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

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Lecture – 24
Cut Fruits and Vegetables: Part I

The concepts covered in this lecture are the fresh-cut produces, their manufacturing processes, quality changes during processing, innovative or novel technologies involved, and processing and desired qualities of popular fresh cut fruits and vegetables which are available in the market.

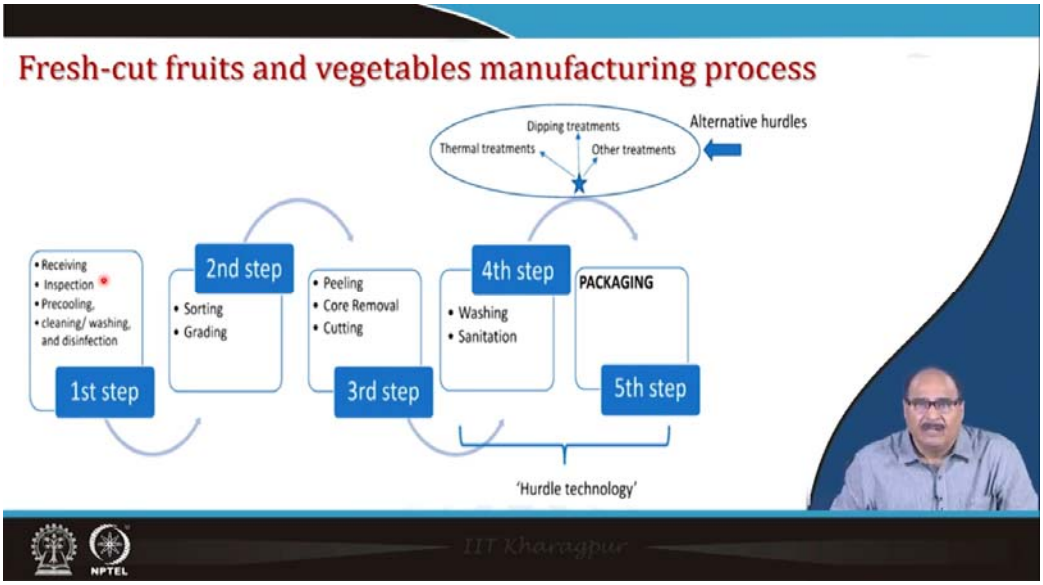
Fresh cut produce

According to the International Fresh Cut Produce Association popularly known as IFPA, "the fresh cut produces are any fruit or vegetable or combination thereoff that has been physically altered from its original form, but it remains in a fresh state".

In the recent past, consumption of ready-to-eat fresh cut fruits has been substantially increased due to the increasing demand for low-calorie food products with fresh-like characteristics. Fresh cut produce may consist of peeled, sliced, shredded, trimmed and/or washed fruits or vegetables.

Fresh cut products

Fresh cut products includes any kind of fresh commodities and their mixtures in different cuts and it is packaged nicely. It may be fresh cut fruits, mixed fresh cut fruits, fresh cut fruit-salad, fresh cut vegetables, and items such as bagged salads, baby carrots, stir fry vegetable mixes, fresh cut apples, pineapple or melon. These are some of the only few examples, the list is very large and exhaustive.



Fresh-cut fruits and vegetables manufacturing process

In the market, variety of fresh-cut fruits and vegetables are available nowadays. And particularly, in recent past, there has been increasing demand of these products, both at the consumer end and in the market. So, I tried to make you aware of the manufacturing process for fresh-cuts fruits and vegetables.

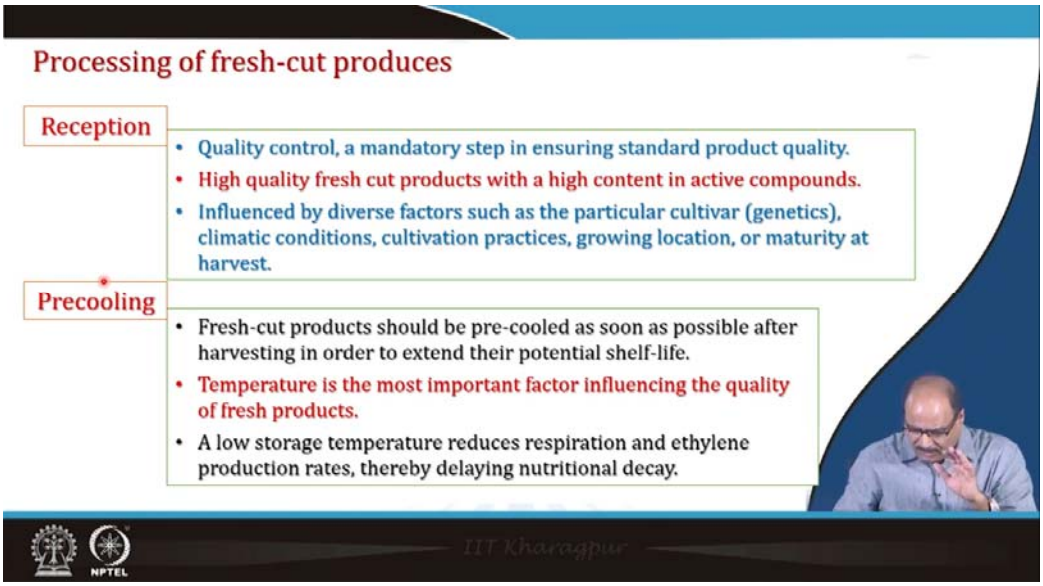
So, the first step was obviously in the facility where these are produce are processed, so, their material either fruit or vegetable is to be received. Then at the time of receiving, inspection, pre-cooling, cleaning, washing and disinfection are carried out. After this, the disinfected produce is sent next to the second step where sorting and grading is done.

Second step is very important as the produce are sorted based on size, grade, color, texture and other characteristics. This will produce the cut pieces or cut slice etc. of desired or uniform size, uniform quality that will make it easier for further processing or handling or even from the shelf life and quality point of view. Then it is taken to the third step which involves peeling, then removal of core etc.

In the third step, after the peeling and core removal, the produce is cut. Cutting may be done into the different shapes and sizes. After cutting, the next step is washing and sanitation. These cut pieces are properly washed and sanitized. There is a chance of contamination during cutting or other processes which invariably occurs. So, these cut pieces should be properly washed, sanitized and after that they are packaged. So, here in the fourth and fifth step, hurdle technology concept should be applied. There is washing, sanitization and appropriate packaging should be done.

There can be alternating hurdles such as thermal treatment, dipping treatment or other treatments etc. should be done. The purpose is to make sure that the quality of the cut

produce is maintained, its texture, color, flavor can be maintained and also it has a comparatively desirable or long shelf life.

