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

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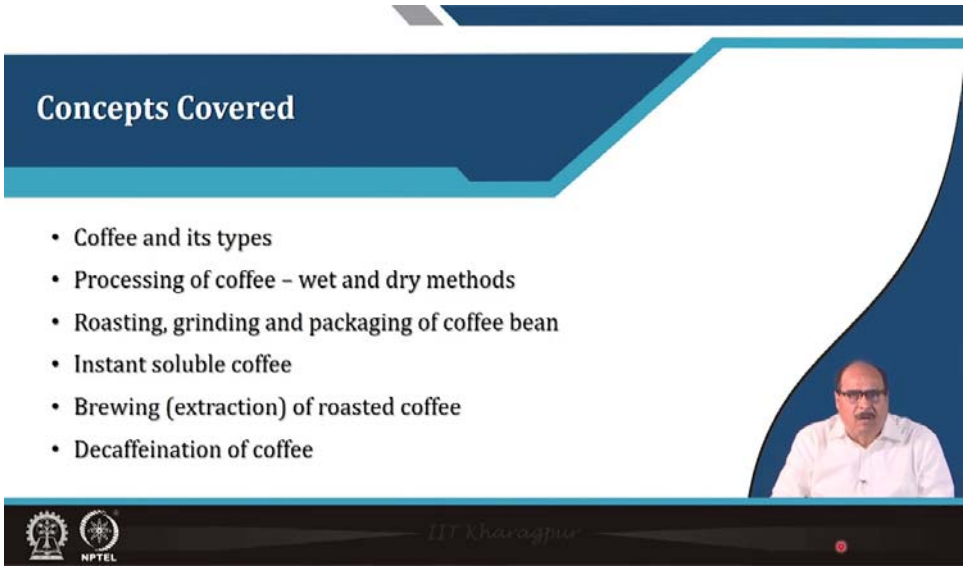
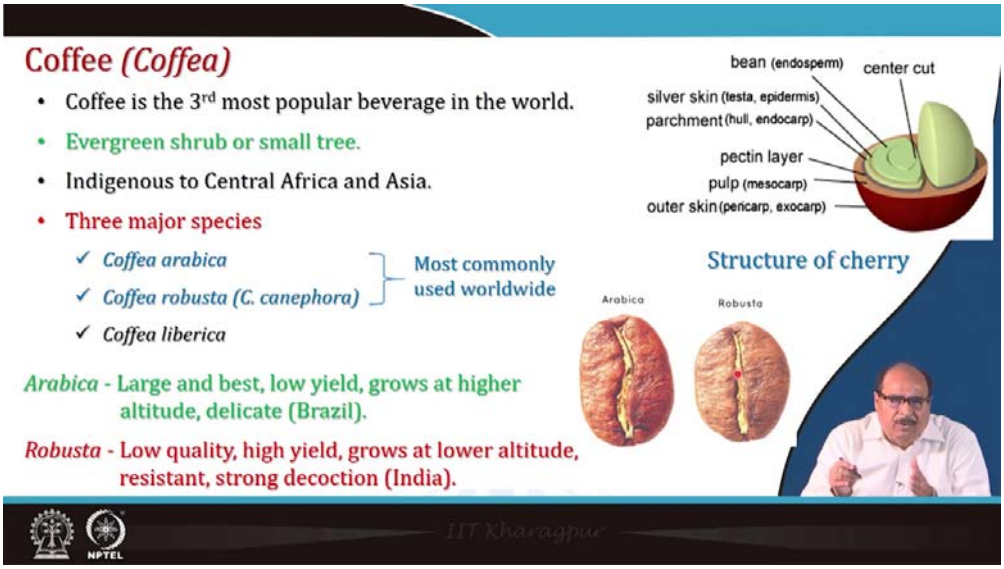
Lecture 37
Coffee Processing

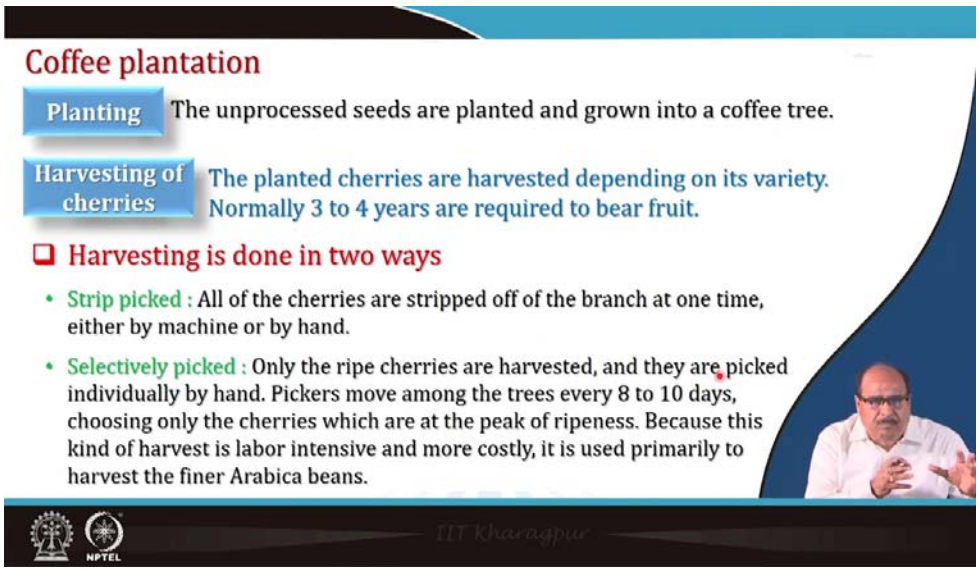


This lecture is about coffee and its types, processing of coffee (wet and dry methods), roasting, grinding and packaging of coffee bean, instant soluble coffee, brewing (extraction) of roasted coffee, and decaffeination of coffee.



Coffee

Coffee is the 3rd most popular beverage in the world. It is evergreen shrub or small tree. It is indigenous to Central Africa and Asia. Coffee is the third most popular beverage in the world. There are three major species of coffee i.e. *Coffea Arabica*, *Coffea robusta* (*C. canephora*), and *Coffea liberica*. *Coffea arabica* and *Coffea robusta* are the two varieties which are most commonly used worldwide. *Arabica* is the largest and best quality beans. However, it has low yield. It grows at higher altitude. It has delicate aroma, and it is mostly grown in Brazil. *Robusta* gives an inferior quality in comparison to that of the *Arabica*. However, its yield is high, it is grows at lower altitudes, it is a resistant variety and gives a strong decoction and this coffee is mainly grown in India.

