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

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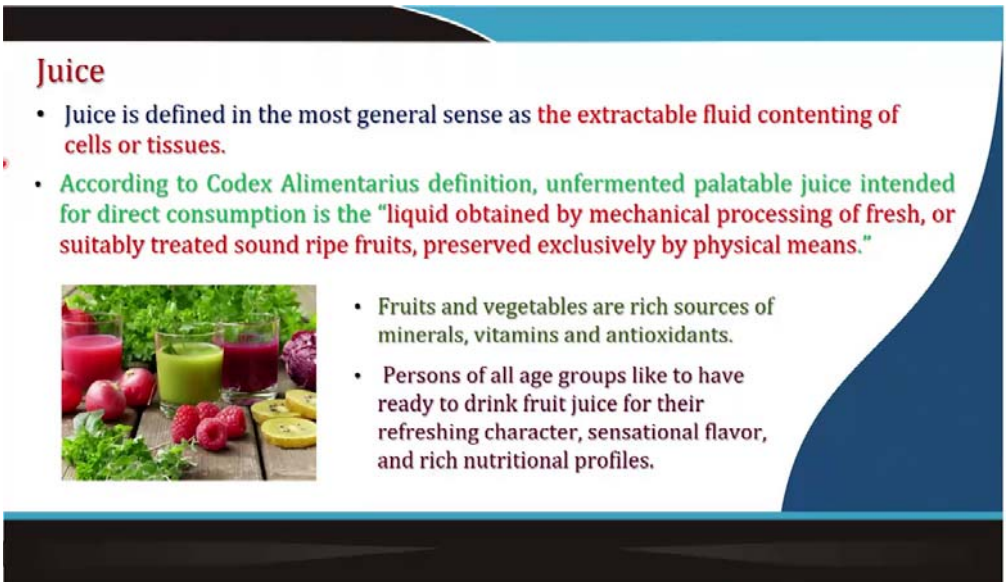
Lecture No: 26

Juice Extraction and Clarification

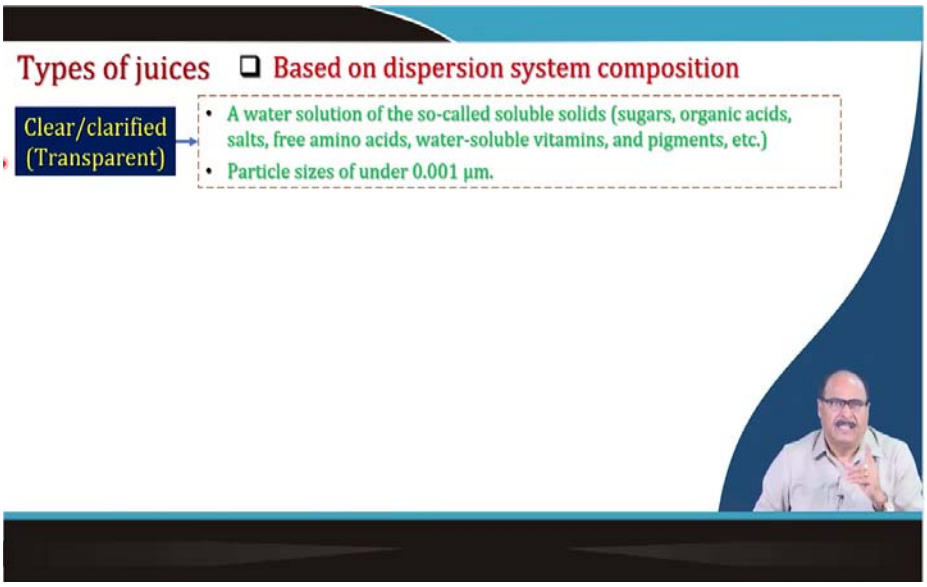
Hello everybody. Now we are entering into the sixth module of the course. In this module that is the sixth week we will discuss various aspects of juices and concentrates. So, in today's lecture we will study juice extraction and clarification.

The concepts and topics which we will cover in today's lecture include juices and their types, juice extraction technologies, how the juices are separated what are the various novel and emerging technologies for juice extraction and finally we will discuss about the clarification of the juice.



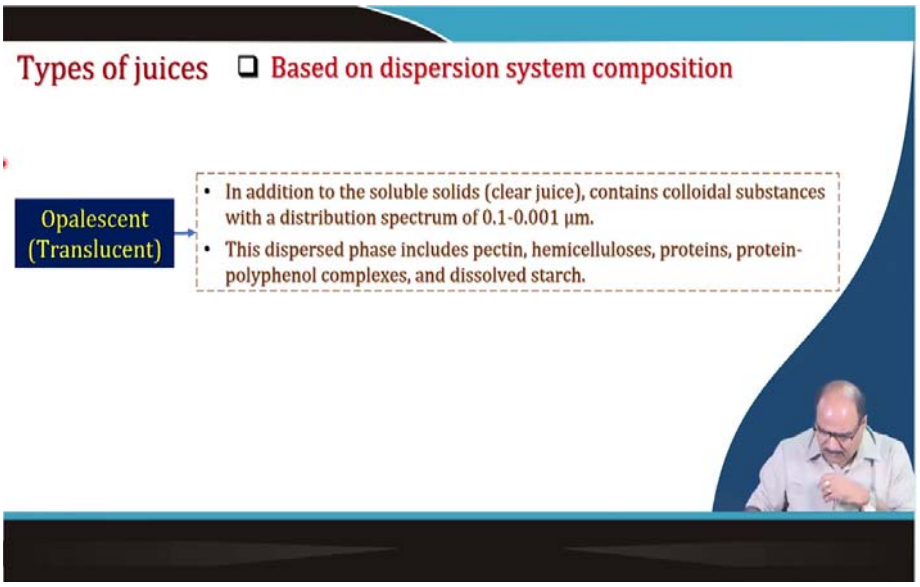
So let us understand what juice means. In the most general sense, it is defined as the extractable fluid content of cells or tissues. According to Codex Alimentarius definition, unfermented palatable juice intended for direct consumption is the liquid obtained by mechanical processing of fresh, or suitably treated sound ripe fruits, preserved exclusively by physical means.

And you know fruits and vegetables are rich sources of minerals, vitamins and antioxidants and therefore these juices become a very good source for supply of these elements to the people. Therefore, these juices are popular amongst all age groups for their refreshing character, sensational flavour and rich nutritional profiles.

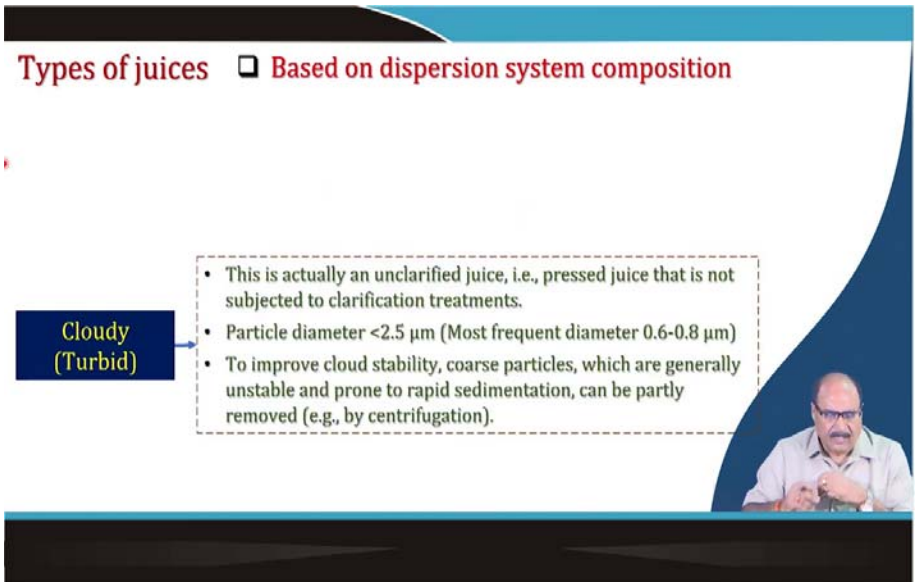


The juices may be classified into various groups depending upon the dispersion systems composition. This category of the juice is clear or clarified or fully transparent juice. This includes a water solution of the so-called soluble solids present in the fruits or vegetables such as sugar, organic acid, salt, free amino acids, water soluble vitamins and pigment etc.