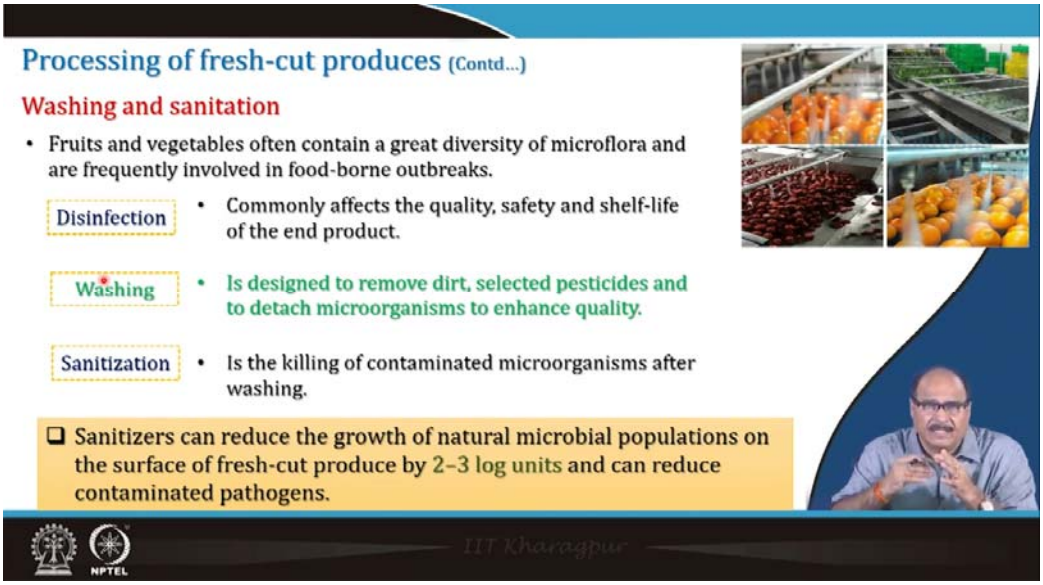


Processing of fresh-cut produces

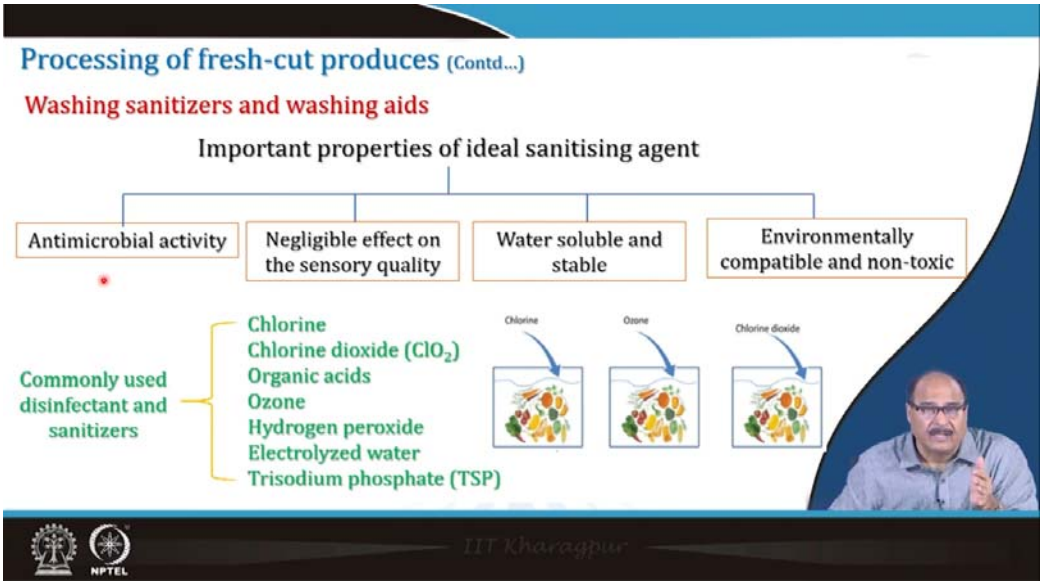
The fresh-cut produce are the hub of nutrients and active components. So, in order to get good quality or high quality cut produces, you have to have a good quality raw material and whole fresh and these as a influenced by diverse such as the particular cultivar (genetics), climatic conditions, cultivation practices, growing locations, or maturity at the time of harvest.

Then comes very important step i.e. pre-cooling. Peels provided the natural protection to the whole fruits or vegetables. Thus, fresh-cut products should be pre-cooled as soon as possible after harvesting in order to extend their potential shelf-life. When peels are removed, the rate of respiration increases. So, it becomes very important that all these operations should be done in a controlled temperature environment and the temperature even during processing, after processing is maintained as low as possible. So, temperature is the most important factor influencing the quality of the fresh products. A low storage temperature reduces respiration and ethylene production rates, thereby delaying nutritional decay. So, it should be precooled before sending to the next treatment.

The next stage is washing and sanitation. Fruits and vegetables depending upon the horticultural practices, may be contaminated with a great diversity of microflora, particularly, vegetables. Because of their proximity to the soil when they are produced and also they are low acid food, so they serve as a vector of majority of the spoilage causing or pathogenic disease causing bacteria.



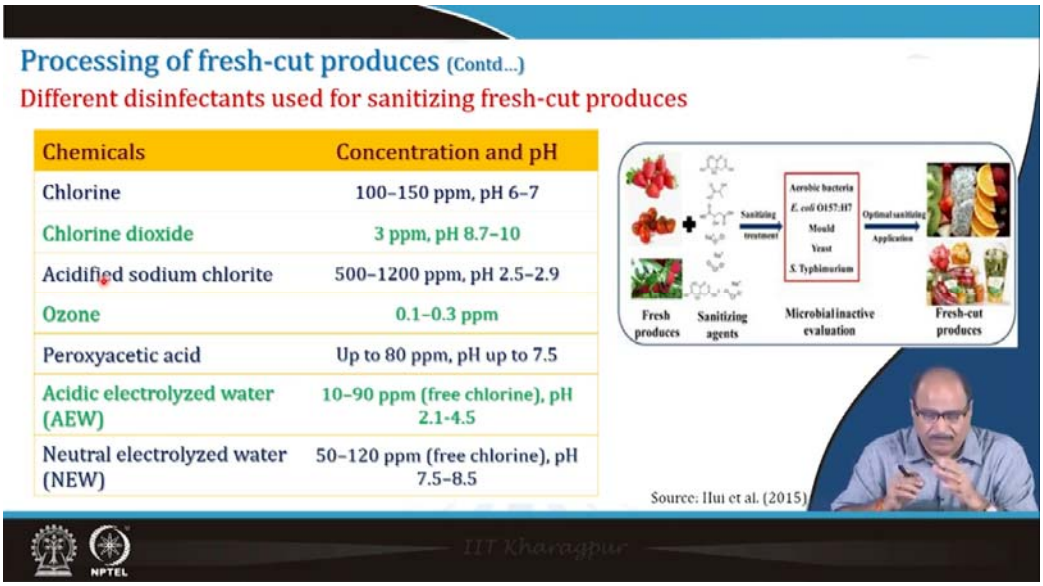
So, washing and sanitization becomes very important i.e. it should be properly disinfected because there may be chemical residue, pesticide residue, etc. The infestation commonly affect the quality, safety and shelf life of the end product, thus disinfestation is needed. Washing is designed to remove any dirt, selected pesticides and to detach microorganisms to enhance quality. Sanitization obviously is the killing of contaminated microbes after washing. Sanitizers can reduce the growth of natural microbial population on the surface of fresh cut produces by 2-3 log units and therefore can reduce the contamination level, contamination of pathogens and extend the shelf life.



Washing sanitizers and washing aids

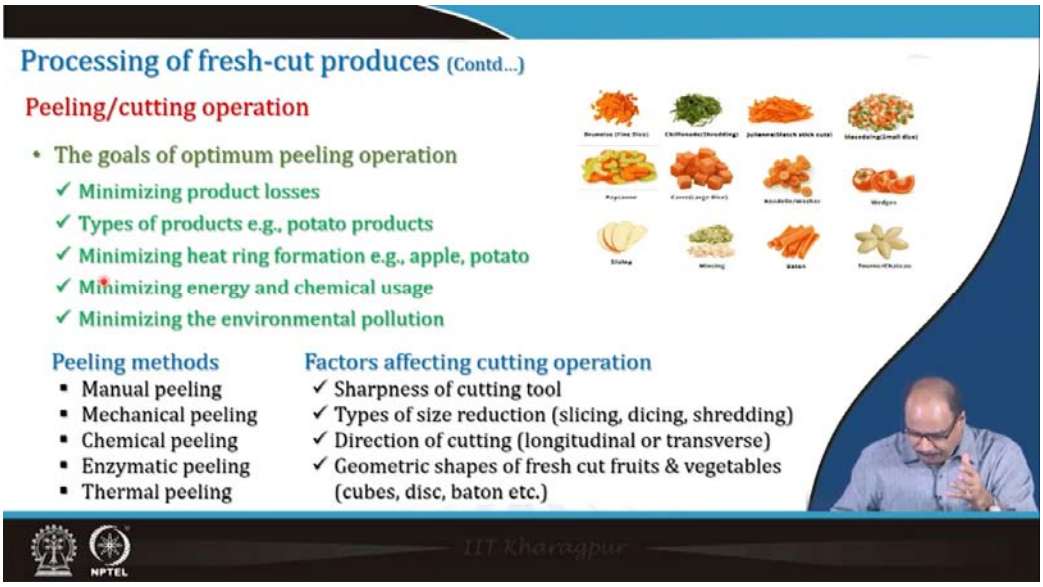
Ideal sanitisng agent should have following properties. They have antimicrobial activity, they may have negligible effect on sensory quality, they should be water-soluble and stable, and they should be environmentally capable and non-toxic. The commonly used disinfectant and

sanitizers in the cut produces include chlorine, chlorine dioxide, organic acids, ozone, hydrogen peroxide, electrolyzed water, trisodium phosphates etc.