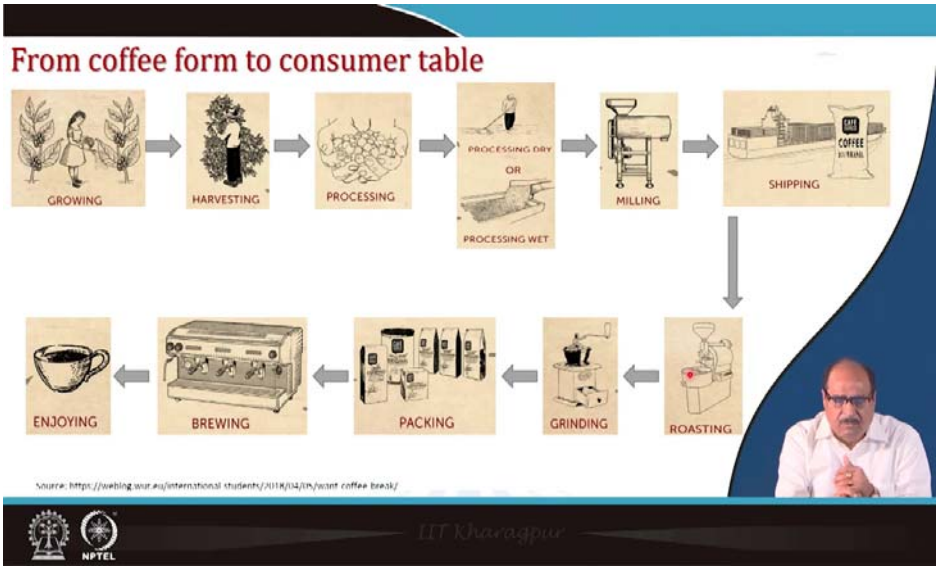


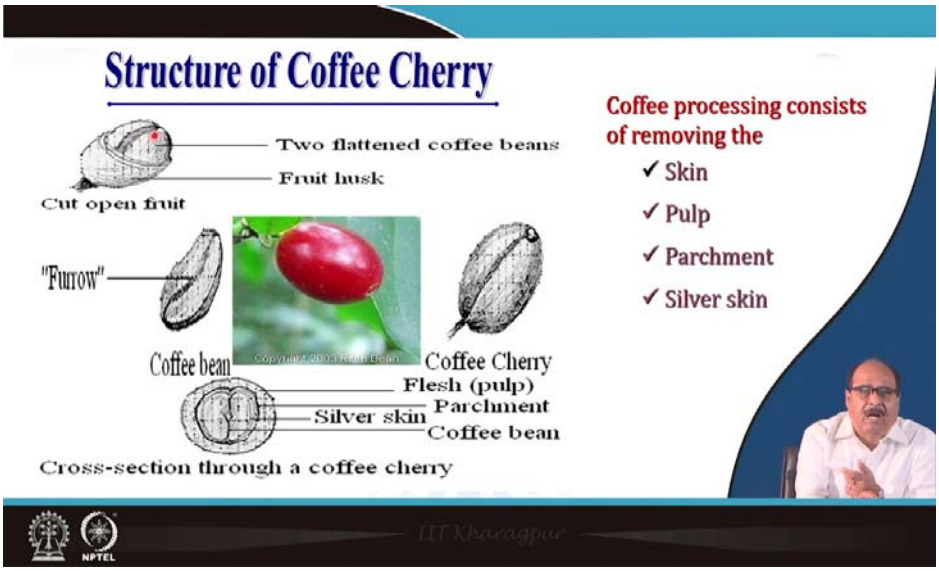
Coffee plantation

The unprocessed seeds of the coffee are planted and grown into a coffee tree. The planted cherries are harvested depending upon its variety. Normally three to four years are required for a tree to bear fruits. The harvesting of the coffee cherry is done in two ways, i.e. strip picked, in which all of the cherries are stripped off the branches at one time, either by hand or by suitable machine. Second method is selectively picked. Here only the ripe cherries are harvested and they are picked individually by hand. Pickers move among the trees by rotation of every 8 to 10 days, choosing only the cherries which are at the peak of their ripeness. And because this kind of harvest is labour intensive and more costly, it is used primarily to harvest the finer Arabica beans.

From coffee farm to consumer table

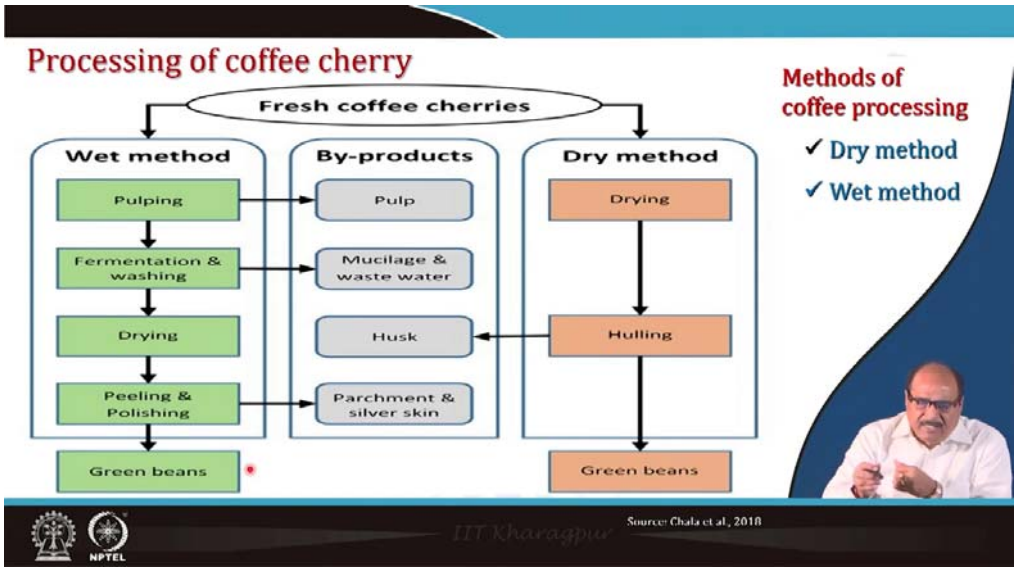
The steps involved are growing, harvesting, processing (wet or dry), milling, shipping, roasting, grinding, packing, brewing, and finally enjoying the coffee beverage.





Structure of coffee cherry

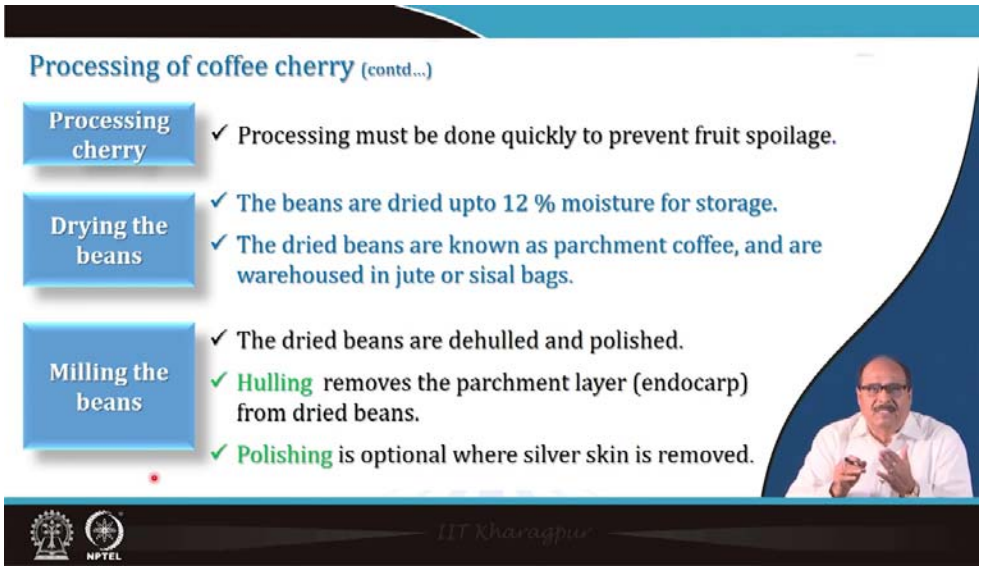
The coffee cherry consists of fruit husk, cotyledons, which are the actually valuable source of the coffee beverage i.e. coffee powder. The coffee beans are covered by a thin silver skin, and consists of parchment, fleshy pulp. Coffee processing consists of removing the skin, pulp, parchment, and silver skin which surrounds the bean.



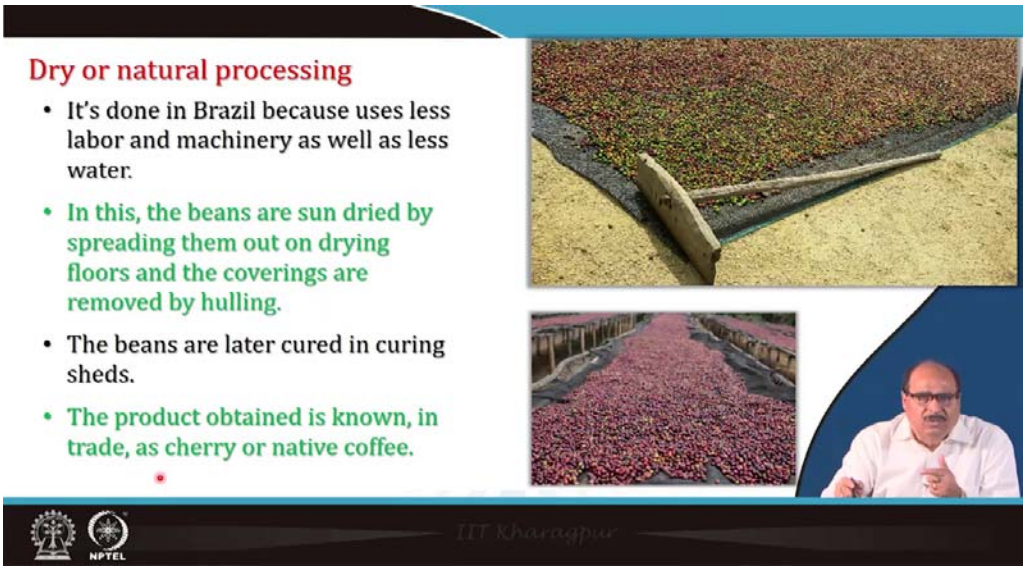
Processing of coffee cherry

There are two methods normally used either dry or wet method. The quality of the coffee bean, processed coffee beverage depends significantly on the nature of the, or method of the processing of the coffee beans. The dry method is very simple, which involves drying, hulling for removal of husk, and the green coffee beans are obtained. The wet method is normally gives

a comparatively better quality of coffee beans. This method consists of pulping, fermentation and washing for the washing and removal of the mucilage, drying, peeling and polishing for removal of parchment silver skins, and the green beans are obtained.