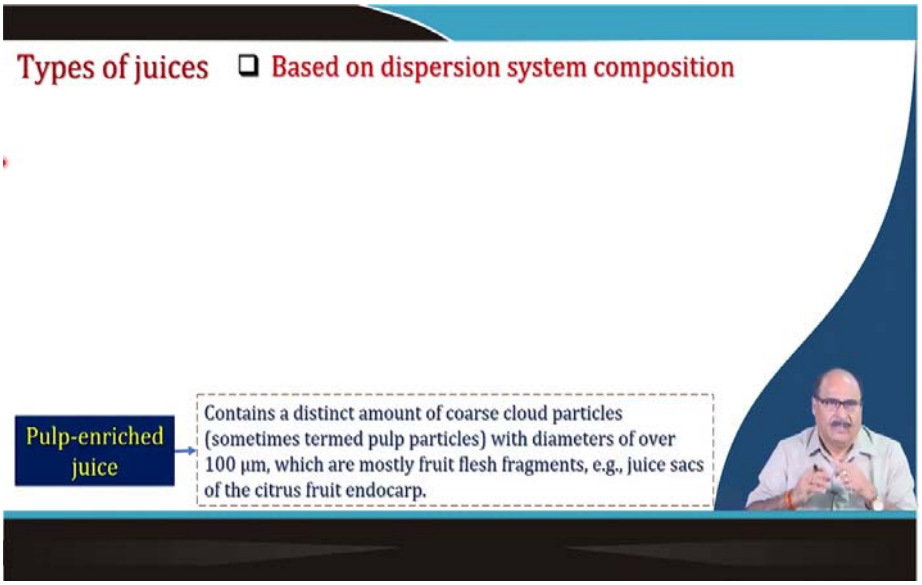
Generally, particle size of these clear or clarified transparent juices is under 0.001 micron.



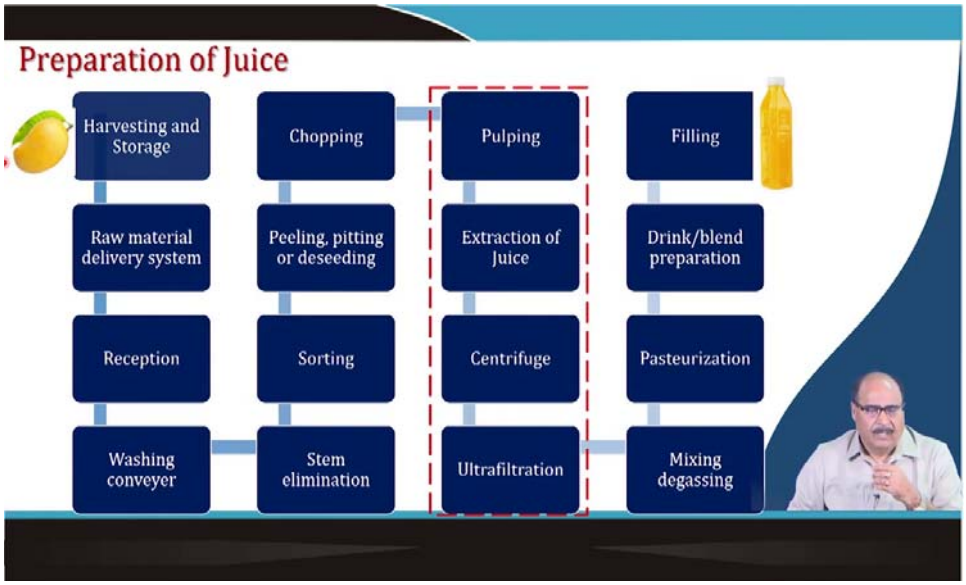
Second category is Opalescent or translucent juices. Here, in addition to the soluble solids (clear juice), it also contains colloidal substances with a distribution spectrum of 0.1-0.001 micron. This dispersed phase includes pectin, hemicelluloses, proteins, protein-polyphenol complexes, and dissolved starch.



Third category is a cloudy or turbid juice. This is actually an unclarified juice, i.e., pressed juice that is not subjected to clarification treatments. Here, the particle diameter is less than 2.5 micron (Most frequent diameter is 0.6 to 0.8 micron). To improve cloud stability, coarse particles, which are generally unstable and prone to rapid sedimentation, can be partly removed by centrifugation method etc.

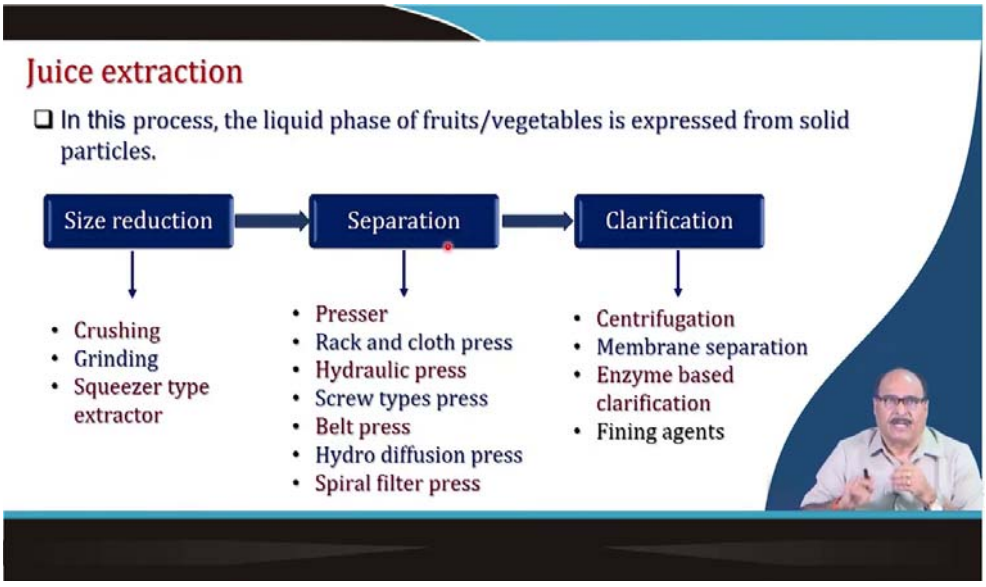


Another category or you can say last category of the fruit juices may be pulp enriched juices. These types of juices contain a distinct amount of coarse cloud particles that is sometimes even termed as pulp particles with a diameter of over 100 microns, which are mostly fruit flesh segments for example juice sacks of the citrus fruits endocarp.



This is the process flow chart for preparation of the juices. The steps include the preparatory treatment like harvesting and storage, raw material delivery system, reception, washing conveying, stem elimination, sorting, peeling cutting or de-seeding and chopping. Thereafter, the prepared chopped fruits is subjected to next treatment which may be pulping, extraction of juice, centrifugation, ulrafiltration and then these prepared and clarified uses may be further subjected to shelf-life extension treatment like degassing or pasteurization and finally blending, filling and packaging are done.

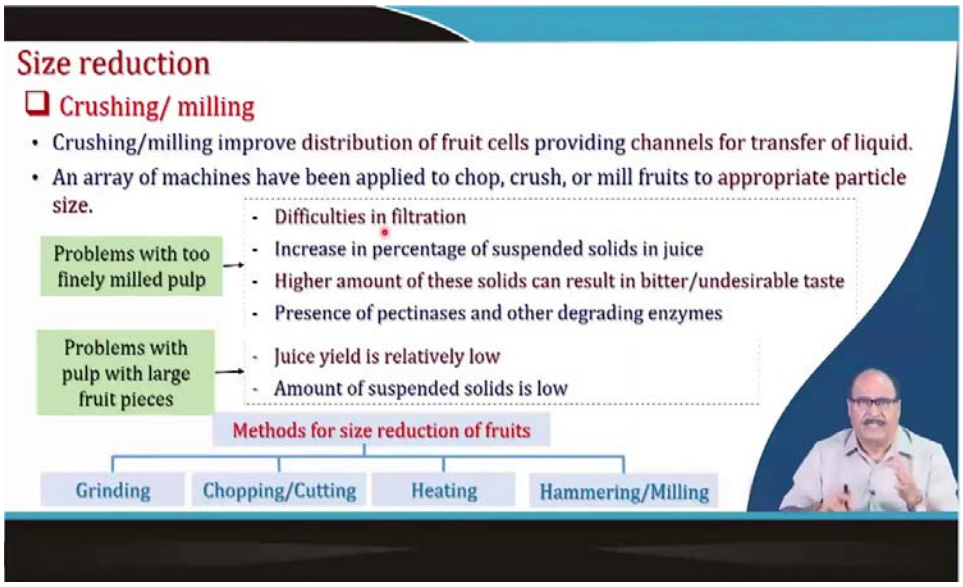
So, in today's lecture we have already discussed about the preparatory treatments and post extraction and post clarification treatments will be discussed later on. In this lecture we will mainly focus on the extraction and clarification of the juice.