Different disinfectants used for sanitizing fresh-cut produces

The disinfectant which are used for sanitizing cut produces and their labels are given like chlorine is generally used in the range of 100 to 150 ppm and the pH range should be 6 to 7. Acidified sodium chlorite may be in between 500 to 1200 ppm with pH 2.5 to 2.9. Acidified electrolyzed water may be in the range of 10 to 90 ppm, and pH is 2.1 to 4.5. These are some examples of disinfectants used for sanitizing fresh cut produces.



Peeling/Cutting Operation

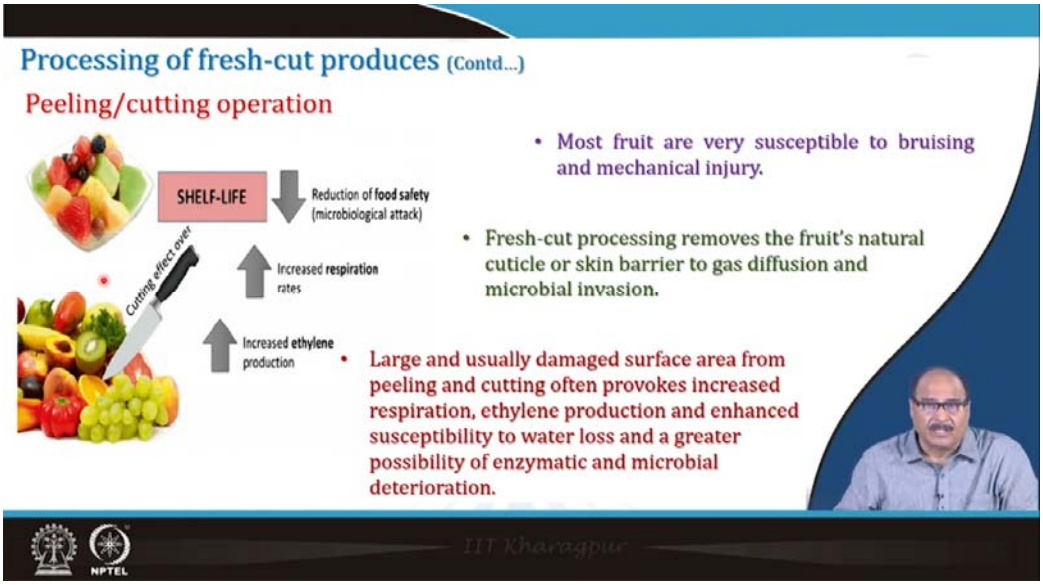
The goal of the optimum peeling operation includes minimizing product losses, types of products like potato products etc. Cutting is very important as it optimum cutting minimizes

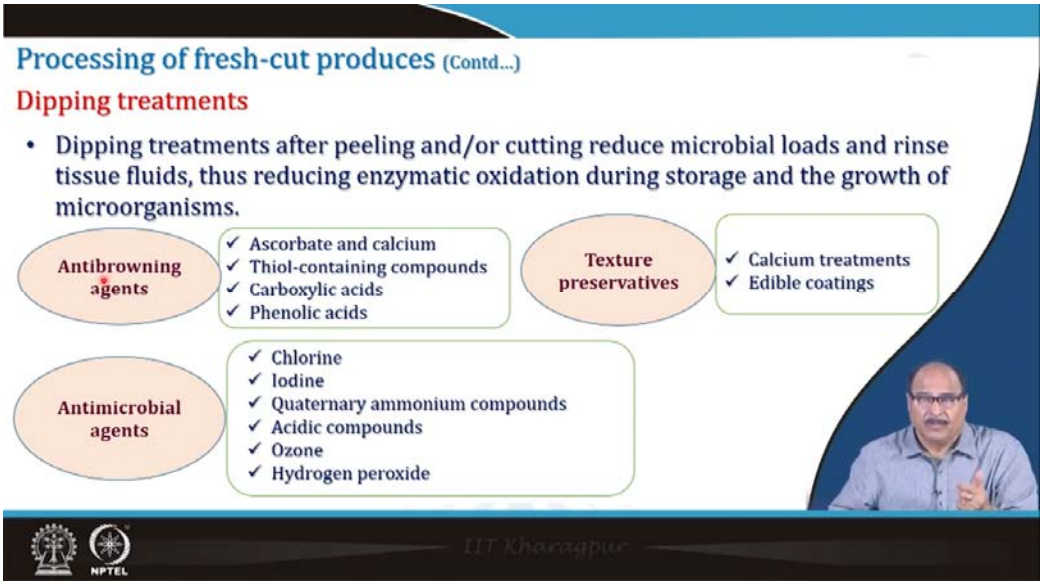
the heat ring formation in case of apples, potato; minimizes energy and chemical usage; minimizes the environmental pollutions.

Peeling methods are categorized into five categories i.e. manual peeling, mechanical peeling, chemical peeling, enzymatic peeling, and thermal peeling. So, one has to adopt a specific method of peeling depending upon the type of the material and its characteristics.

The factors which influence the cutting operation include sharpness of the cutting tool, types of size reduction (slicing, dicing, shredding), direction of cutting (longitudinal or traverse), and geometric shape of the fresh cut fruits and vegetables (cubes, disc, baton etc.).

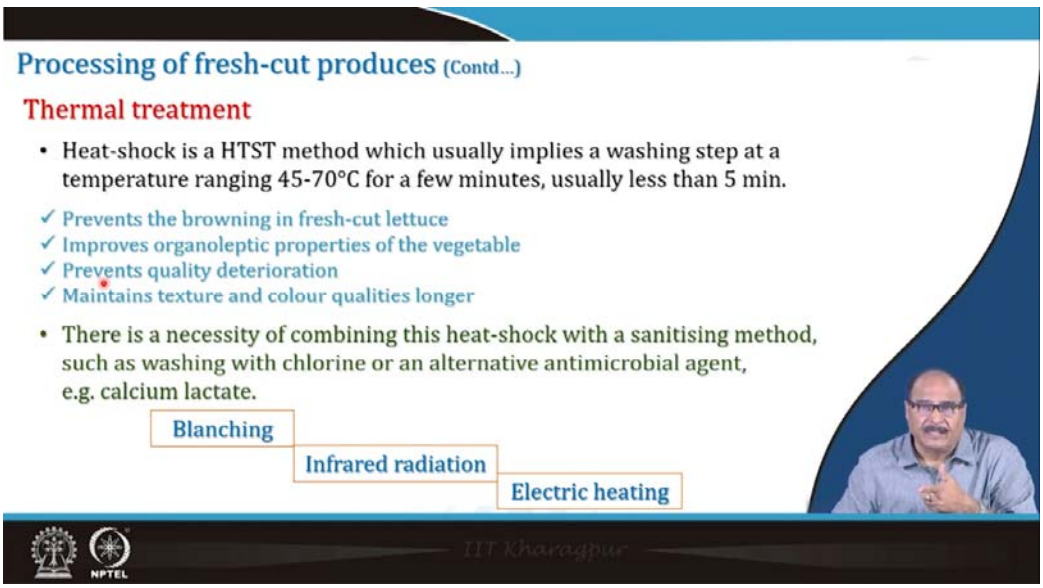
The peeling and cutting operation should be properly maintained as most fruits are susceptible to bruising and mechanical injury. Proper care should be taken that during peeling and cutting operations, excessive damage is not there to the tissue. Otherwise, it will increase the rate of respiration. Fresh cut processing also removes the fruit's natural cuticle or skin which is its natural protection against gas diffusion and microbial invasion. So, it may increase the gas diffusion and microbial invasion etcetera. Large and usually damaged surface area from peeling and cutting often provokes increased respiration, ethylene production and enhance susceptibility to water loss and a greater possibility of enzymatic and microbial deterioration.