The processing must be done quickly to prevent the fruit or cherry spoilage. The beans are dried up to 12% moisture for storage. The dried beans are known as parchment coffee and are warehoused in jute or sisal bags. The dried beans are de-hulled and polished, hulling removes the parchment layer from the dried beans and polishing is optional where silver skin is removed.



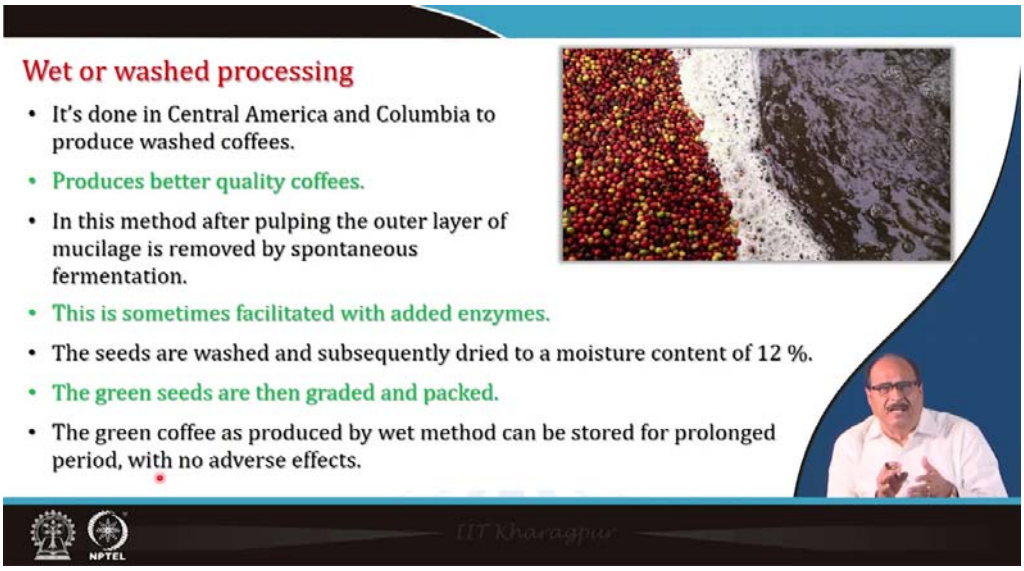
Dry or natural processing

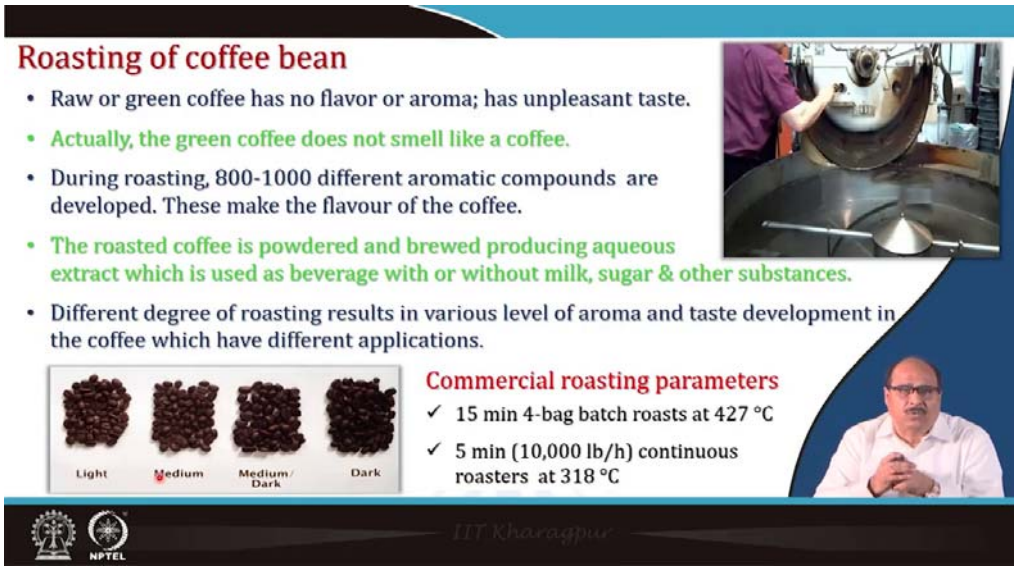
It's done in Brazil because uses less labor and machinery as well as less water. In this, the beans are sun dried by spreading them out on drying floors and the coverings are removed by hulling.

The beans are later cured in curing sheds. The product obtained is known, in trade, as cherry or native coffee.

Wet or washed processing

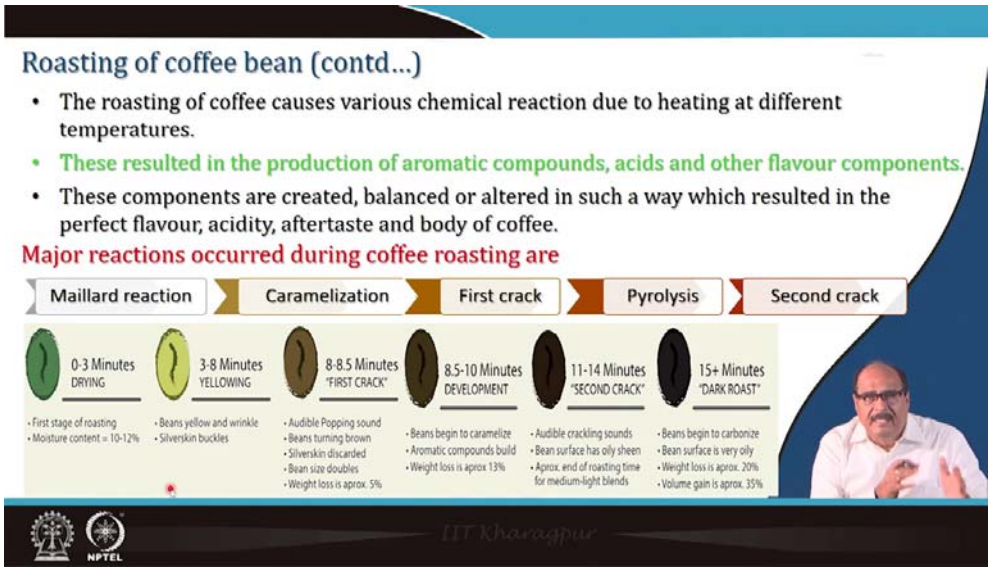
It's done in Central America and Columbia to produce washed coffees. Produces better quality coffees. In this method after pulping the outer layer of mucilage is removed by spontaneous fermentation. This is sometimes facilitated with added enzymes. The seeds are washed and subsequently dried to a moisture content of 12%. The green seeds are then graded and packed. The green coffee as produced by wet method can be stored for prolonged period, with no adverse effects.