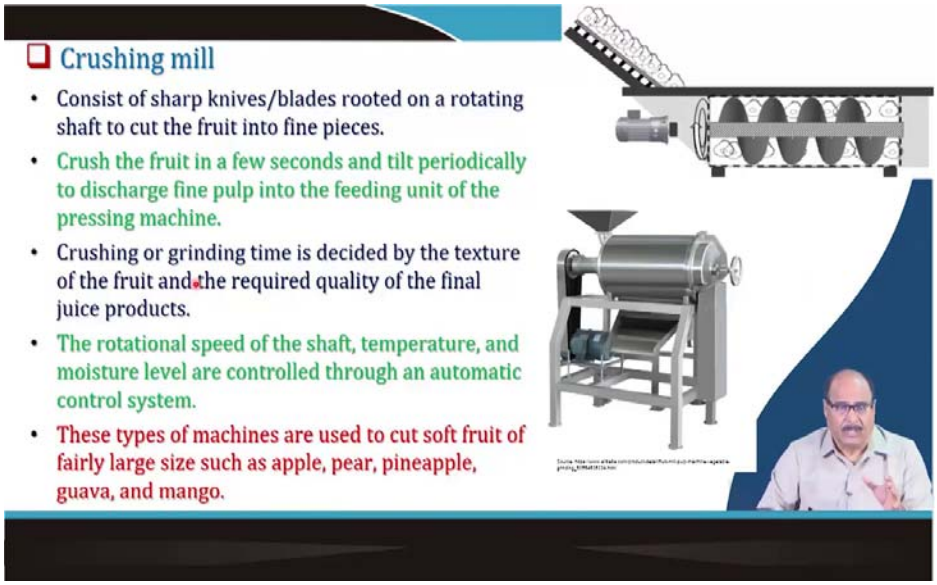
So let us switch to juice extraction. In this process the liquid phase of the fruits or vegetables is expressed from solid particles. This involves the size reduction where, crushing, grinding, squeezer type extractors are used to comminute the fruits. Then this is taken for separation process where, the fruit pieces are squeezed or juice is separated from the pulp or ground

using various equipments like presser, rack and cloth press, hydraulic press, screw type press, belt press, hydro diffusion press or spiral filter press.

And finally, these juices are sent to some other processes of like centrifugation, membrane separation, enzyme-based clarification and fining agent treatment to clarify the juices.

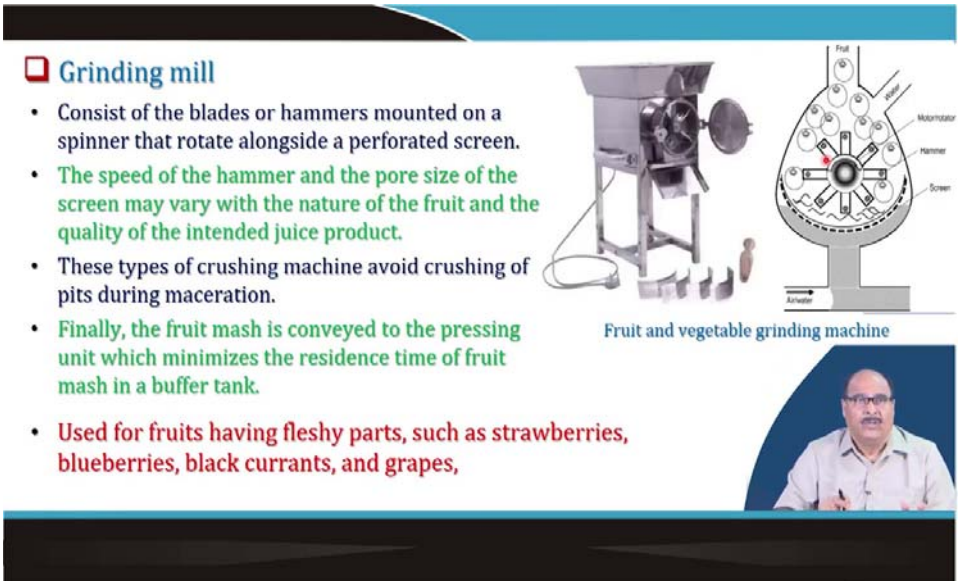


So let us study little details of all these processes. Crushing/milling improve distribution of fruit cells providing channels for transfer of liquid. An array of machines has been applied to chop, crush, or mill fruits to appropriate particle size. The problems associated with too finely milled pulp are Difficulties in filtration, increase in percentage of suspended solids in juice, higher amount of these solids can result in bitter/undesirable taste, presence of pectinases and other degrading enzymes. The Problems with pulp with large fruit pieces are juice yield is relatively low and amount of suspended solids is low. Methods for size reduction of fruits include grinding, chopping or cutting, heating and hammering or miling.

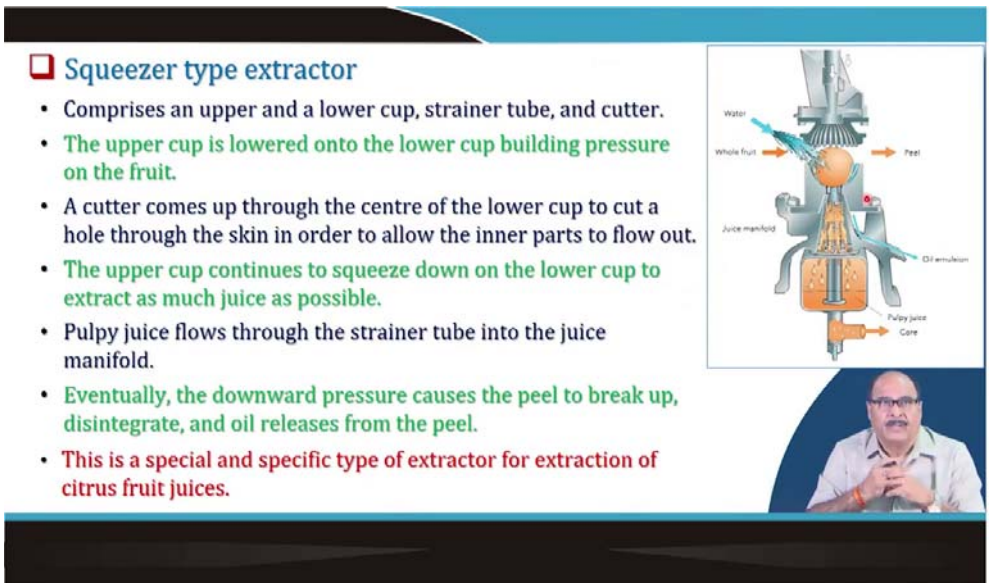


A crushing mill Consist of sharp knives/blades rooted on a rotating shaft to cut the fruit into fine pieces. Crush the fruit in a few seconds and tilt periodically to discharge fine pulp into

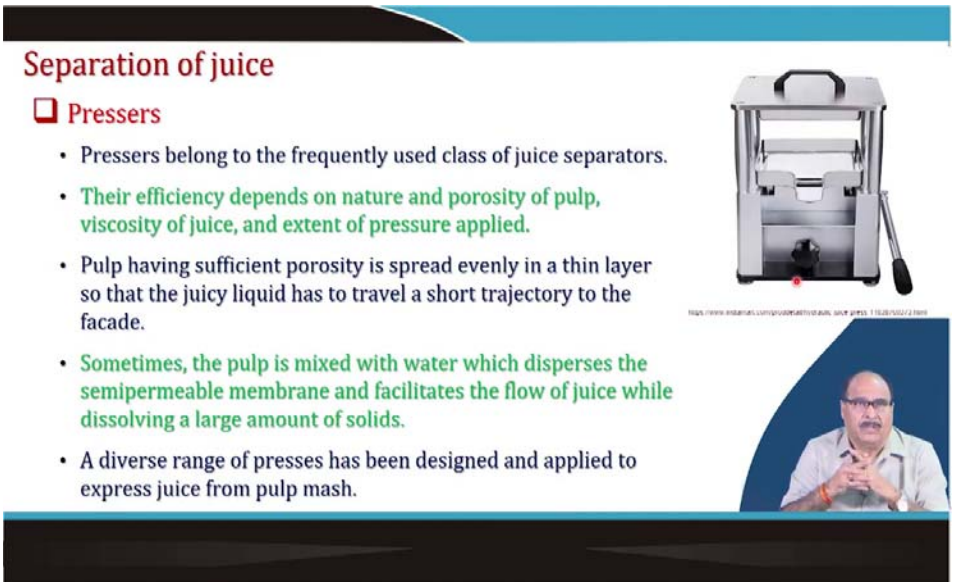
the feeding unit of the pressing machine. Crushing or grinding time is decided by the texture of the fruit and the required quality of the final juice products. The rotational speed of the shaft, temperature, and moisture level are controlled through an automatic control system. These types of machines are used to cut soft fruit of fairly large size such as apple, pear, pineapple, guava, and mango.



The other type of mill is the grinding mill you can see here in the figure. Consist of the blades or hammers mounted on a spinner that rotate alongside a perforated screen. The speed of the hammer and the pore size of the screen may vary with the nature of the fruit and the quality of the intended juice product. These types of crushing machine avoid crushing of pits during maceration. Finally, the fruit mash is conveyed to the pressing unit which minimizes the residence time of fruit mash in a buffer tank. Used for fruits having fleshy parts, such as strawberries, blueberries, black currants, and grapes.