Dipping treatments

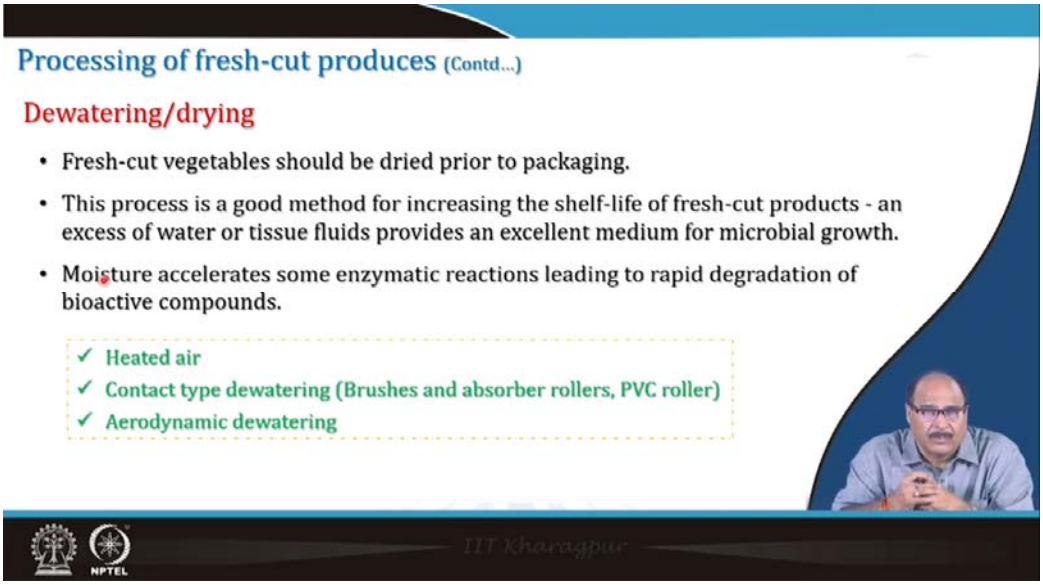
The fresh produces are susceptible to various enzymes. During peeling or immediately after peeling, the treatment like dripping or such other treatment are given to the commodity. Dipping treatments after peeling and/or cutting reduce microbial loads and rinse tissue fluids, thus reducing enzymatic oxidation during storage and the growth of microorganisms. Fresh produce is dipped in antibrowning agents which may include ascorbate and calcium, thiol-containing compounds, carboxylic acid, phenolic acid or even the dipping solution may contain antimicrobial agents like chlorine, iodine, quaternary ammonium compounds, acidic compounds, ozone, hydrogen peroxide, etc. It may also include texture agent or preservatives such as calcium treatment, edible coatings.



Thermal treatment

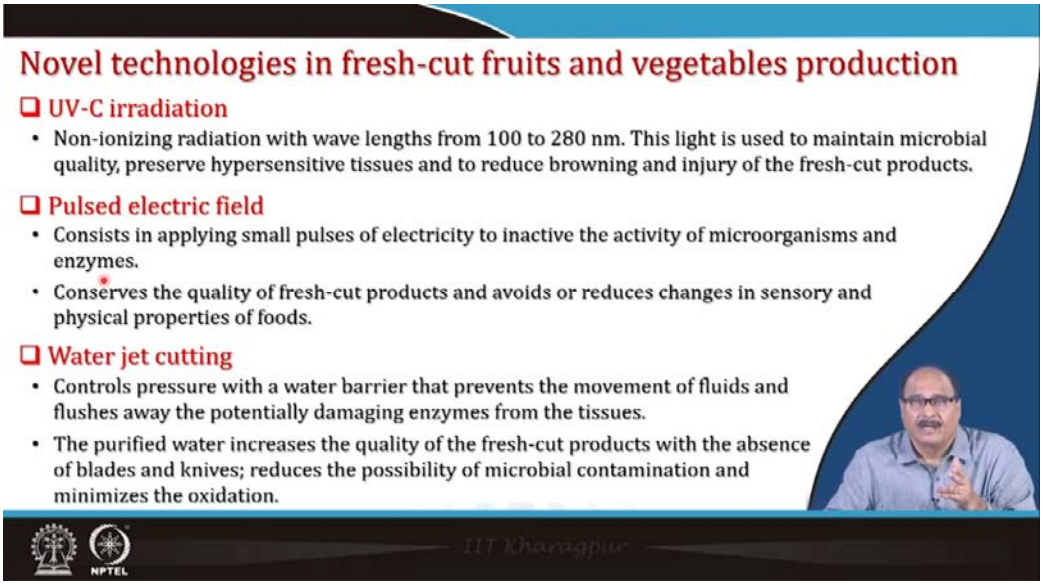
The dipping treatment may be followed by a heat shock like HTST method which usually implies a washing step at a temperature ranging from 45 to 70 °C for a few minutes, usually less than 5 minutes. Sometimes, depending upon the type of commodity that is being processed, dipping treatment and heat shock needs to be combined. The thermal treatment prevents the browning in fresh cut lettuces, improves organoleptic properties of vegetables, prevents quality deterioration, and maintains texture and color quality. There is a necessity of combining this heat shock with a sanitizing method such as washing with chlorine or an alternative antimicrobial agent like calcium lactate.

Blanching is a mild heat treatment, it may be steam blanching or infrared radiation or electrical heating. So, a mild treatment can be used to inactivate microorganism or enzymes as well as appropriate dipping in the prepared solution.



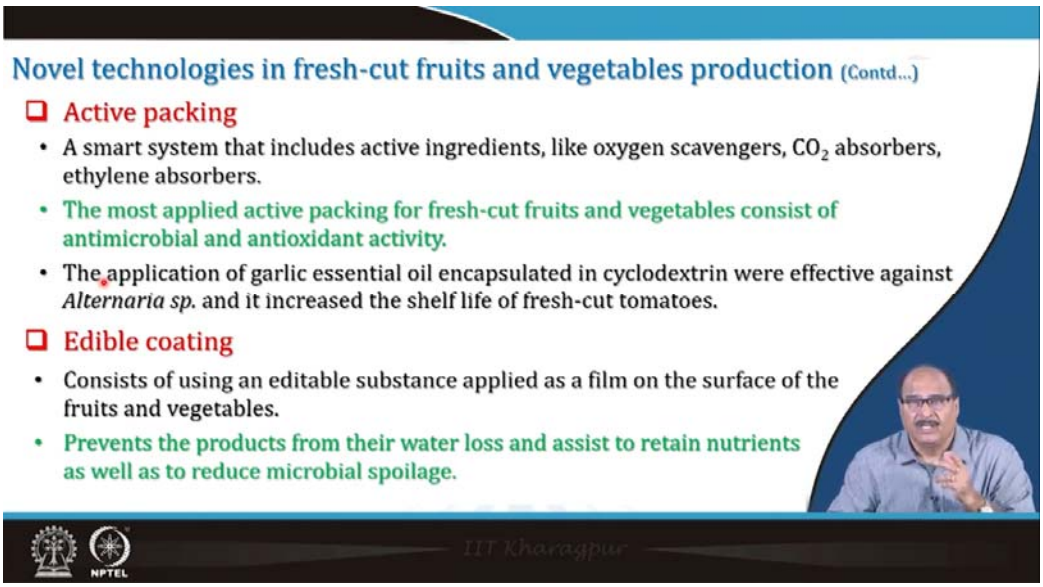
Dewatering/drying

During the cutting operation, some tissues are damaged. So, some water may be oozing out and surface may contain somewhat moisture which will act as a vector for microbial growth. So, they should be dried appropriately prior to packaging. Drying is a good method for increasing the shelf life because an excess of water and the tissue fluids provides an excellent medium for microbial growth. This drying can be done within the controlled heated air, or contact type dewatering (brushes, absorber rollers, PVC rollers) or aerodynamic dewatering can be used.