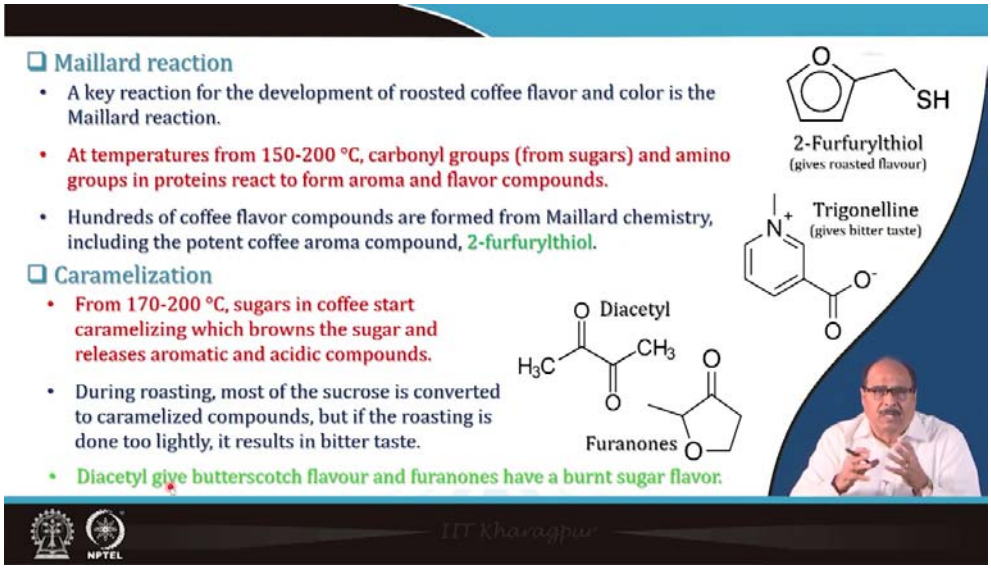


Roasting of coffee bean

Raw or green coffee has no flavor or aroma; has unpleasant taste. Actually, the green coffee does not smell like a coffee. During roasting, 800-1000 different aromatic compounds are developed. These make the flavour of the coffee. The roasted coffee is powdered and brewed producing aqueous extract which is used as beverage with or without milk, sugar & other substances. Different degree of roasting results in various level of aroma and taste development in the coffee which have different applications. The commercial roasting parameters may be about 15 minutes 4-bag batch roasts at a 427 ˚C or 5 minutes (10,000 pound per hour) continuous roasters at about 318 ˚C.



The roasting of coffee causes various chemical reaction due to heating at different temperatures. These resulted in the production of aromatic compounds, acids and other flavour components. These components are created, balanced or altered in such a way which resulted in the perfect flavour, acidity, aftertaste and body of coffee. Major reactions occurred during coffee roasting include Maillard reaction, caramelization, first crack, pyrolysis, and second crack. And this is depending upon the time, during the time that is for the initial 2 to 3 minutes there will be drying and then after 3 to 8 minutes, there will be a yellowing which is followed by, there is the first crack and then once there is first crack, then there are a minute development inside the bean which leads to the paralysis. Finally, second crack, and then further development of the compounds.



Maillard reaction

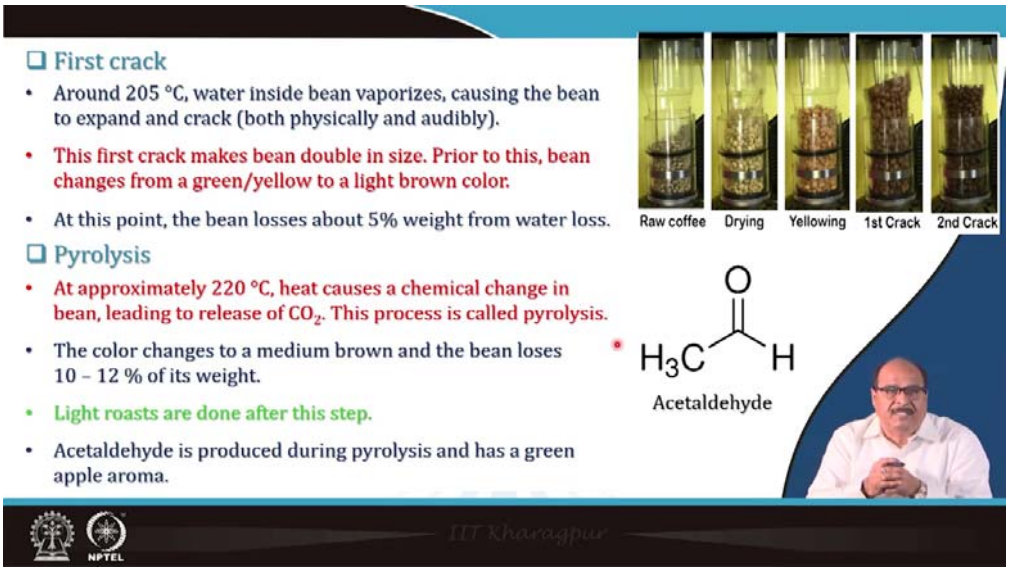
A key reaction for the development of roosted coffee flavor and color is the Maillard reaction. At temperatures from 150-200 °C, carbonyl groups (from sugars) and amino groups in proteins react to form aroma and flavor compounds. Hundreds of coffee flavor compounds are formed from Maillard chemistry, including the potent coffee aroma compound, 2-furfurylthiol.

Caramelization

From 170-200 °C, sugars in coffee start caramelizing which browns the sugar and releases aromatic and acidic compounds. During roasting, most of the sucrose is converted to caramelized compounds, but if the roasting is done too lightly, it results in bitter taste. Diacetyl give butterscotch flavour and furanones have a burnt sugar flavor.

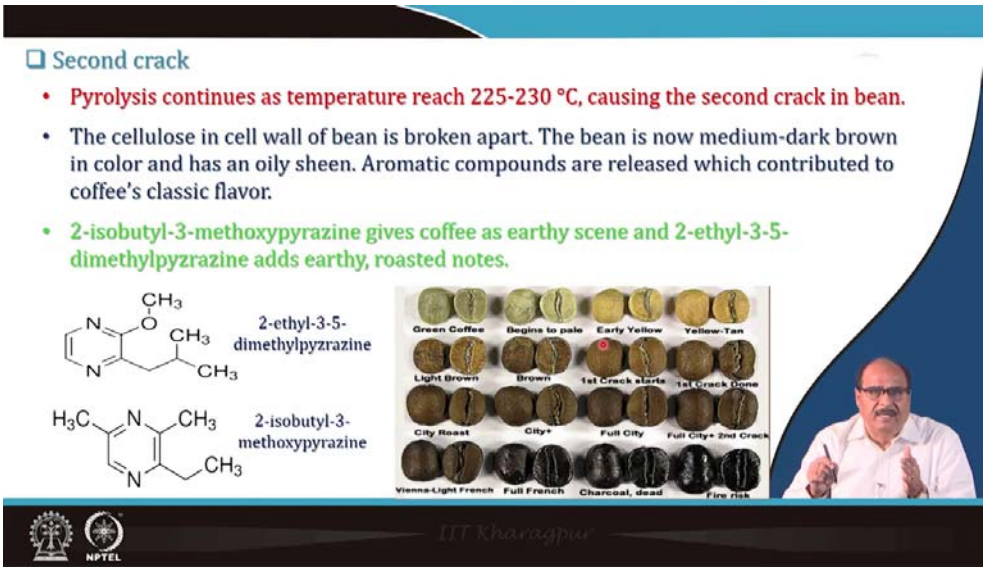
First crack

Around 205 °C, water inside bean vaporizes, causing the bean to expand and crack (both physically and audibly). This first crack makes bean double in size. Prior to this, bean changes from a green/yellow to a light brown color. At this point, the bean losses about 5% weight from water loss.



Pyrolysis

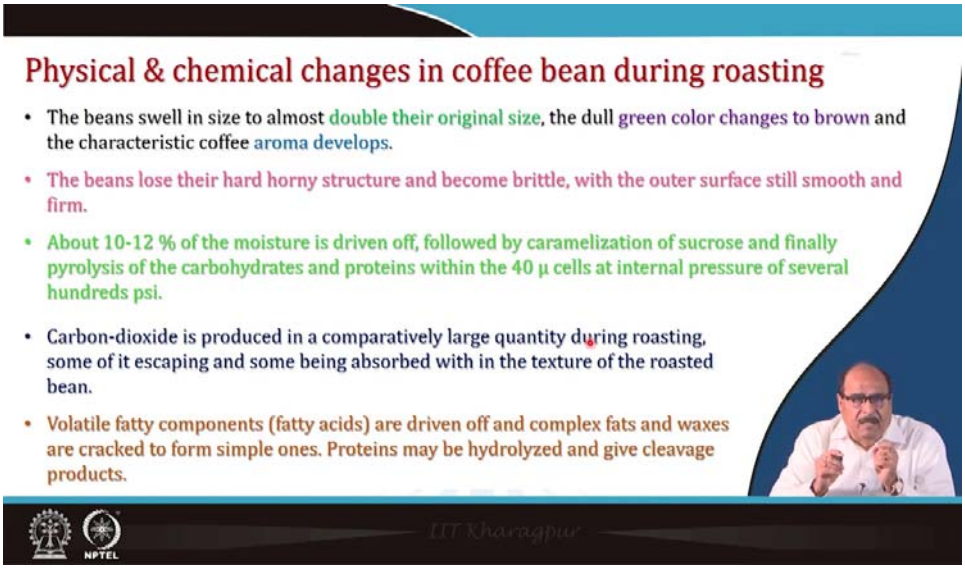
At approximately 220 °C, heat causes a chemical change in bean, leading to release of CO2. This process is called pyrolysis. The color changes to a medium brown and the bean loses 10 – 12 % of its weight. Light roasts are done after this step. Acetaldehyde is produced during pyrolysis and has a green apple aroma.



