alcohol has been accumulated. For this reason, the fermentation is cooled and the temperature is maintained at around 24°C with cooling coils mounted in the fermentor.

(b) **Yeast nutrition:** Yeasts normally ferment the glucose preferentially although some yeasts e.g. *Sacch. elegans* prefer fructose. Most nutrients including macro- and micro-nutrients are usually abundant in must; occasionally, however, nitrogenous compounds are limiting. They are then made adequate with small amounts of  $(\text{NH}_4)_2\text{SO}_4$ .

(c) **Oxygen:** As with beer, oxygen is required in the earlier stage of fermentation when yeast multiplication is occurring. In the second stage when alcohol is produced the growth is anaerobic and this forces the yeasts to utilize such intermediate products as acetaldehydes as hydrogen acceptors and hence encourage alcohol production.

(d) **Flavor development:** Although some flavor materials come from the grape most of it comes from yeast action and has been shown to be due to alcohols, esters, fatty acids, and carbonyl compounds, the esters being the most important. Diacetyl, acetoin, fuel oils, volatile esters, and hydrogen sulfide have received special attention.

### d. Ageing and Storage

The fermentation is usually over in three to five days. At this time 'pomace' formed from grape skins (in red wines) will have risen to the top of the brew. At the end of this fermentation, the wine is allowed to flow through a perforated bottom if pomace had been allowed. When the pomace has been separated from the wine and the fermentation is complete or stopped, the next stage is 'racking'. The wine is allowed to stand until a major portion of the yeast cells and other fine suspended materials have collected at the bottom of the container as sediment or 'lees.' It is then 'racked', during which process the clear wine is carefully pumped. The wine is then transferred to wooden casks (100-1,000 gallons), barrels (about 50 gallons), or tanks (several thousand gallons). The wood allows the wine only slow access to oxygen. Water and ethanol evaporate slowly leading to air pockets that permit the growth of aerobic wine spoilers e.g. acetic acid bacteria and some yeasts. The casks are, therefore regularly topped up to prevent the pockets. In modern tanks made of stainless steel, the problem of air pockets is tackled by filling the airspace with an inert gas such as carbon dioxide or nitrogen. During aging desirable changes occur in the wine. These changes are due to a number of factors:

### e. Clarification

The wine is allowed to age in a period ranging from two years to five years, depending on the type of wine. At the end of the period, some will have cleared naturally. For others, artificial clarification may be necessary. The addition of a fining agent is often practiced to help clarify. Fining agents react with the tannin, acid, protein, or with some added substance to give heavy

quick-settling coagulums. The usual fining agents for wine are gelatin, casein, tannin, egg albumin, and bentonite.

#### **f. Packaging**

Before packing in bottles the wine from various sources is sometimes blended and then pasteurized. In some wineries, the wine is not pasteurized, rather it is sterilized by filtration. In many countries, the wine is packaged and distributed in casks.

#### **g. Wine defects**

The most important cause of wine spoilage is microbial; less important defects are acidity and cloudiness. Factors that influence spoilage by bacteria and yeasts include the following (a) wine composition, specifically the sugar, alcohol, and sulfur dioxide content; (b) storage conditions e.g. high temperature and the amount of air space in the container; (c) the extent of the initial contamination by microorganism during the bottling process. When proper hygiene is practiced bacterial spoilage is rare. When it does occur the microorganisms concerned are acetic acid bacteria which cause sourness in the wine. Lactic acid bacteria especially *Leuconostoc*, and sometimes *Lactobacillus* also spoil wines. Various spoilage yeasts may also grow in wine. The most prevalent is *Brettanomyces*, slow-growing yeasts which grow in wine causing turbidities and off-flavors. Other wine spoilage yeasts are *Saccharomyces oviformis*, which may use up residual sugars in sweet wine, and *Saccharomyces bayanus* which may cause turbidity and sedimentation in dry wines with some residual sugar. *Pichia membranaefaciens* is an aerobic yeast that grows especially in young wines with sufficient oxygen. Other defects of wine include cloudiness and acidity.

## **PROCESSING OF COFFEE**

Coffee is an important beverage used all over the world. Brazil and Colombia are the largest coffee producers. The bulk of coffee grown in India is coffee Arabica and the main centers of production are Tamil Nadu, Karnataka, Kerala, and Orissa. The coffee plant grows 6 to 20 feet high depending on size but in India, the plant is kept pruned to a height of 4 to 5 feet. The evergreen coffee plant bears white flowers which give place to a fruit that resembles a small cherry with a dark red-purple cover. The fleshy mucilaginous pulp of the fruit encloses two oval greenish-grey seeds or beans each covered by a thin membrane, the silver skin. Both seeds are enclosed in a common husk-like membrane or parchment. Ripe beans are used for coffee beverages.

### **Processing**

Coffee processing consists of removing the skin, pulp, parchment, and silver screen. The quality of the final product depends upon the manner of processing. Curing is done before going to the market. Two methods are employed for processing - the dry and the wet. In the dry method, the beans are sun-dried. In the wet method known as washed coffee process pectin enzymes are used on selectively picked cherries to replace spontaneous fermentation. Plantation coffee is generally favored by the market.