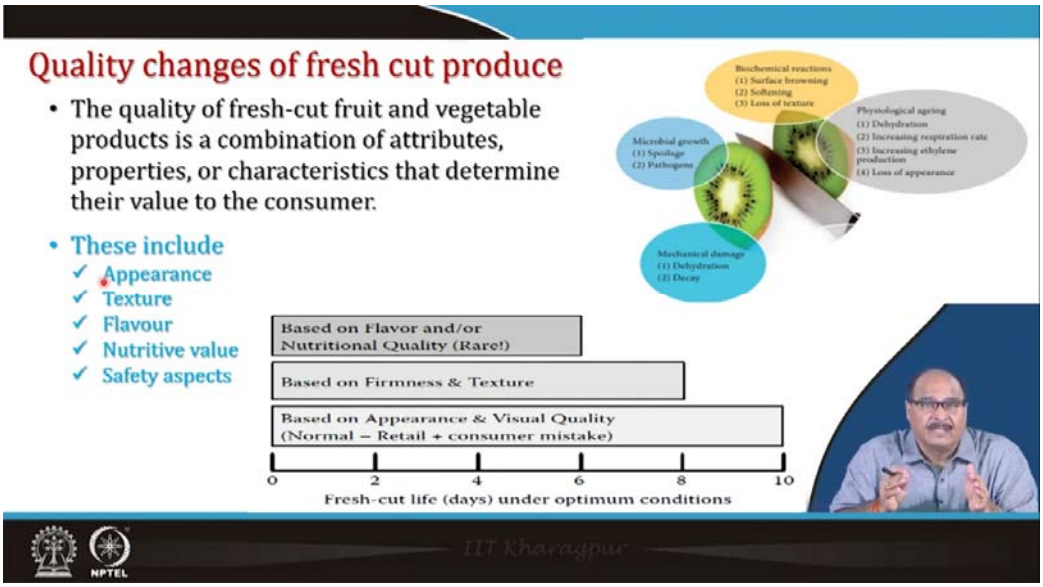


Novel technologies in fresh-cut fruits and vegetables production

The novel technologies involved in the manufacture and processing of fresh-cuts and vegetables are UV-C irradiation, pulsed electric field (PEF), water jet cutting, active packaging, edible coating and many more. UV-C radiation is a non-ionizing radiation in the wavelength from 100 to 280 nm. This light is used to maintain microbial quality, preserve hypersensitive tissues and to reduce browning and injury of the fresh-cut products. PEF consists in applying small pulses of electricity to inactivate the activity of microorganisms and enzymes. PEF conserves the quality of fresh cut produces and avoids or reduces changes in sensory and physical properties of the foods. Water jet cutting can be used as it controls the pressure with a water barrier that prevents the movement of fluids and flushes away the potentially damaging enzymes from the tissues. The purified water increases the quality of the fresh cut products with the absence of blades and knives thereby reducing the possibility of microbial contamination and minimizes the oxidation.



The active packaging is a smart system that includes active ingredients like oxygen scavengers, carbon dioxide absorbers, ethylene absorbers, etc. The most applied active packaging for fresh-cut fruits and vegetables consists of antimicrobial and antioxidant activity because fresh cut produces are more likely to be attacked by the microorganism or oxidative changes. The application of garlic essential oil encapsulated in cyclodexrtin were found effective against *Alternaria sp.* and it increased the the shelf life of fresh-cut tomatoes. Similarly, edible coating consists of using an edible substance applied as a film or the surface of the cut produces and it prevents the product from their water loss and assist to retain nutrients as well as reduce the microbial spoilage.

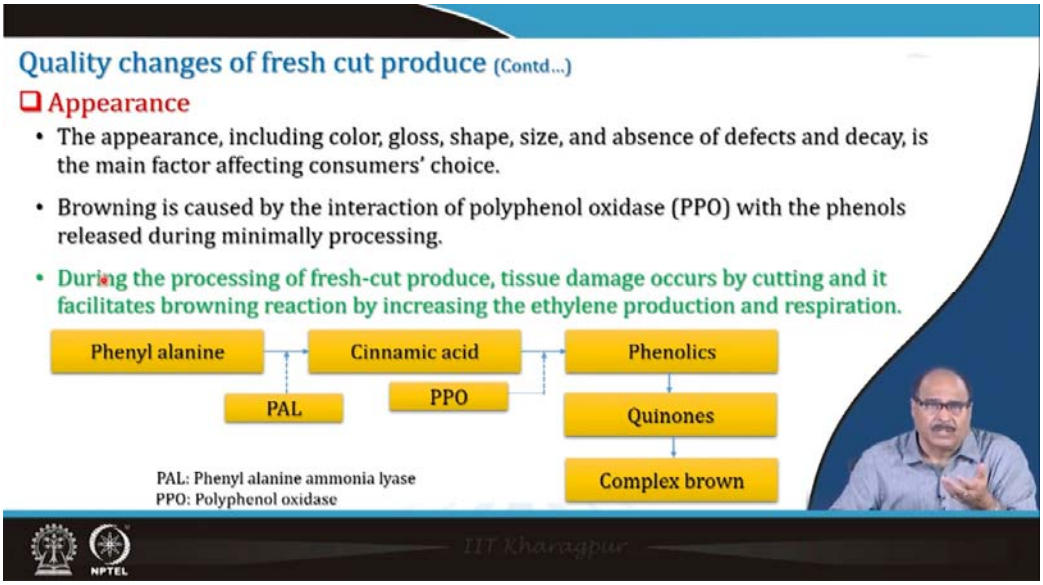


Quality changes of fresh-cut produce

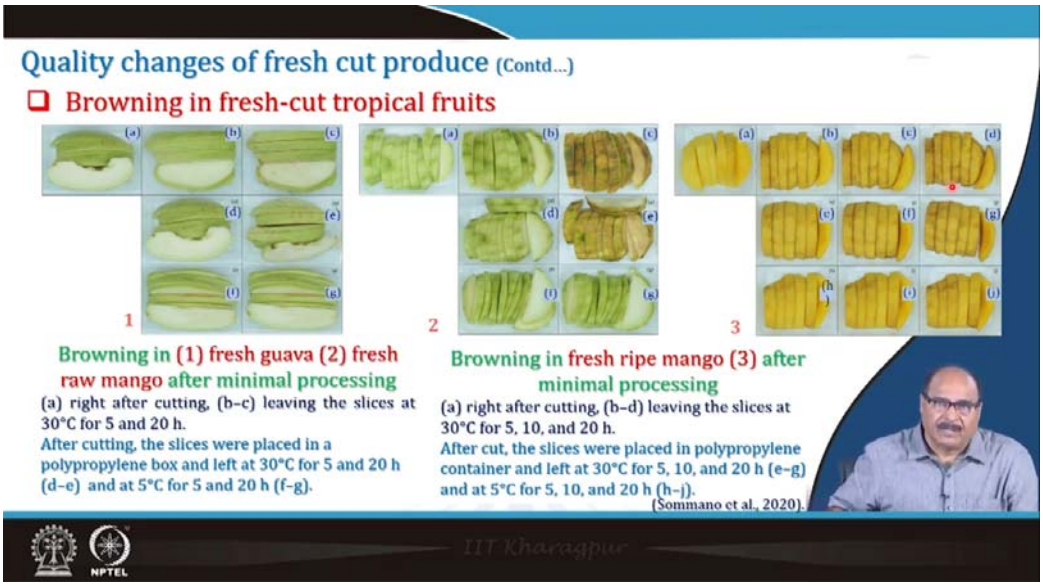
Quality is a very important aspect as fruits and vegetables they are very susceptible to the microbial growth, biochemical reactions, mechanical damage, physiological aging, etc. The quality of fresh-cut fruit and vegetable products is a combination of attributes, properties, or characteristics that determine their value to the consumer. So, proper care has to be taken for appearance, texture, flavor, nutritive value and safety aspects of the cut fruits and vegetables.