Second crack

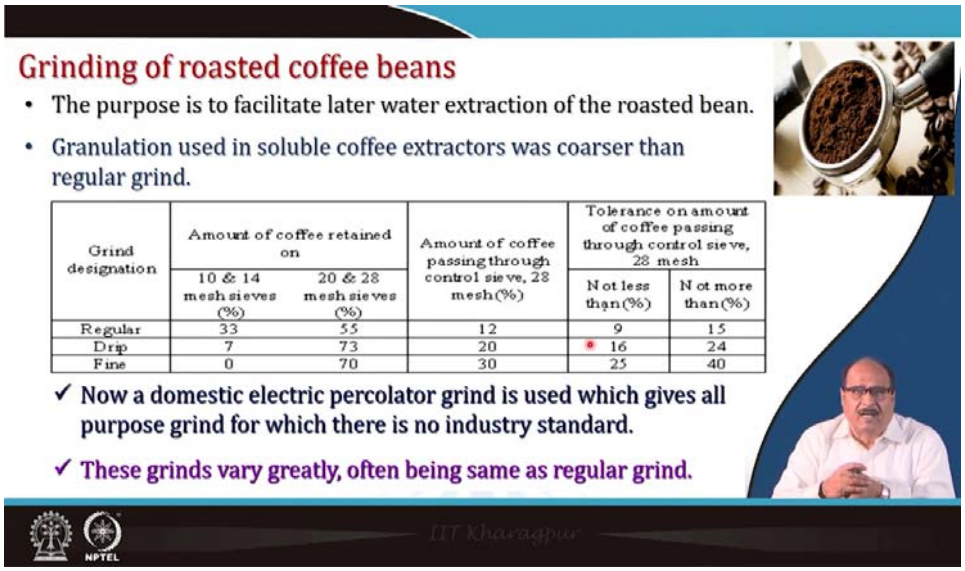
Pyrolysis continues as temperature reach 225-230 °C, causing the second crack in bean. The cellulose in cell wall of bean is broken apart. The bean is now medium-dark brown in color and has an oily sheen. Aromatic compounds are released which contributed to coffee's classic flavor.

2-isobutyl-3-methoxypyrazine gives coffee as earthy scene and 2-ethyl-3-5-dimethylpyzrazine adds earthy, roasted notes.



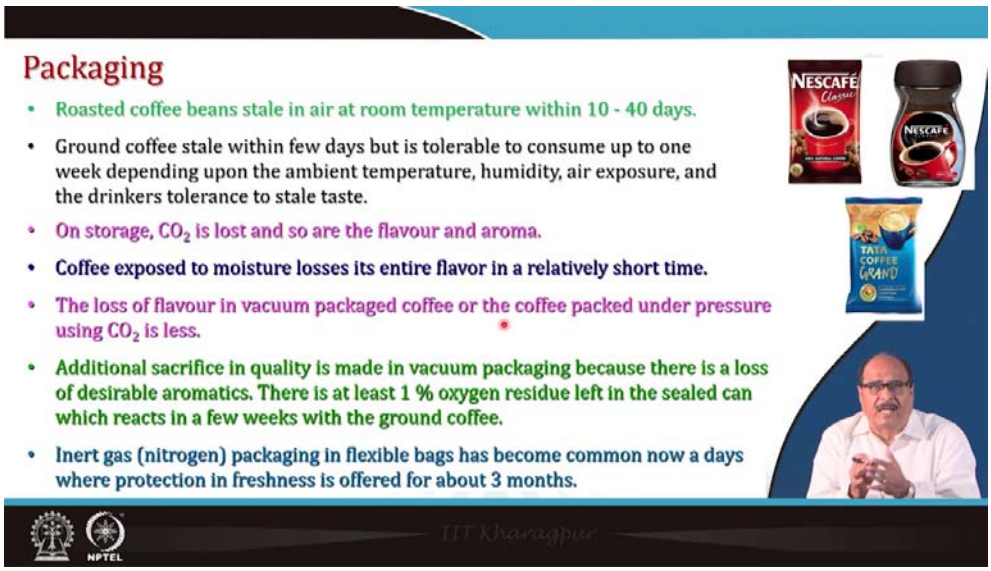
Physical & chemical changes in coffee bean during roasting

The beans swell in size to almost double their original size, the dull green color changes to brown and the characteristic coffee aroma develops. The beans lose their hard horny structure and become brittle, with the outer surface still smooth and firm. About 10-12 % of the moisture is driven off, followed by caramelization of sucrose and finally pyrolysis of the carbohydrates and proteins within the 40 µ cells at internal pressure of several hundred psi. Carbon-dioxide is produced in a comparatively large quantity during roasting, some of it escaping and some being absorbed with in the texture of the roasted bean. Volatile fatty components (fatty acids) are driven off and complex fats and waxes are cracked to form simple ones. Proteins may be hydrolyzed and give cleavage products.



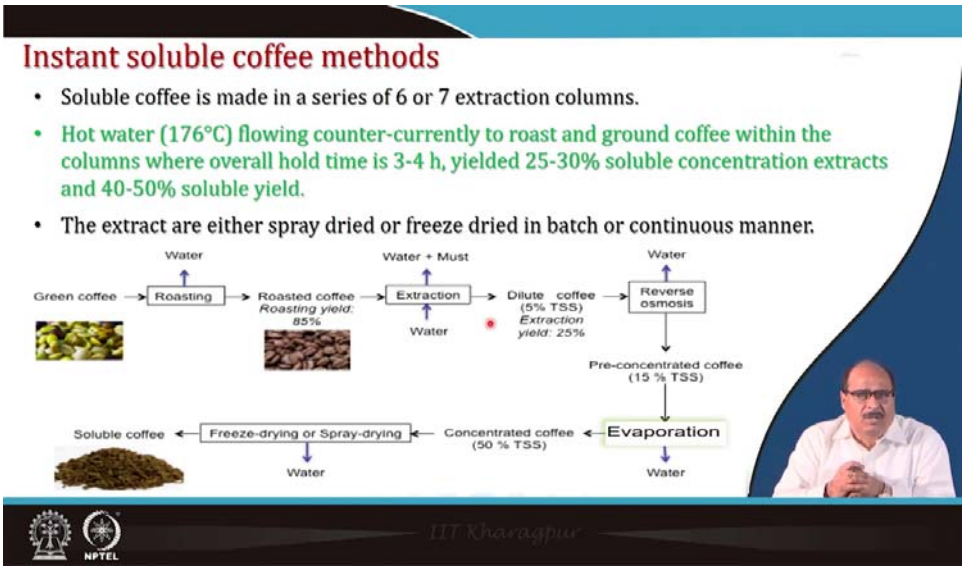
Grinding of roasted coffee beans

The purpose is to facilitate later water extraction of the roasted bean. Granulation used in soluble coffee extractors was coarser than regular grind. The table represents different grind designations such as regular, drip, and firm with the amount of coffee retained on different size of mesh sieves. Regular grind that is about 33% of the coffee is retained on 10 to 14 mesh sieves and about 55% of coffee is retained on 20 and 28 mesh sieves, and amount of the coffee passing through the control sieves that is 28 mesh is 12% in the regular grind. Now a domestic electric percolator grind is used which gives all-purpose grind for which there is no industry standard. These grinds vary greatly, often being same as regular grind.