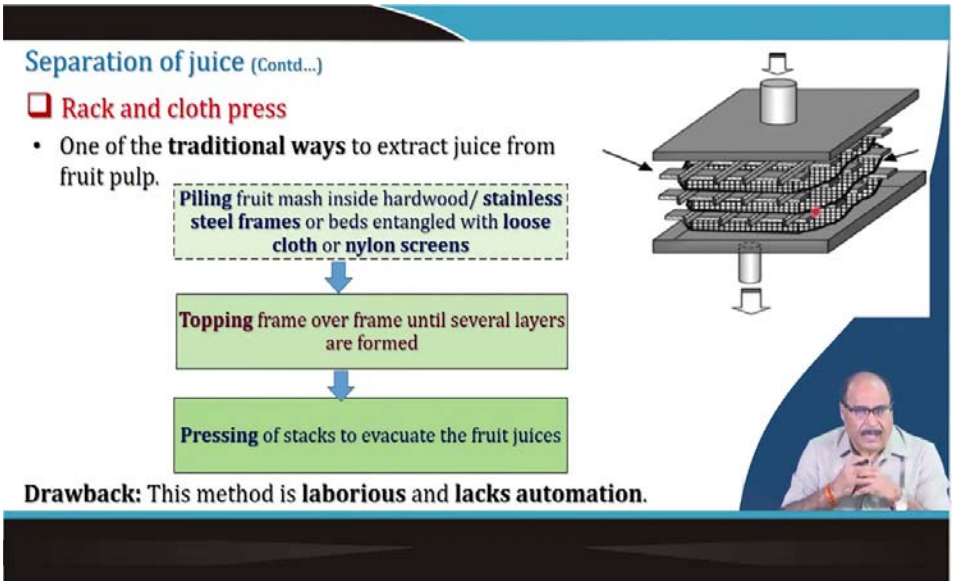


Squeezer type extractor comprises an upper and a lower cup, strainer tube, and cutter. The upper cup is lowered onto the lower cup building pressure on the fruit. A cutter comes up through the centre of the lower cup to cut a hole through the skin in order to allow the inner parts to flow out. The upper cup continues to squeeze down on the lower cup to extract as much juice as possible. Pulpy juice flows through the strainer tube into the juice manifold. Eventually, the downward pressure causes the peel to break up, disintegrate, and oil releases from the peel. This is a special and specific type of extractor for extraction of citrus fruit juices.



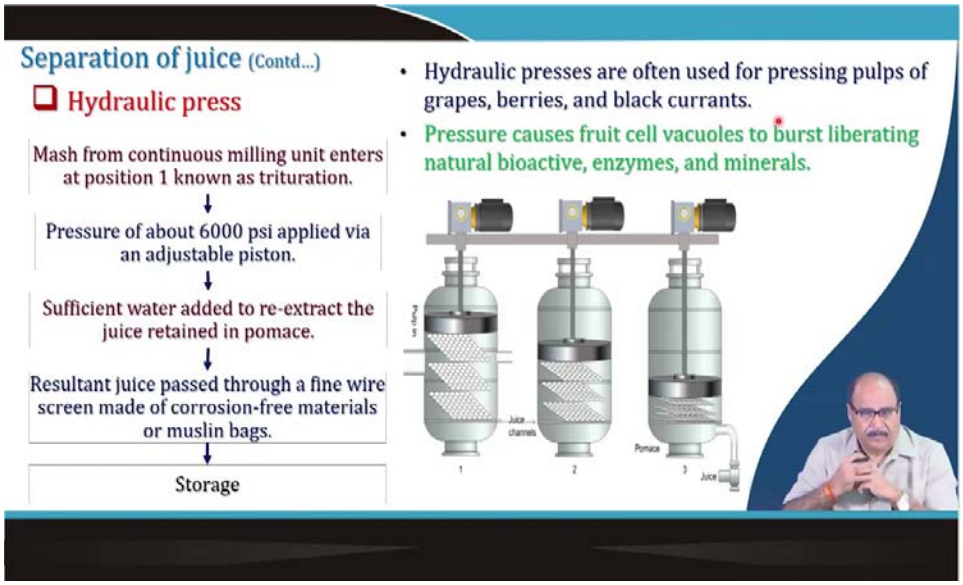
Separation of juice

Pressers belong to the frequently used class of juice separators. Their efficiency depends on nature and porosity of pulp, viscosity of juice, and extent of pressure applied. Pulp having sufficient porosity is spread evenly in a thin layer so that the juicy liquid has to travel a short trajectory to the facade. Sometimes, the pulp is mixed with water which disperses the semi permeable membrane and facilitates the flow of juice while dissolving a large amount of solids. A diverse range of presses has been designed and applied to express juice from pulp mash.



Rack and cloth press

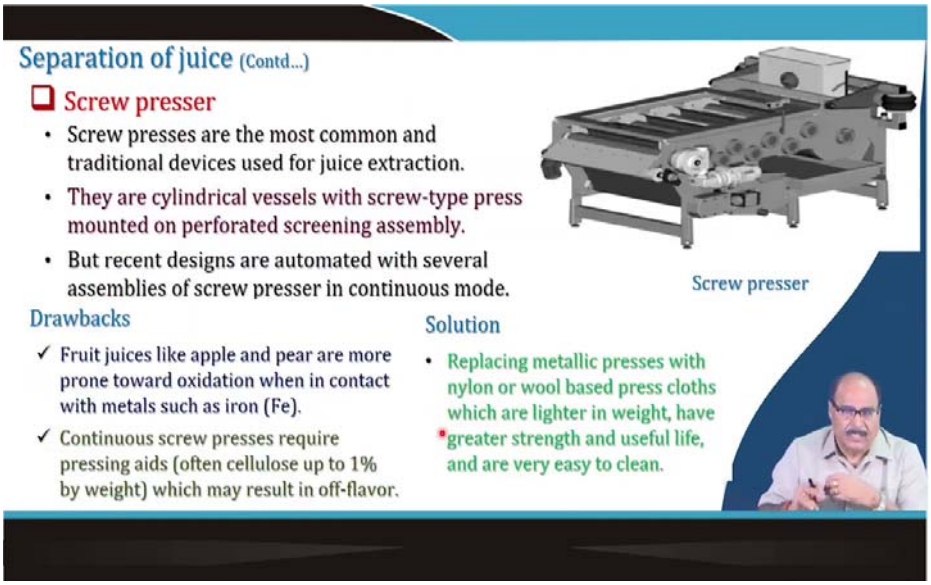
It is one of the traditional ways to extract juice from fruit pulp. First, piling fruit mash inside hardwood/ stainless steel frames or beds entangled with loose cloth or nylon screens is done. Second, topping frame over frame until several layers are formed and third, pressing of stacks to evacuate the fruit juices is done. Drawback of the method is that it is laborious and lacks automation.



Hydraulic press

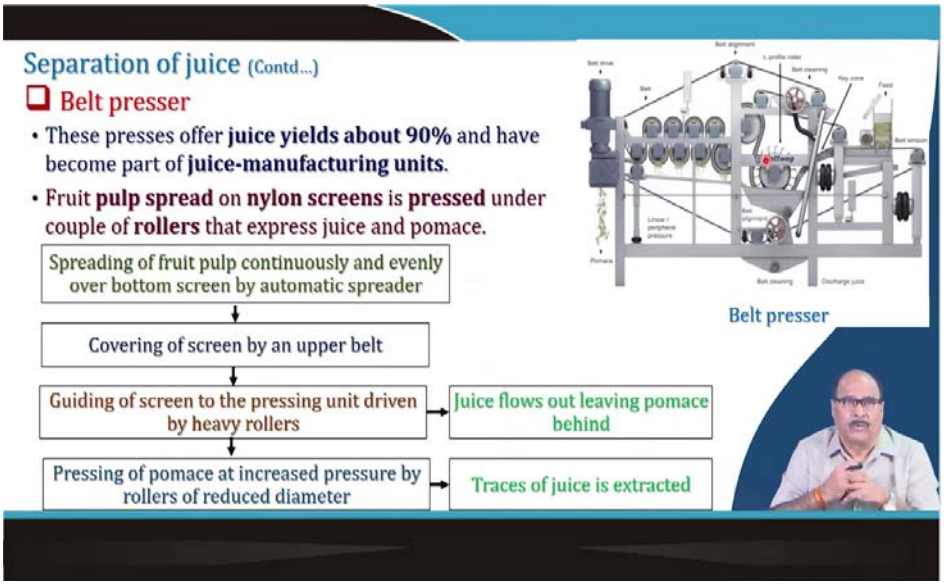
Hydraulic presses are often used for pressing pulps of grapes, berries, and black currants. Pressure causes fruit cell vacuoles to burst liberating natural bioactive, enzymes, and

minerals. Figure shows a Mash from continuous milling unit enters at position 1 known as trituration. Pressure of about 6000 psi applied via an adjustable piston. Sufficient water added to re-extract the juice retained in pomace. Resultant juice passed through a fine wire screen made of corrosion-free materials or muslin bags. Then finally storage is done.