Appearance

The appearance of the commodity i.e. including color, gloss, shape, size and absence of defects, and decay, is the main factor which influences the consumers' choice. Browning is caused by the interaction of the enzyme polyphenol oxidase (PPO) with the phenols released during minimally processing. So, during the processing of the fresh cut produce, tissue damages occurs by cutting and it facilitates browning reaction by increasing the ethylene production and respiration.

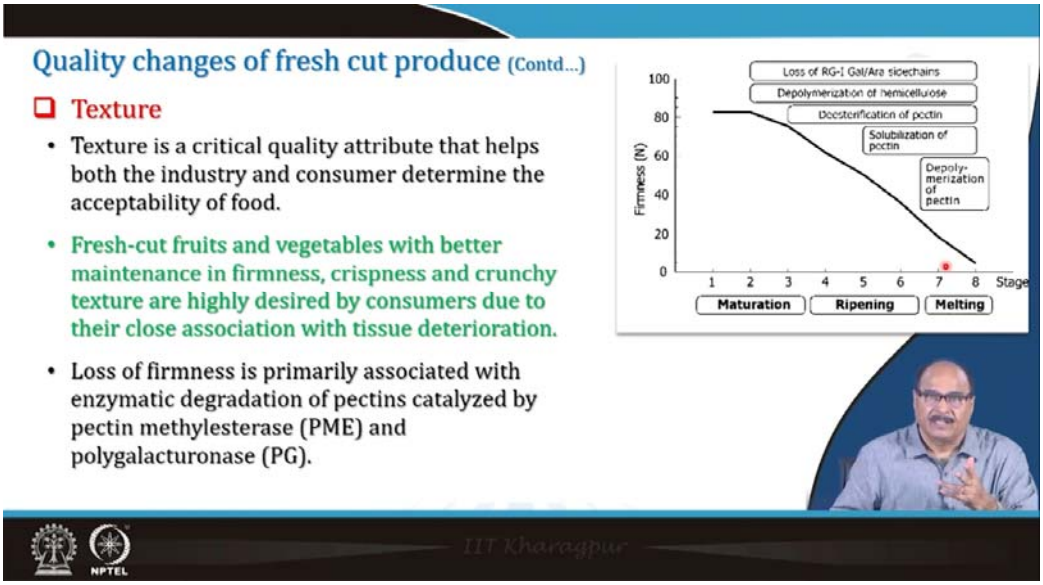


There are a group of complex reactions involved where phenyl alanine ammonia lyase (PAL) and polyphenol oxidase (PPO) enzymes are added, complex organic compounds are formed which gives the brown color and causes undesirable flavor in the cut produces.



Browning in fresh-cut tropical fruits

Browning in the fresh cut tropical fruits is shown by Sommano et al. (2020). The sample number 1 (fresh guava) and 2 (fresh raw mango) after minimal processing where (a) is fresh cut slices, and (b-c) is slices kept at 30 °C for 5 and 20 h, respectively. The slices were placed in a polypropylene box and left at 30 °C for 5 (d) and 20 h (e) and 5 °C for 5 and 20 h (f-g). You can see the visible changes in the color and the browning is visible. In the third figure, it is the fresh ripe mango and the similar treatment was provided. At higher temperature and where there is no packaging, the browning is more in both the fresh guava, fresh raw mango, fresh ripe mango.

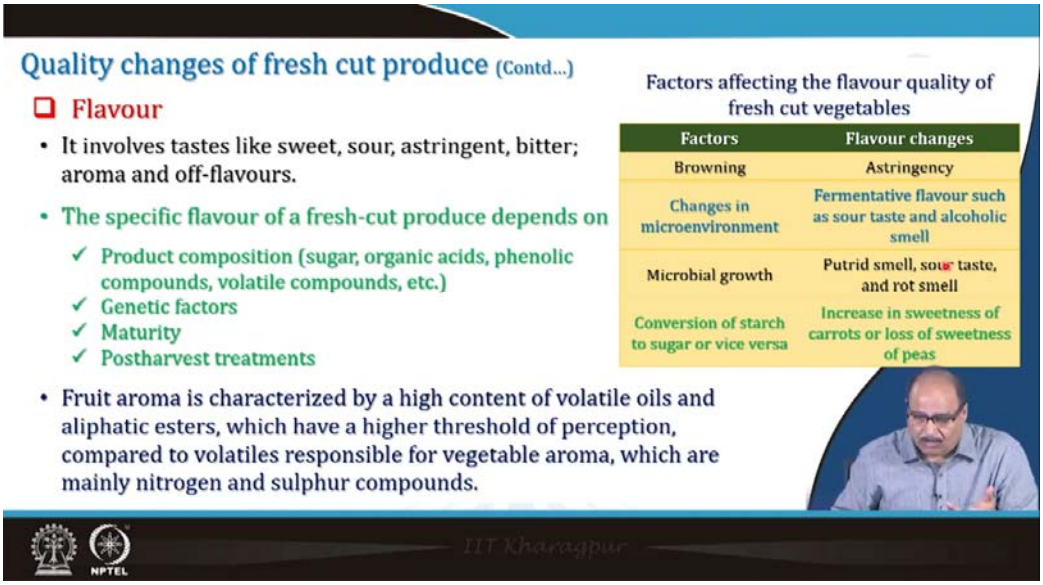


Texture

Texture is a critical quality attribute that helps both the industry and consumer determine the acceptability of food. Fresh cut fruits and vegetables with better maintenance in firmness, crispiness, and crunchy texture are highly desired by the consumers due to their close association with tissue deterioration. The loss of firmness, is particularly associated with enzymatic degradation of pectins catalyzed by pectin methyl esterase (PME) and polygalacturonase (PG). In the figure, maturation, ripening and melting is given in x-axis and firmness is provided in y-axis. At the time of maturation, it is the pectic substances fruit, it is in optimum firmness. After it ripens, there are particularly changes in the pectic substances may be depolymerization of hemicellulose, desterification of pectin, solubilization of pectin or depolymerization of pectin, due to the reaction of polymethyl pectin, polymethyl enzymes etc., causing softening of the tissues. So, during the manufacturing of cut fruits and vegetables, appropriate care should be taken such as dipping and other methods discussed earlier to manitain the firmness.

Flavour

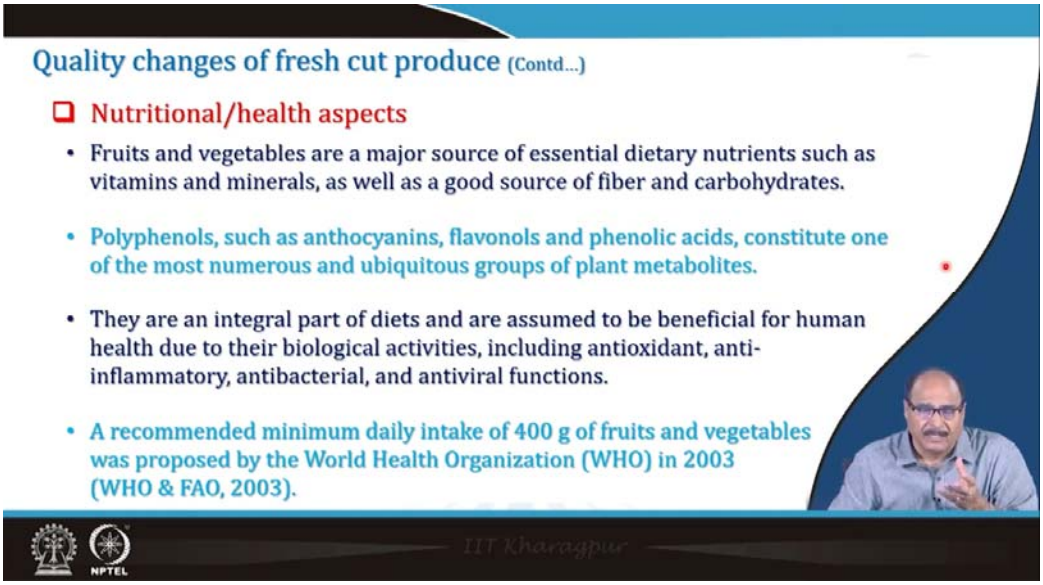
Flavour involves tastes like sweet, sour, astringent, bitter; aroma and off-flavours. The specific flavour of fresh-cut produces depends upon the product composition, its genetic factors, maturity, and post-harvest treatment. Fruit aroma is characterized by a high content of volatile oils and aliphatic esters, which have a higher threshold of perception, compared to volatiles responsible for vegetable aroma, which are mainly nitrogen and sulphur compounds. Environmental conditions should be properly maintained as it may result in the changes in this flavor compound.