Packaging

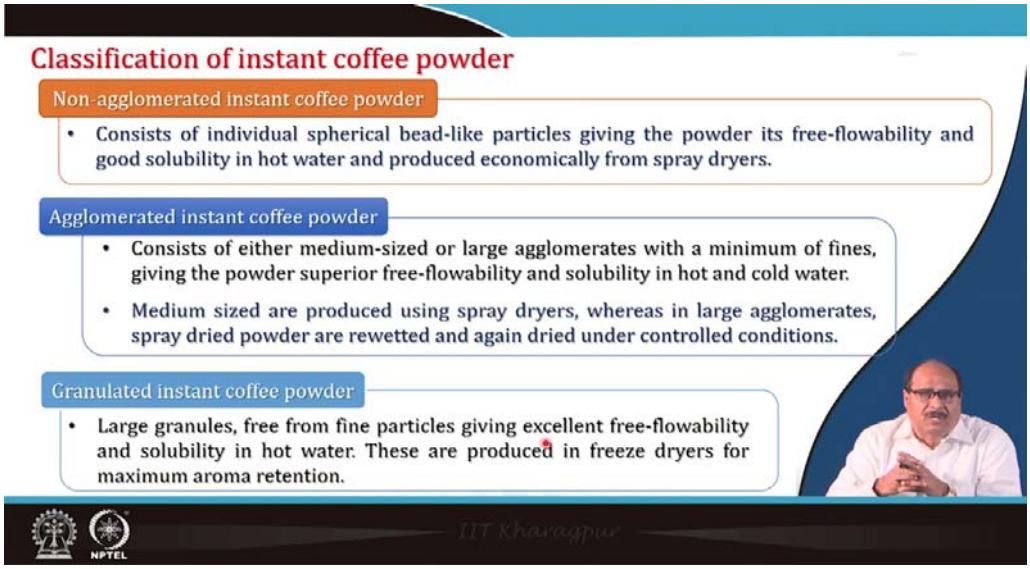
Roasted coffee beans stale in air at room temperature within 10-40 days. Ground coffee stale within few days but is tolerable to consume up to one week depending upon the ambient temperature, humidity, air exposure, and the drinkers tolerance to stale taste. On storage, CO_2 is lost and so are the flavour and aroma. Coffee exposed to moisture losses its entire flavor in a relatively short time. The loss of flavour in vacuum packaged coffee or the coffee packed under pressure using CO_2 is less. Additional sacrifice in quality is made in vacuum packaging because there is a loss of desirable aromatics. There is at least 1% oxygen residue left in the sealed can which reacts in a few weeks with the ground coffee. Inert gas (nitrogen) packaging in flexible bags has become common now a days where protection in freshness is offered for about 3 months.



Instant soluble coffee methods

Then important product is the instant soluble coffee, that method for the preparation of instant soluble coffee. So, in fact, that is, like we make brew in our home that is in the hot water or hot milk coffee powder is used. So, the same process in fact is used at the industrial scale. First, the coffee that is the water soluble components present in the coffee cheery or roasted coffee beans, they are extracted using 6 or 7 extraction columns. In these columns, that is hot water at around 176 to 80 °C flows in a counter current manner to the over the roasted and ground coffee within the column, where that overall hold time is around 3 to 4 hours and it yields about 25 to 30 % of the soluble concentration extract and around 40 to 50 percent of the soluble yields. These extract which is obtained, this is further concentrated normally either by vacuum concentration, but the method of choice in the freeze concentration process. And then this concentrated coffee beans are next send to that it has a concentrated coffee. It has a TSS of about 50 % or so. And then this is sent to the freeze drying or spray drying, where that in the freeze drying sublimation process is used or in the spray drying that hot air that is spray is atomized and we get the soluble coffee

powder. Mostly, the choice grade coffee is made by the freeze drying process. Although, industrial operation makes the spray drying better.



Classification of instant coffee powder

Non-agglomerated instant coffee powder

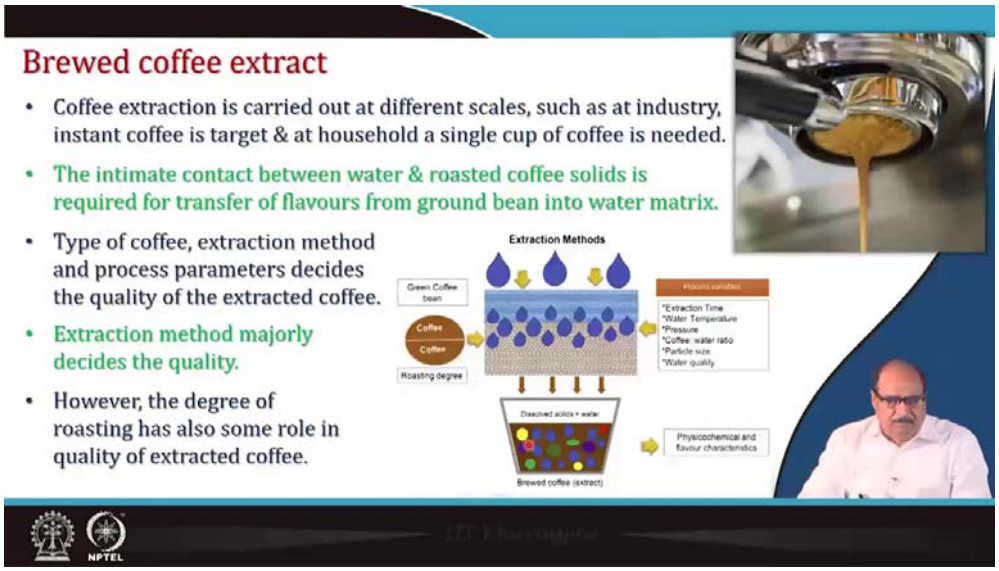
Consists of individual spherical bead-like particles giving the powder its free-flowability and good solubility in hot water and produced economically from spray dryers.

Agglomerated instant coffee powder

Consists of either medium-sized or large agglomerates with a minimum of fines, giving the powder superior free-flowability and solubility in hot and cold water. Medium sized are produced using spray dryers, whereas in large agglomerates, spray dried powder are rewetted and again dried under controlled conditions.

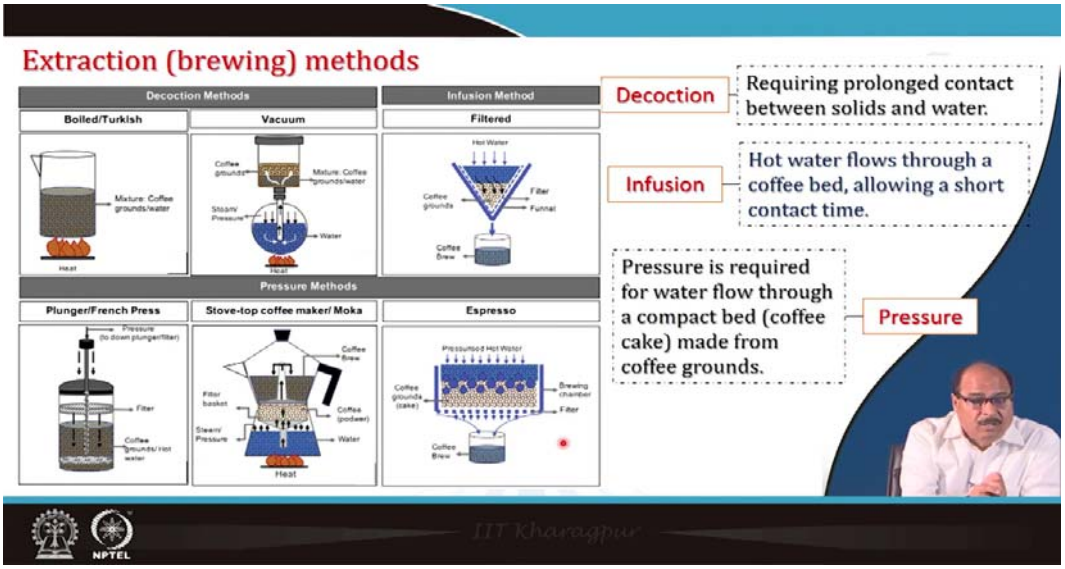
Granulated instant coffee powder

Large granules, free from fine particles giving excellent free-flowability and solubility in hot water. These are produced in freeze dryers for maximum aroma retention.



Brewed coffee extract

Coffee extraction is carried out at different scales, such as at industry, instant coffee is target & at household a single cup of coffee is needed. The intimate contact between water & roasted coffee solids is required for transfer of flavours from ground bean into water matrix. Type of coffee, extraction method and process parameters decides the quality of the extracted coffee. Extraction method majorly decides the quality. However, the degree of roasting has also some role in quality of extracted coffee. So, the process variable may be extraction time water temperature, pressure, coffee to water ratio, particle size of the coffee powder, water quality etc.