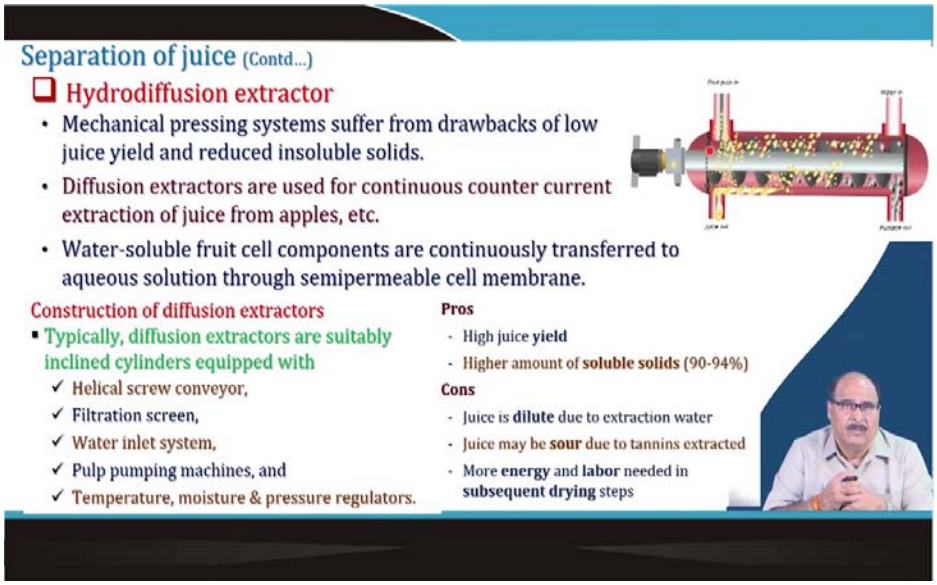
Screw presser

Screw presses are the most common and traditional devices used for juice extraction. They are cylindrical vessels with screw-type press mounted on perforated screening assembly. But recent designs are automated with several assemblies of screw presser in continuous mode. Major drawbacks involve Fruit juices like apple and pear are more prone toward oxidation when in contact with metals such as iron (Fe). Continuous screw presses require pressing aids (often cellulose up to 1% by weight) which may result in off-flavor. The solutions for these issues include replacing metallic presses with nylon or wool based press cloths which are lighter in weight, have greater strength and useful life, and are very easy to clean.



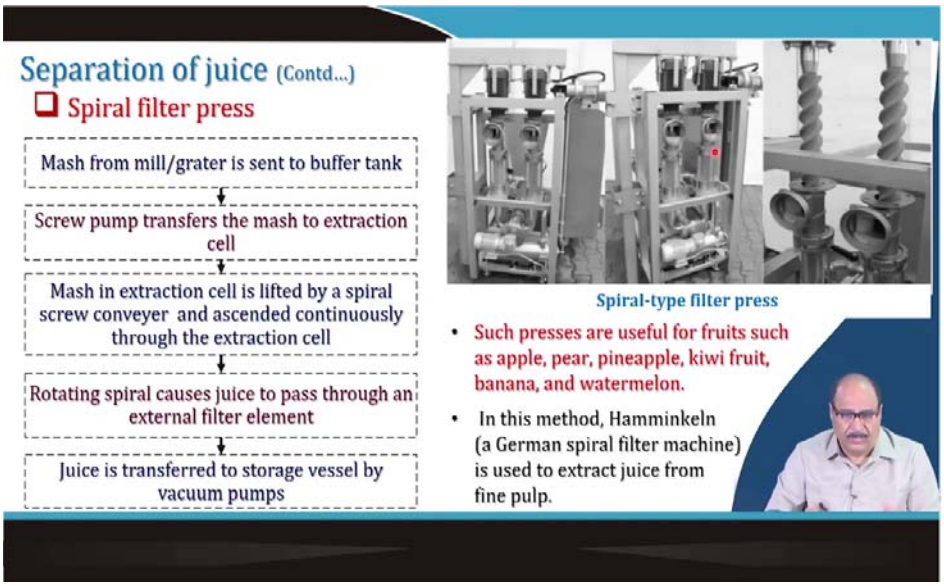
Belt presser

These presses offer juice yields about 90% and have become part of juice-manufacturing units. Fruit pulp spread on nylon screens is pressed under couple of rollers that express juice and pomace. The processes include Spreading of fruit pulp continuously and evenly over bottom screen by automatic spreader, covering of screen by an upper belt, Guiding of screen to the pressing unit driven by heavy rollers where Juice flows out leaving pomace behind and pressing of pomace at increased pressure by rollers of reduced diameter where traces of juice is extracted.



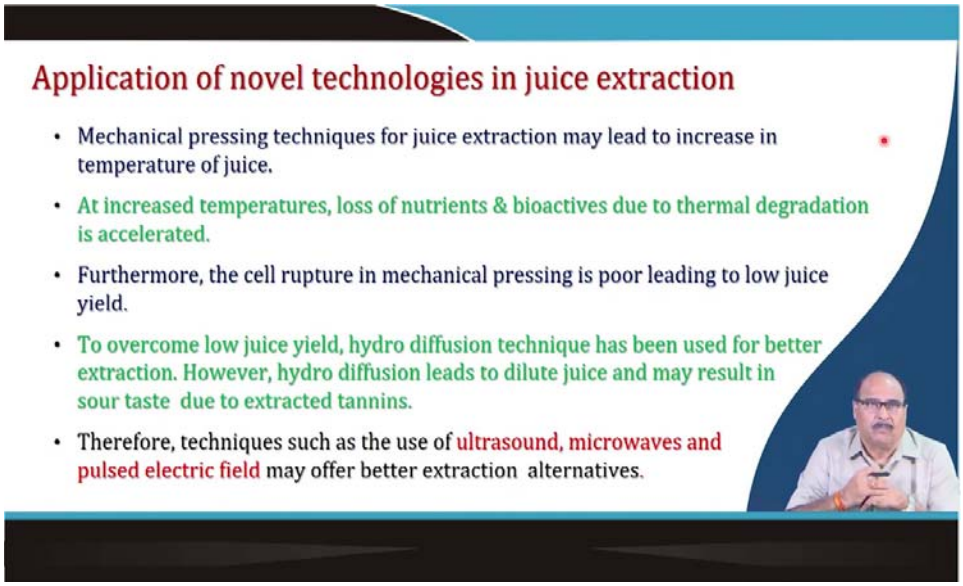
Hydro-diffusion extractor

Mechanical pressing systems suffer from drawbacks of low juice yield and reduced insoluble solids. Diffusion extractors are used for continuous counter current extraction of juice from apples, etc. Water-soluble fruit cell components are continuously transferred to aqueous solution through semipermeable cell membrane. Construction of diffusion extractors: Typically, diffusion extractors are suitably inclined cylinders equipped with helical screw conveyor, filtration screen, water inlet system, pulp pumping machines, and temperature, moisture & pressure regulators. The pros are high juice yield and higher amount of soluble solids (90-94%). Cons are juice is dilute due to extraction water, juice may be sour due to tannins extracted and more energy and labor needed in subsequent drying steps.



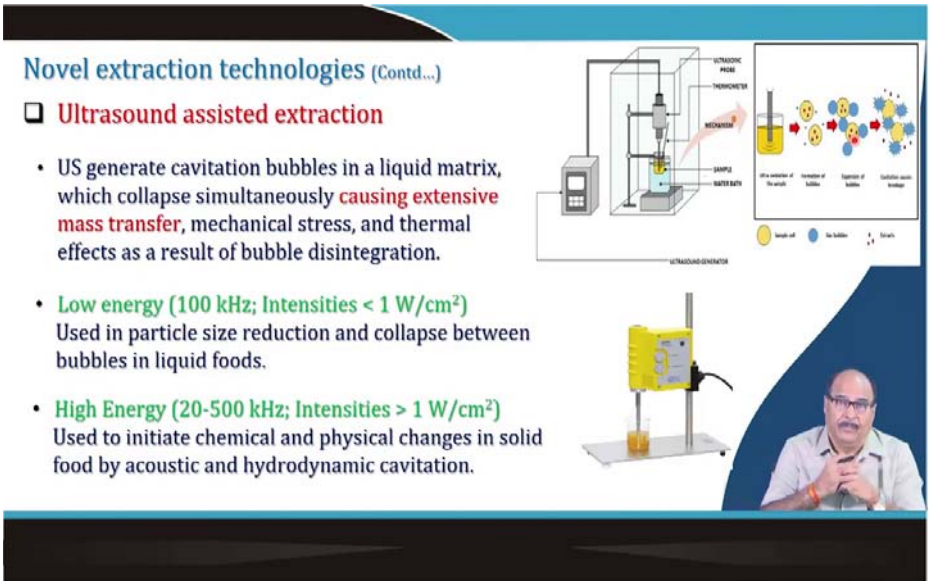
Spiral filter press

Here, the mash from mill/grater is sent to buffer tank, screw pump transfers the mash to extraction cell, mash in extraction cell is lifted by a spiral screw conveyer and ascended continuously through the extraction cell, rotating spiral causes juice to pass through an external filter element and finally Juice is transferred to storage vessel by vacuum pumps. Such presses are useful for fruits such as apple, pear, pineapple, kiwi fruit, banana, and watermelon. In this method, Hamminkeln (a German spiral filter machine) is used to extract juice from fine pulp.