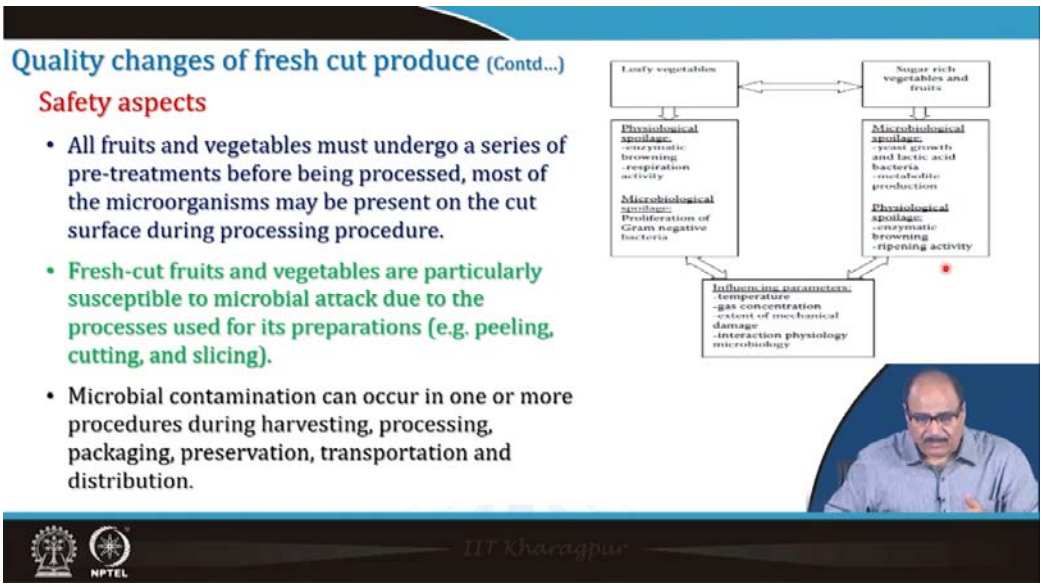


The factors affecting the flavour quality of fresh cut vegetables are browning, changes in microenvironment, microbial growth, conversion of starch to sugar or vice-versa. Browning may cause astringency, reduction in extinction; changes in the microenvironment in the produce may result in the fermentative flavor such as sour taste and alcoholic smell; microbial growth may result in the putrid smell, sour taste, and rot smell; conversion of starch to sugar or sugar to starch as the case may result in the increasiness in the sweetness of carrots or there is a sugars in the tender peas, sugar is converted into starch after dryness then the it reduces the sweetness.

Nutritional/health aspects

The fruits and vegetables are major source of essential dietary nutrients such as vitamins and minerals, as well as a good source of fiber and carbohydrates and healthy bioactives. So, polyphenols such as anthocyanins, flavonoids, phenolic acids, etc. are the most important component present in fruits and vegetables. They are an integral part of diets and are assumed to be beneficial for human health due to their biological activities, including antioxidant, anti-inflammatory, antibacterial, and antiviral functions. WHO in 2003 recommended minimum consumption of around 400 g of fruits and vegetables per day.

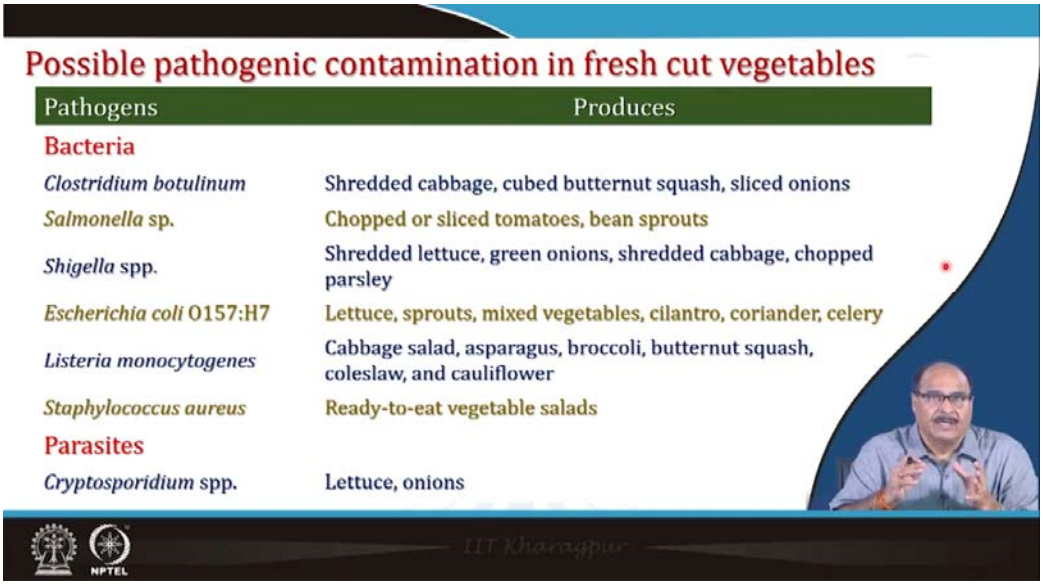




Safety aspects

The fresh cut fruits and vegetables are susceptible to microbial attacks due to processes used in its preparation such as peeling, cutting, slicing, etc. Microbial contamination can occur in one or more procedures during harvesting, processing, packaging, preservation, transportation and distribution. Thus, proper care should be taken so as to maintain the safety of fresh-cut produces.

In leafy vegetables, physiological reactions dominate whereas in the sugar cane, sugar rich vegetables and fruits, microbiological spoilage may dominate. So, proper management of the temperature, gas concentration etc. should be taken.

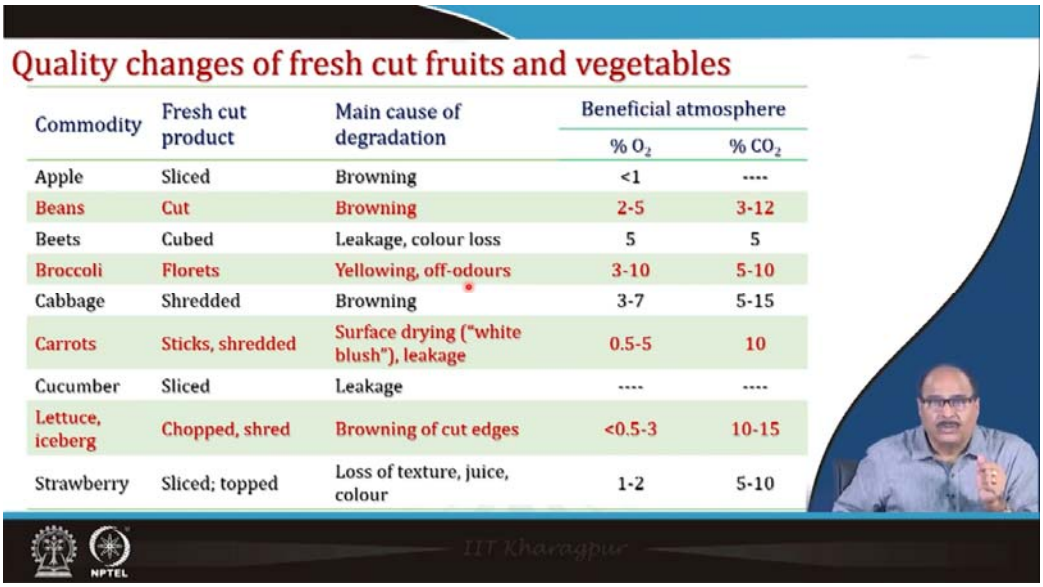


Possible pathogenic contamination in fresh cut vegetables

In the fresh cut produces, especially vegetables, chances of pathogenic contamination is very high because they are low pH commodities. For example, pathogenic contamination like *Clostridium botulinum* in shredded cabbage, cubed butternut squash, sliced onions. *Salmonella sp.* in chopped or sliced tomatoes, *Listeria monocytogenes* in cabbage salad, asparagus, broccoli. Parasites like *Cryptosporidium spp.* may be found in lettuce and onions. So, these, the fresh cut, particularly vegetables, they are very prone to a contamination with the pathogenic disease producing microorganism bacteria. So, this should be properly taken care of.