Extraction (brewing) methods

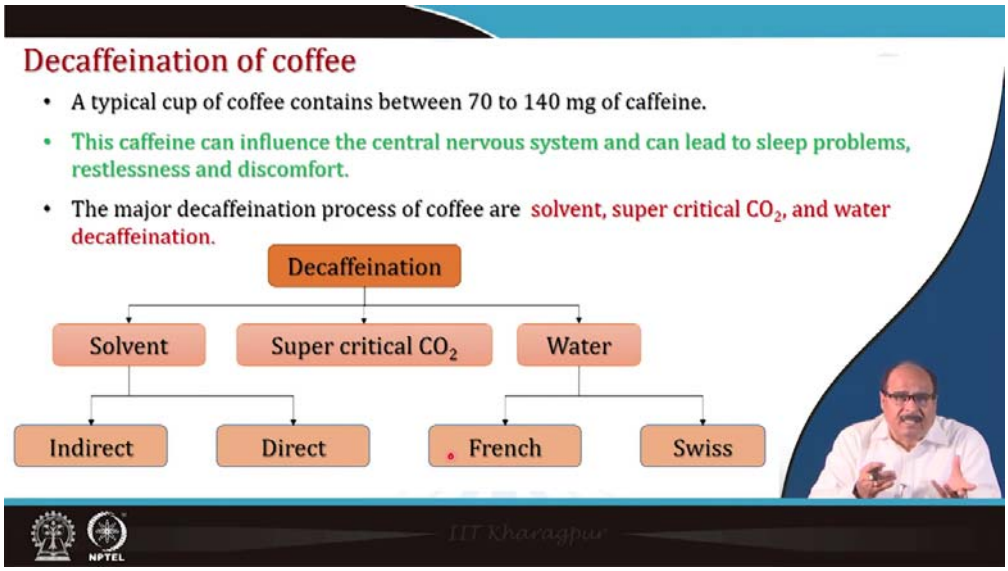
The extraction method maybe the decoction methods, include boiled or Turkish method or vacuum method as shown in the figure. This method basically requires prolonged contact between the solid and the water. In the infusion methods like in the making filtered coffee, the hot water flows a coffee bed, allowing a short contact time. So, the soluble flavouring and colouring compounds are extracted and come in the coffee brew.

The pressure method like plunger French press or stove top coffee maker or Mocha or espresso coffee machine, as shown schematically in the figure. Basically, here the pressure is used. Pressure is required for the continuous or uniform flow through a compact bed of the coffee cake. And it is made from the ground coffee or coffee powder. As shown in the figure, espresso coffee that is this coffee grounds or cake is put and the pressurized hot water is flown. And then in the brewing chamber, a filter medium, it filters and the coffee brew is obtained.

Instant coffee v/s freshly brewed coffee

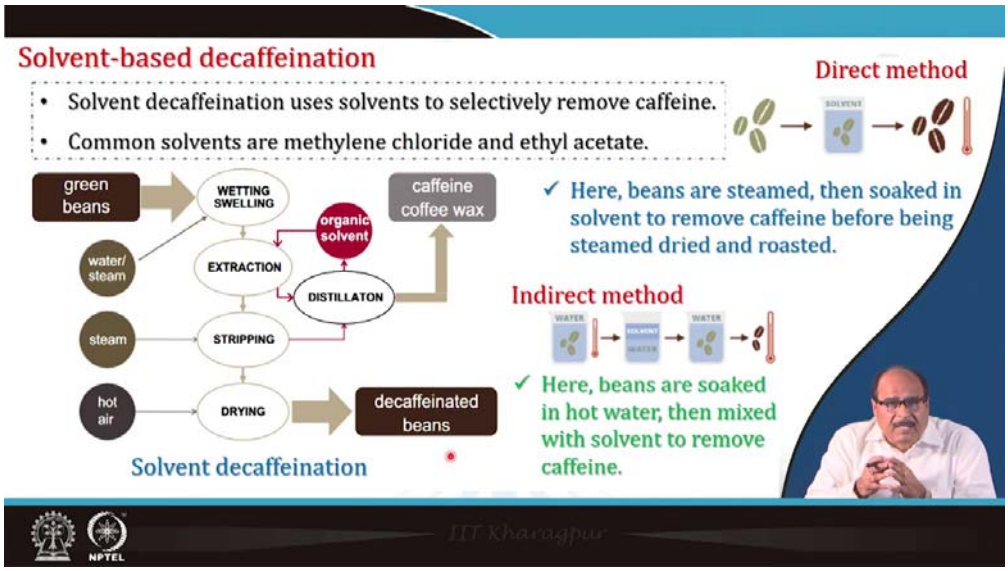
One cup instant coffee contains 60-80 mg of caffeine. It has less chlorogenic acid, high phenol and flavonoids, it has low cost and convenience is the key advantage of this. There are no by-product and less time is required in its manufacturing.

Whereas the freshly brewed coffee, it contains 60 to 120 milligrams of caffeine per cup, more chlorogenic acid, low phenols and flavonoids. It is expensive process, but it has been in the traditional, a ritual process. In many countries, it is being used, there are some by-products, and it is a time consuming method.



Decaffeination of coffee

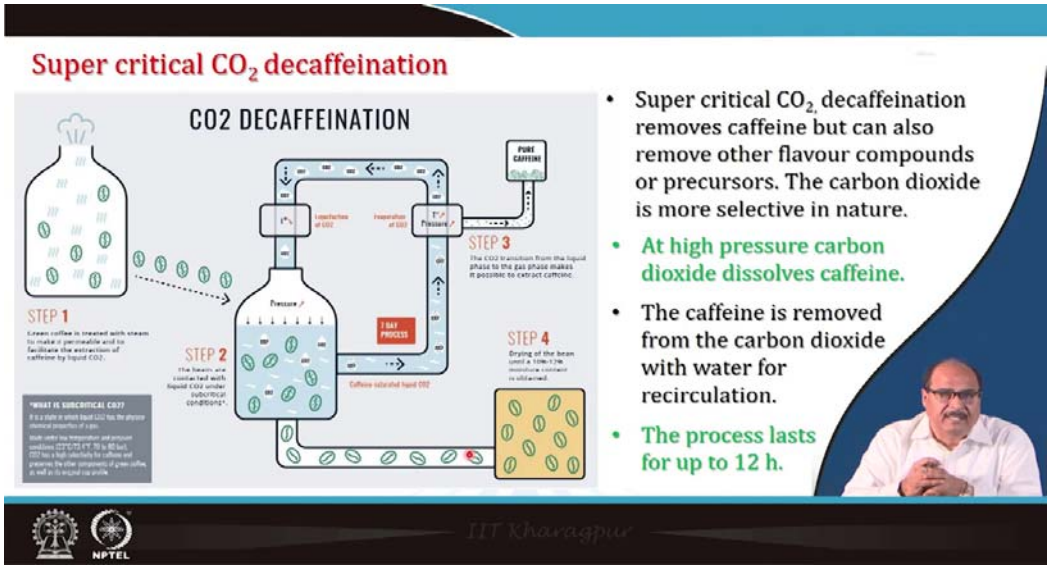
A typical cup of coffee contains between 70 to 140 mg of caffeine. This caffeine can influence the central nervous system and can lead to sleep problems, restlessness and discomfort. That is called extreme caffeinism. The major decaffeination process of coffee are solvent, super critical CO_2, and water decaffeination.



Solvent-based decaffeination

Solvent decaffeination uses solvents to selectively remove caffeine. Common solvents are methylene chloride and ethyl acetate. The process may be a direct method or indirect method. In the direct method, beans are steamed, then soaked in solvent to remove caffeine before being

steamed dried and roasted. In the indirect method, beans are soaked in hot water then mixed with solvent to remove the caffeine.