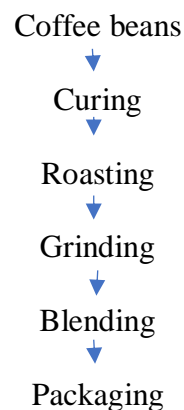
**Roasting-** Raw and green coffee does not have flavor or aroma and has an unpleasant taste. During roasting many physical and chemical changes occur. The beans swell in size to almost double the original size. The dull green color changes to brown. Water is driven off and loses

12 to 25% of its weight. The beans lose their hard horny structure and become brittle. During roasting pressure develops in the beans and this appears to be necessary for the proper development of coffee flavor. Carbon dioxide is produced in a large quantity. Carbohydrates decompose, caramelize and perhaps in combination with other substances contribute to the aroma. The roasted product is spread out for cooling either on wooden platforms or fanned for 10 to 15 minutes. The cooling must be quick in order to preserve the flavor and aroma and the keeping quality. Surface cooling closes the pores and seals the berries. The flavor and aroma of the coffee are best when it is freshly roasted and deteriorate on standing. The flavor is largely due to 2-thiofuran.

**Grinding** – The bulk of roasted beans is ground to powder and sold as ground coffee. Roasted beans are ground into three sizes namely fine, medium, and coarse. Coarse ground retains aroma and flavor better.

**Blending-** Strength, aroma flavor, and acidity are the chief criteria in judging the quality of coffee, and blending of different grades brings out these qualities.

**Packaging** - For larger packs of roasted and ground coffee gas packing under carbon dioxide and vacuum is effective.



## PROCESSING OF TEA

Tea is grown in China, Japan, Java, and India. India is the largest producer and consumer of black tea in the world. There are three types of tea depending on the processing of tea leaves. They are black, green and oolong. Any size of leaves may be made into any type of tea. Black tea is the most popular among the three.

### Black tea

Various processing steps involved in the manufacture of black tea are withering, rolling, fermentation, drying, grading, and packing.

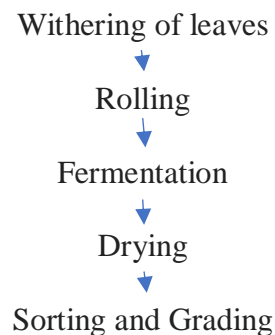
**Withering** – It is carried out by spreading tea leaves thinly on racks or shelves. Air is blown to make them soft and flexible. They are dried till the moisture content is lowered to 40%. It takes 16 to 24 hours for the leaves to wither to the required degree.

**Rolling** - The withered leaves are then rolled to break open the cells and release the juices and the enzymes. Various rolling techniques are employed for rolling. The flavor characteristics inherent in various teas partially depend on the technique used.

**Fermentation** - After rolling the leaves are spread out thinly on suitable platforms and allowed to ferment for 2 to 6 hours at temperatures between 21 to 27°C. During fermentation polyphenol substances also called tannins are oxidized by phenoloxidase. The color of the leaves changes to black. Enzymatic browning which is desirable takes place. The beverage made from black tea is less bitter and astringent than green tea and it has a rich aroma and flavor.

**Drying** – The fermented leaves are passed through the dryer. The leaf is dried at 87.7 to 93.3° C for 30 to 40 minutes. The dried product contains 3 to 4% moisture.

**Sorting and grading** - Grading of tea is done according to its size.



### **Green tea**

Green tea is produced in Japan. Here withering and fermentation are completely omitted. It is made by first steaming the leaves to prevent the leaves from changing color and to inactivate the enzymes. Steaming is then followed by rolling and drying. The leaves retain much of their original green color, especially the finer leaves. The older leaves often have a blackish-grey color.

### **Oolong tea**

This has a special market in America. Oolong tea is partially fermented. The fermentation period is too short to change the color of the leaf completely. It is only partially blackened. The beverage is intermediate between those produced from green and black teas.

## **COCOA PROCESSING**

Cocoa and chocolate are made by grinding the seeds of the pods of the cocoa tree. The pods are 4 to 7 inches in diameter having thick leathery rings containing 25 to 75 seeds inside in rows. The seeds are embedded in white or pinkish pulp and possess excellent aroma and flavor.

### **Processing**

**Fermentation** - The cocoa pods after harvesting are cautiously opened. The beans and the mucilage are scooped out and subjected to natural fermentation. They are piled in heaps in perforated wooden boxes for a period of 3 to 12 days depending on the type of beans. The heat produced during fermentation raises the temperature of mass to about 45 to 60°C. The fermentation is complete when the temperature of mass begins to fall. At the end of fermentation, the pulp breaks down and there is a change in the color of the seeds from pale

yellow to violet to brown. The endogenous enzymes activated by the heat of fermentation bring about changes in protein and polyphenols in the kernels.

**Curing** - The fermented beans contain about 33% water. They are therefore dried to a moisture content of 5 to 8% in the sun or in the hot air dryer. During this process, the color of the shell becomes dark brown.

**Roasting** - The dried beans are cleaned, sorted, and roasted at 210°C for 10 to 15 minutes. Roasting develops characteristic flavor and color. The roasted beans are passed through corrugated rollers to break their shells and separate the gum. The roasted dehulled and degermed beans are called nibs.

**Grinding and Defatting** - The roasted nibs are ground using stone mills to a fine paste or liquor. The heat produced during grinding causes the cocoa fat to melt. This is called cocoa mass or chocolate liquor or bitter chocolate. The mass solidifies at 30°C. Cocoa mass is very rich in fat 50 to 55% and cannot be used directly for the preparation of any beverage. It is subjected to filter pressing to separate out a major part of the fat (cocoa butter). This pressed cake is then cooled, ground in special mills and shifted through fine silk screens.

**Conching** - After the grinding, the process called conching takes place. During the conching, the chocolate liquid mass is stirred and mixed at a temperature of about 180°F. During this process, friction between the sugar and cocoa particles occurs. This causes further polishing of the cocoa particles thus contributing to the smooth taste of the finished chocolate. According to BIS specifications cocoa used for beverages should contain 20% cocoa fat. Medium fat Cocoa contains 10 to 20% and low fat contains less than 10%.