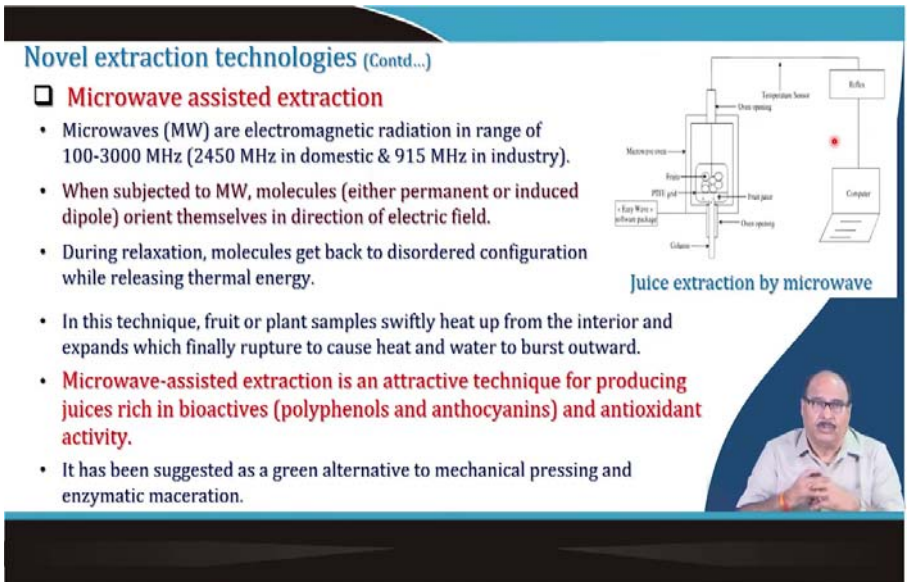
Application of novel technologies in juice extraction

Mechanical pressing techniques for juice extraction may lead to increase in temperature of juice. At increased temperatures, loss of nutrients & bioactives due to thermal degradation is accelerated. Furthermore, the cell rupture in mechanical pressing is poor leading to low juice yield. To overcome low juice yield, hydro diffusion technique has been used for better extraction. However, hydro diffusion leads to dilute juice and may result in sour taste due to extracted tannins. Therefore, techniques such as the use of ultrasound, microwaves and pulsed electric field may offer better extraction alternatives.



Novel extraction technologies

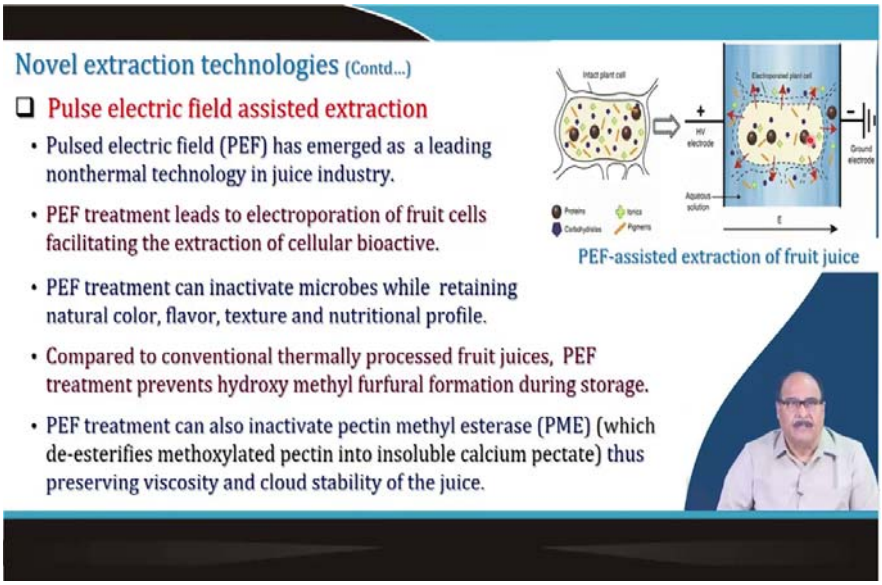
Ultrasound assisted extraction generate cavitation bubbles in a liquid matrix, which collapse simultaneously causing extensive mass transfer, mechanical stress, and thermal effects as a result of bubble disintegration. Low energy (100 kHz; Intensities < 1 W/cm2) are generally used in particle size reduction and collapse between bubbles in liquid foods. High Energy (20-500 kHz; Intensities > 1 W/cm2) are used to initiate chemical and physical changes in solid food by acoustic and hydrodynamic cavitations.



Microwave assisted extraction

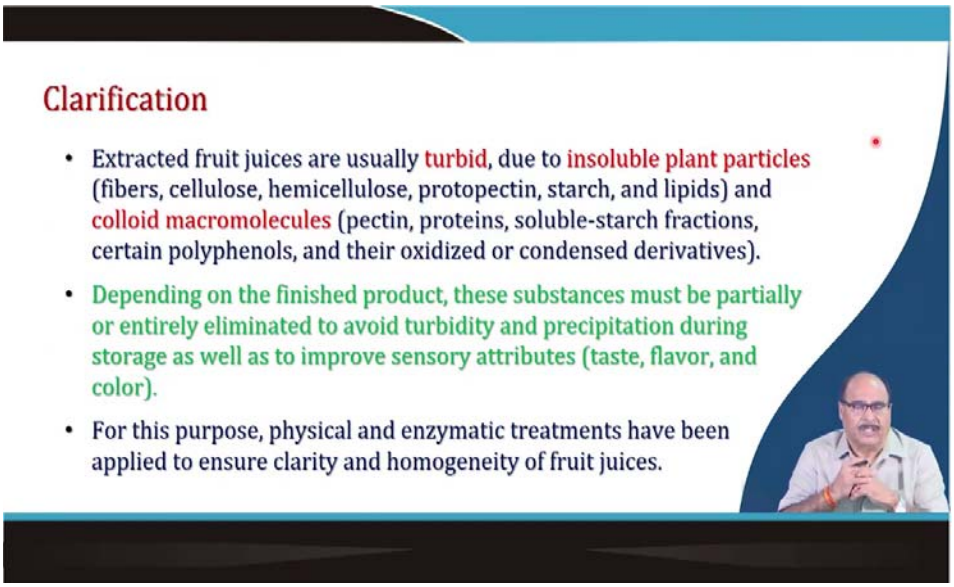
Microwaves (MW) are electromagnetic radiation in range of 100-3000 MHz (2450 MHz in domestic & 915 MHz in industry). When subjected to MW, molecules (either permanent or induced dipole) orient themselves in direction of electric field. During relaxation, molecules get back to disordered configuration while releasing thermal energy. In this technique, fruit or plant samples swiftly heat up from the interior and expand which finally rupture to cause heat and water to burst outward. Microwave-assisted extraction is an attractive technique for

producing juices rich in bioactives (polyphenols and anthocyanins) and antioxidant activity. It has been suggested as a green alternative to mechanical pressing and enzymatic maceration.



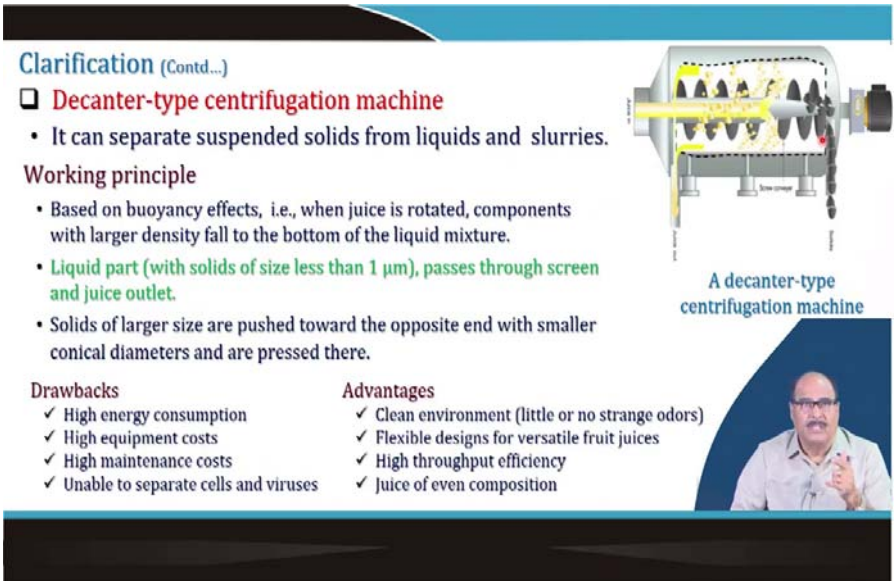
Pulse electric field assisted extraction

Pulsed electric field (PEF) has emerged as a leading nonthermal technology in juice industry. PEF treatment leads to electroporation of fruit cells facilitating the extraction of cellular bioactive. PEF treatment can inactivate microbes while retaining natural color, flavor, texture and nutritional profile. Compared to conventional thermally processed fruit juices, PEF treatment prevents hydroxy methyl furfural formation during storage. PEF treatment can also inactivate pectin methyl esterase (PME) (which de-esterifies methoxylated pectin into insoluble calcium pectate) thus preserving viscosity and cloud stability of the juice.