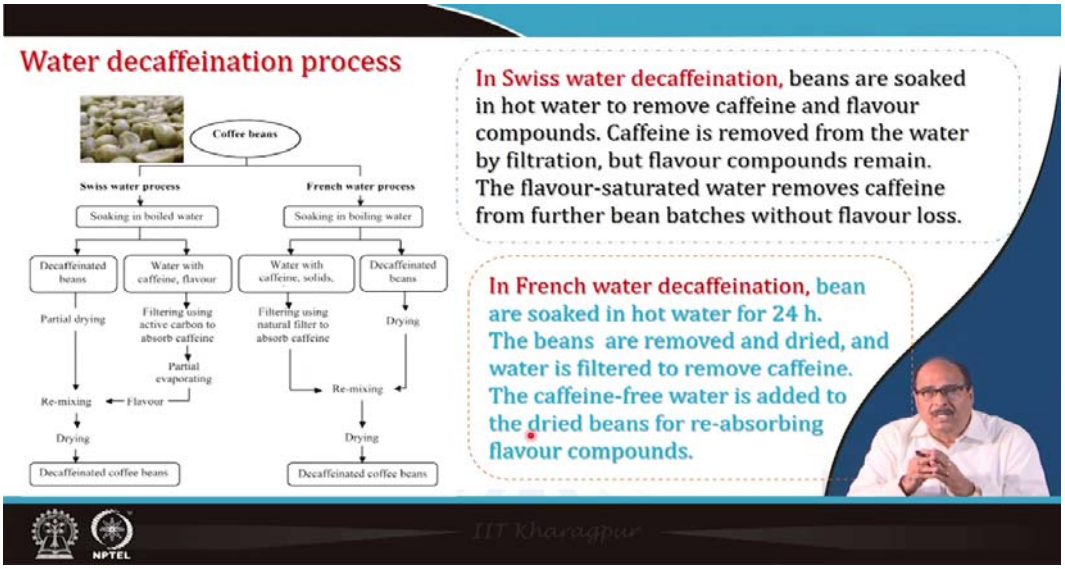
Super critical CO_2 decaffeination

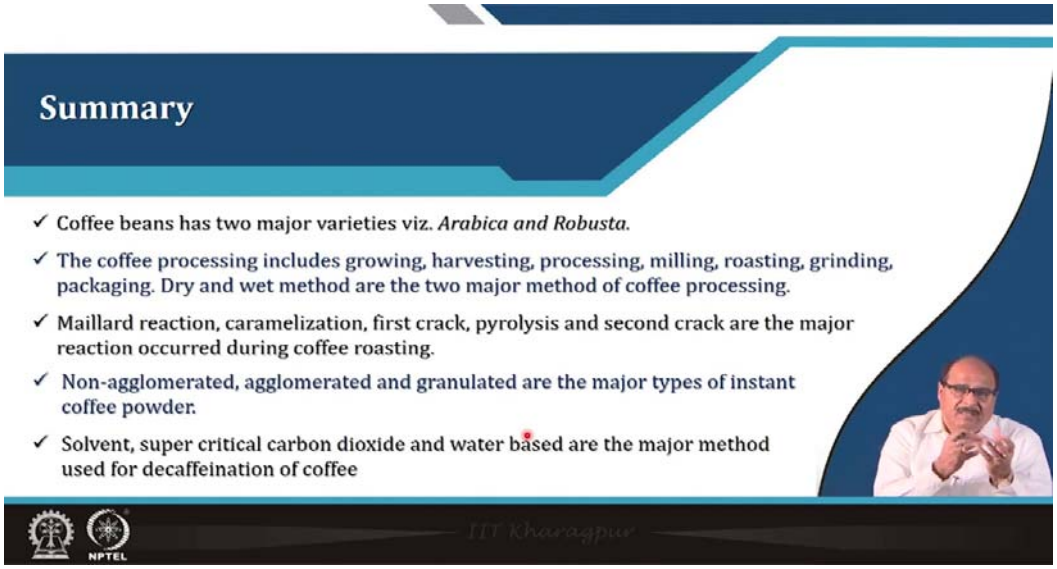
The supercritical carbon dioxide, decaffeination methods, green coffee is treated with the steam to make it permeable and to facilitate the extraction of caffeine by liquid carbon dioxide supercritical carbon dioxide, in the first step. In the second step, the beans are contacted with the carbon dioxide under supercritical conditions at a particular pressure and temperature, where this flavour, that is de-caffeine is solubilized in the supercritical carbon dioxide. Super critical CO_2, decaffeination removes caffeine but can also remove other flavour compounds or precursors. The carbon dioxide is more selective in nature. At high pressure carbon dioxide dissolves caffeine. The caffeine is removed from the carbon dioxide with water for recirculation. The process lasts for up to 12 h.

Water decaffeination process

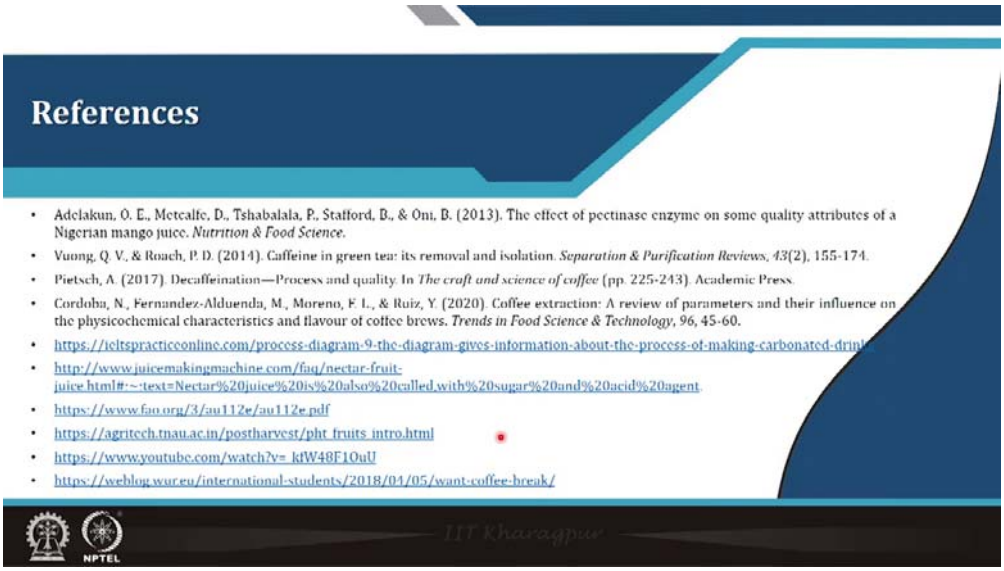
In Swiss water decaffeination, beans are soaked in hot water to remove caffeine and flavour compounds. Caffeine is removed from the water by filtration, but flavour compounds remain. The flavour-saturated water removes caffeine from further bean batches without flavour loss.

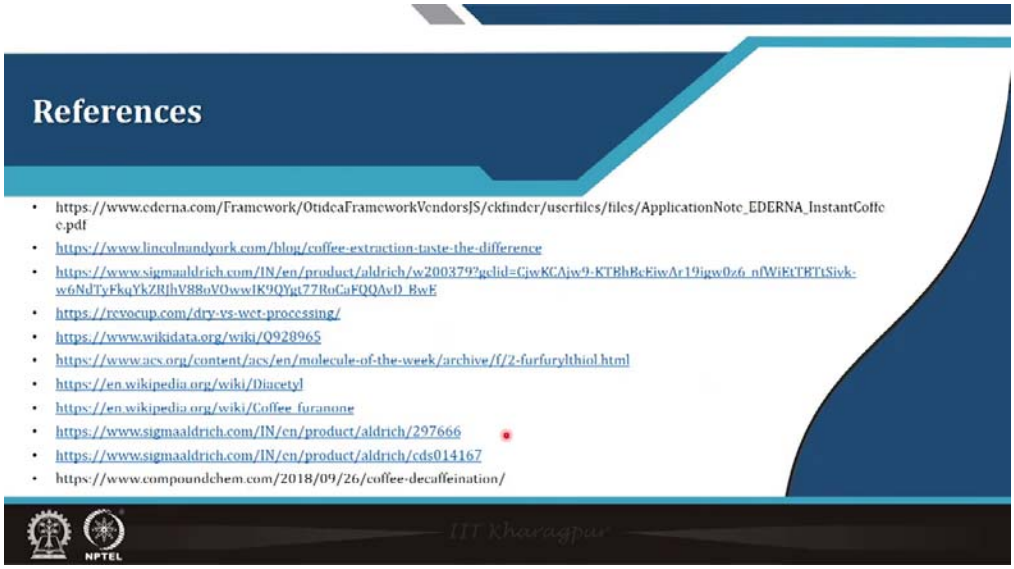
In French water decaffeination, bean are soaked in hot water for 24 h. The beans are removed and dried, and water is filtered to remove caffeine. The caffeine-free water is added to the dried beans for re-absorbing flavour compounds.





In summary, coffee beans has two major varieties viz. *Arabica* and *Robusta*. The coffee processing includes growing, harvesting, processing, milling, roasting, grinding, packaging. Dry and wet method are the two major method of coffee processing. Maillard reaction, caramelization, first crack, pyrolysis and second crack are the major reaction occurred during coffee roasting. Non-agglomerated, agglomerated and granulated are the major types of instant coffee powder. Solvent, super critical carbon dioxide and water based are the major method used for decaffeination of coffee





These are the references for further study. Thank you.