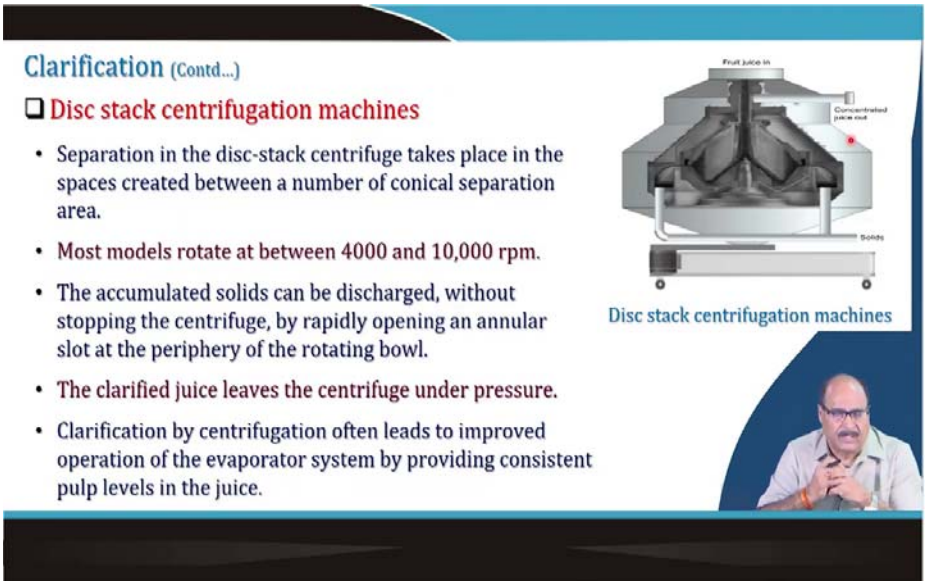
Clarification

Extracted fruit juices are usually turbid, due to insoluble plant particles (fibers, cellulose, hemicellulose, protopectin, starch, and lipids) and colloid macromolecules (pectin, proteins, soluble-starch fractions, certain polyphenols, and their oxidized or condensed derivatives). Depending on the finished product, these substances must be partially or entirely eliminated to avoid turbidity and precipitation during storage as well as to improve sensory attributes (taste, flavor, and color). For this purpose, physical and enzymatic treatments have been applied to ensure clarity and homogeneity of fruit juices.



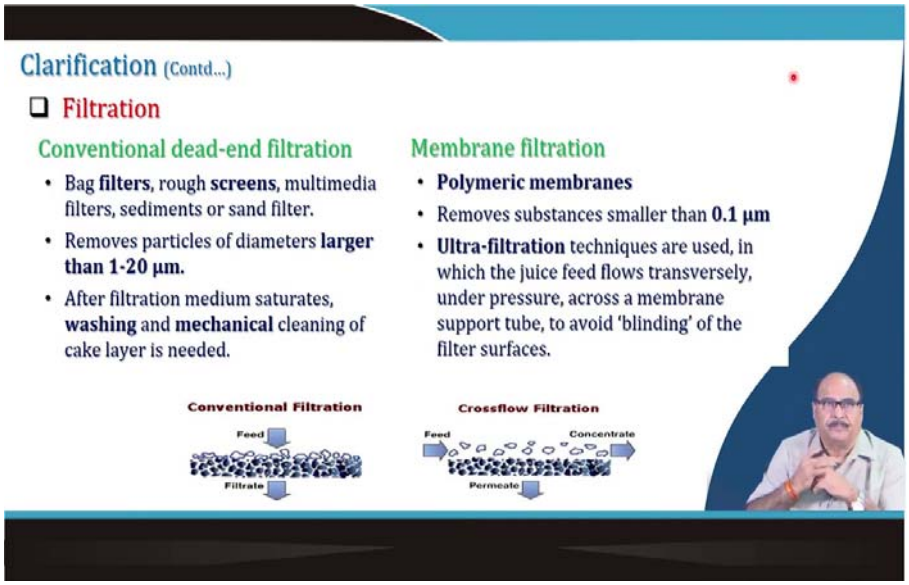
Decanter-type centrifugation machine

It can separate suspended solids from liquids and slurries. The working principle is based on buoyancy effects, i.e., when juice is rotated, components with larger density fall to the bottom of the liquid mixture. Liquid part (with solids of size less than 1 µm), passes through screen and juice outlet. Solids of larger size are pushed toward the opposite end with smaller conical diameters and are pressed there. Major drawbacks are high energy consumption, high equipment costs, high maintenance costs and unable to separate cells and viruses. Advantages include clean environment (little or no strange odors), flexible designs for versatile fruit juices, high throughput efficiency and juice of even composition.



Disc stack centrifugation machines

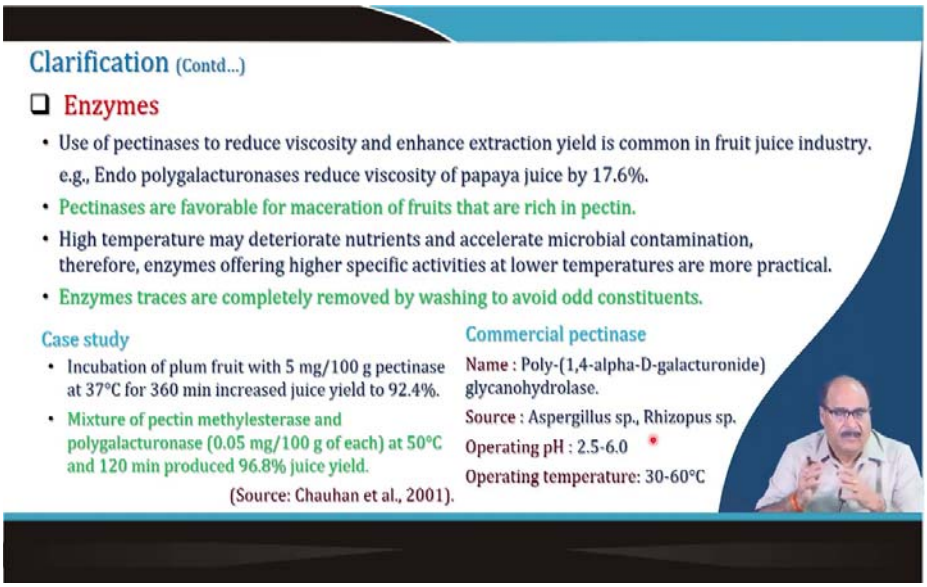
Separation in the disc-stack centrifuge takes place in the spaces created between a numbers of conical separation area. Most models rotate at between 4000 and 10,000 rpm. The accumulated solids can be discharged, without stopping the centrifuge, by rapidly opening an annular slot at the periphery of the rotating bowl. The clarified juice leaves the centrifuge under pressure. Clarification by centrifugation often leads to improved operation of the evaporator system by providing consistent pulp levels in the juice.



Filtration

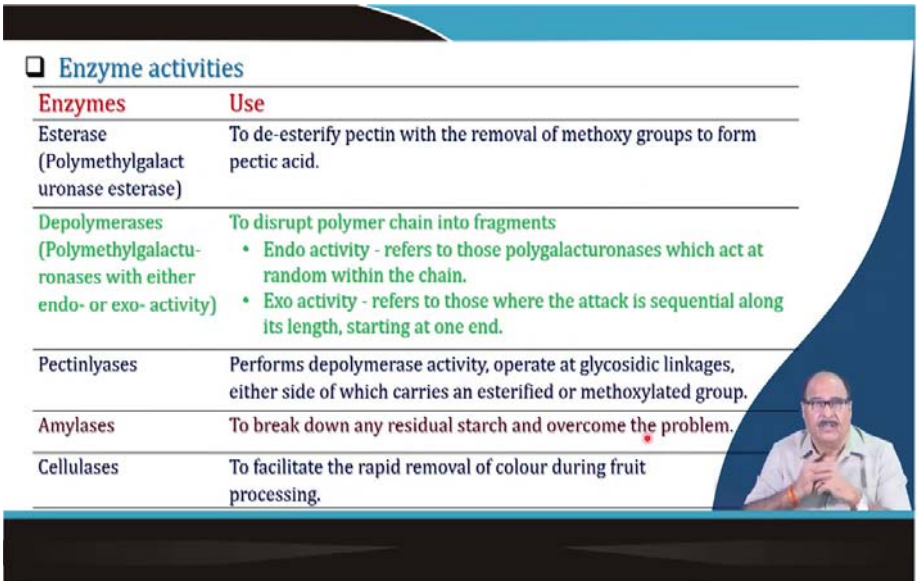
Conventional dead-end filtration is bag filters, rough screens, multimedia filters, sediments or sand filter. It remove particle having diameter of 1 to 20 micron. Membrane filtration is

polymeric membranes and removes substances smaller than 0.1 µm. Ultra-filtration techniques are used, in which the juice feed flows transversely, under pressure, across a membrane support tube, to avoid 'blinding' of the filter surfaces.



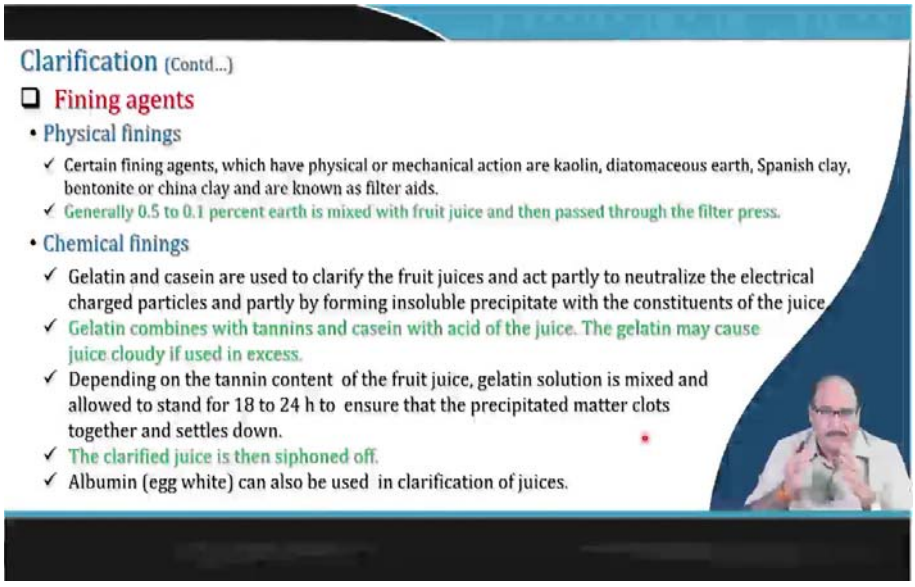
Enzymes

Use of pectinases to reduce viscosity and enhance extraction yield is common in fruit juice industry. For example, endo polygalacturonases reduce viscosity of papaya juice by 17.6%. Pectinases are favorable for maceration of fruits that are rich in pectin. High temperature may deteriorate nutrients and accelerate microbial contamination; therefore, enzymes offering higher specific activities at lower temperatures are more practical. Enzymes traces are completely removed by washing to avoid odd constituents. One case study by Chauhan et al., 2001 suggest that incubation of plum fruit with 5 mg/100 g pectinase at 37°C for 360 min increased juice yield to 92.4%. Mixture of pectin methylesterase and polygalacturonase (0.05 mg/100 g of each) at 50°C and 120 min produced 96.8% juice yield. Commercial pectinase such as Poly-(1,4-alpha-D-galacturonide) glycanohydrolase are extracted from the source Aspergillus sp., Rhizopus sp which operate at pH of 2.5-6.0 and temperature of 30-60°C.



Enzyme activities

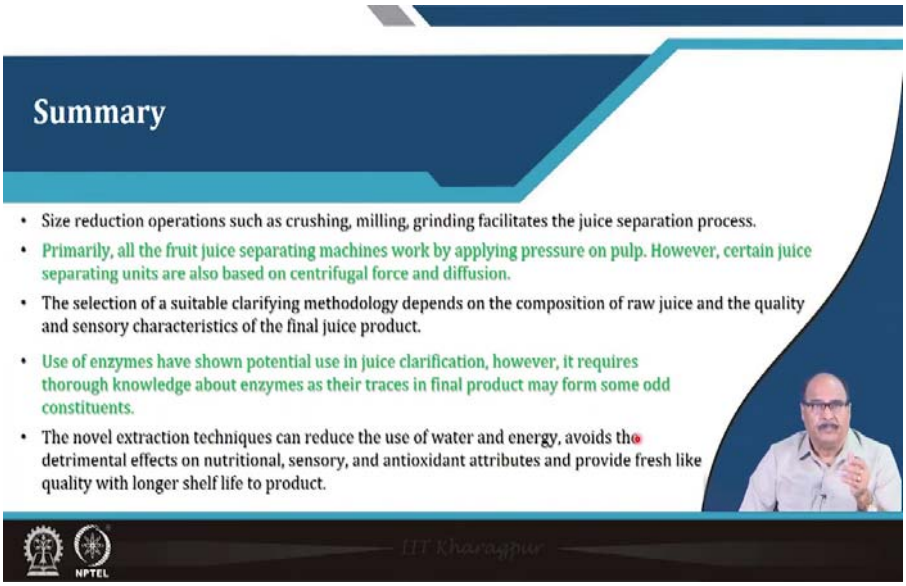
Enzymes such as Esterase (Polymethylgalact uronase esterase) are used to de-esterify pectin with the removal of methoxy groups to form pectic acid. Depolymerases (Polymethylgalactu-ronases with either endo- or exo- activity) are used to disrupt polymer chain into fragments, which involve endo activity - refers to those polygalacturonases which act at random within the chain and exo activity - refers to those where the attack is sequential along its length, starting at one end. Pectinlyases perform depolymerase activity; operate at glycosidic linkages, either side of which carries an esterified or methoxylated group. Amylases are used to break down any residual starch and overcome the problem. Cellulases are used to facilitate the rapid removal of colour during fruit processing.



Fining agents

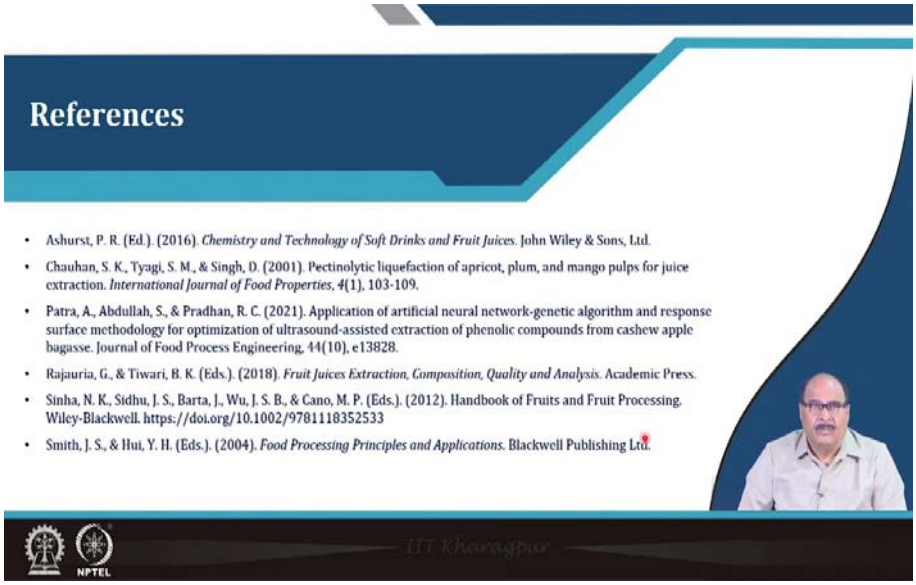
Physical finings are certain fining agents, which have physical or mechanical action, examples are kaolin, diatomaceous earth, Spanish clay, bentonite or china clay and are known as filter aids. Generally 0.5 to 0.1 percent earth is mixed with fruit juice and then passed

through the filter press. Chemical finings such as gelatin and casein are used to clarify the fruit juices and act partly to neutralize the electrical charged particles and partly by forming insoluble precipitate with the constituents of the juice. Gelatin combines with tannins and casein with acid of the juice. The gelatin may cause juice cloudy if used in excess. Depending on the tannin content of the fruit juice, gelatin solution is mixed and allowed to stand for 18 to 24 h to ensure that the precipitated matter clots together and settles down. The clarified juice is then siphoned off. Albumin (egg white) can also be used in clarification of juices.



Summary

Size reduction operations such as crushing, milling, grinding facilitates the juice separation process. Primarily, all the fruit juice separating machines work by applying pressure on pulp. However, certain juice separating units are also based on centrifugal force and diffusion. The selection of a suitable clarifying methodology depends on the composition of raw juice and the quality and sensory characteristics of the final juice product. Use of enzymes has shown potential use in juice clarification, however, it requires thorough knowledge about enzymes as their traces in final product may form some odd constituents. The novel extraction techniques can reduce the use of water and energy avoids the detrimental effects on nutritional, sensory, and antioxidant attributes and provides fresh like quality with longer shelf life to product.



These are the references for this lecture. Thank you very much for your patience hearing.