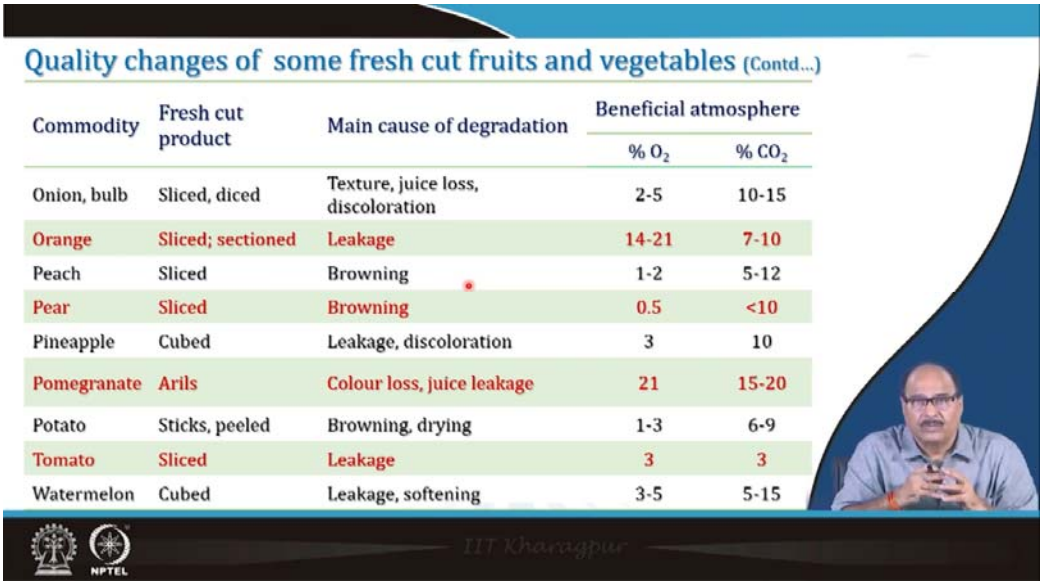
Quality changes of fresh cut fruits and vegetables

The beneficial atmosphere i.e. O_2 and CO_2 concentration helps to keep the fresh cut fruits and vegetables from degradation, for example, in apple slices, browning is the main cause of deterioration. So, it should be properly packed and atmosphere inside the packet should be maintained as less than 1 % O_2. Similarly, in broccoli, if the fluorets set broccoli yellowing or off odours is the main cause of degradation and here in the packet in the environment where it is stored after production, it should be having 3 to 10 % O_2 or 5 to 20 % CO_2. In sliced cucumber, leakage is the main cause of degradation. So, it can be kept in an airtight package and there should be no leakage of the gaseous environment. In sliced or topped strawberry, loss of texture, juice, color is the major cause of degradation which can be prevented by maintaining 1 to 2 % O_2 and 5 to 12 % CO_2 in the commodity.



Quality changes of fresh cut fruits and vegetables

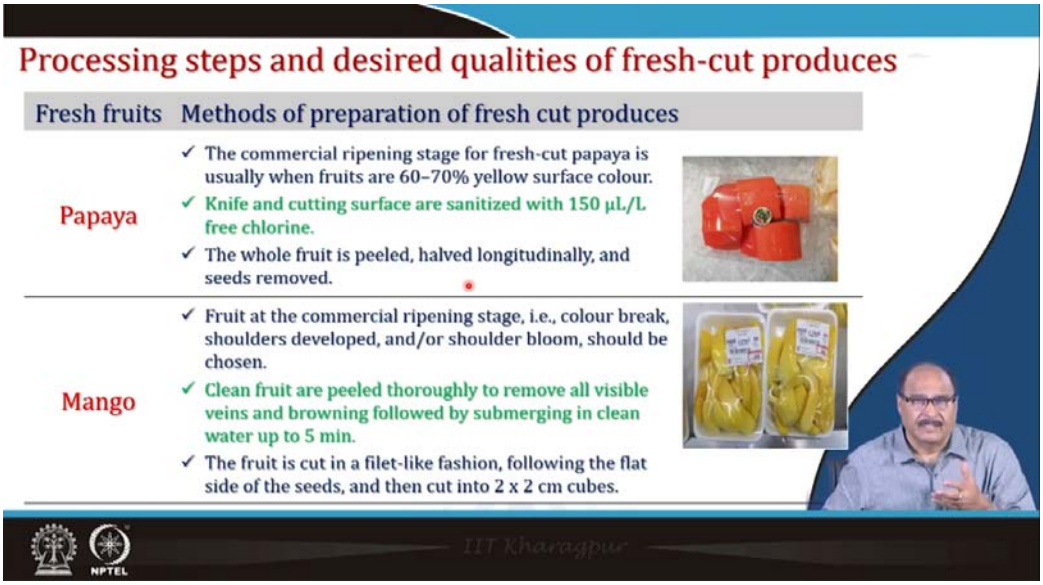
Commodity	Fresh cut product	Main cause of degradation	Beneficial atmosphere	
			% O_2	% CO_2
Apple	Sliced	Browning	<1	----
Beans	Cut	Browning	2-5	3-12
Beets	Cubed	Leakage, colour loss	5	5
Broccoli	Florets	Yellowing, off-odours	3-10	5-10
Cabbage	Shredded	Browning	3-7	5-15
Carrots	Sticks, shredded	Surface drying ("white blush"), leakage	0.5-5	10
Cucumber	Sliced	Leakage	----	----
Lettuce, iceberg	Chopped, shred	Browning of cut edges	<0.5-3	10-15
Strawberry	Sliced; topped	Loss of texture, juice, colour	1-2	5-10



Quality changes of some fresh cut fruits and vegetables (Contd...)

Commodity	Fresh cut product	Main cause of degradation	Beneficial atmosphere	
			% O_2	% CO_2
Onion, bulb	Sliced, diced	Texture, juice loss, discoloration	2-5	10-15
Orange	Sliced; sectioned	Leakage	14-21	7-10
Peach	Sliced	Browning	1-2	5-12
Pear	Sliced	Browning	0.5	<10
Pineapple	Cubed	Leakage, discoloration	3	10
Pomegranate	Arils	Colour loss, juice leakage	21	15-20
Potato	Sticks, peeled	Browning, drying	1-3	6-9
Tomato	Sliced	Leakage	3	3
Watermelon	Cubed	Leakage, softening	3-5	5-15

Similarly, here in sliced or dried onion bulb, texture, juice loss, discoloration is the major cause of degradation which can be controlled with 2 to 5 % O_2 and 10 to 15 % CO_2. In pomegranate arils, color loss, or juice leakage is the major cause. So, about 21 % O_2 and 15 to 20 % CO_2 may help in extending its shelf life and maintaining its quality. In sliced tomato, leakage to the environment is major problem which can be reduced by 3 % O_2 and 3 % CO_2 for maintaining the shelf life of cut sliced tomatoes.



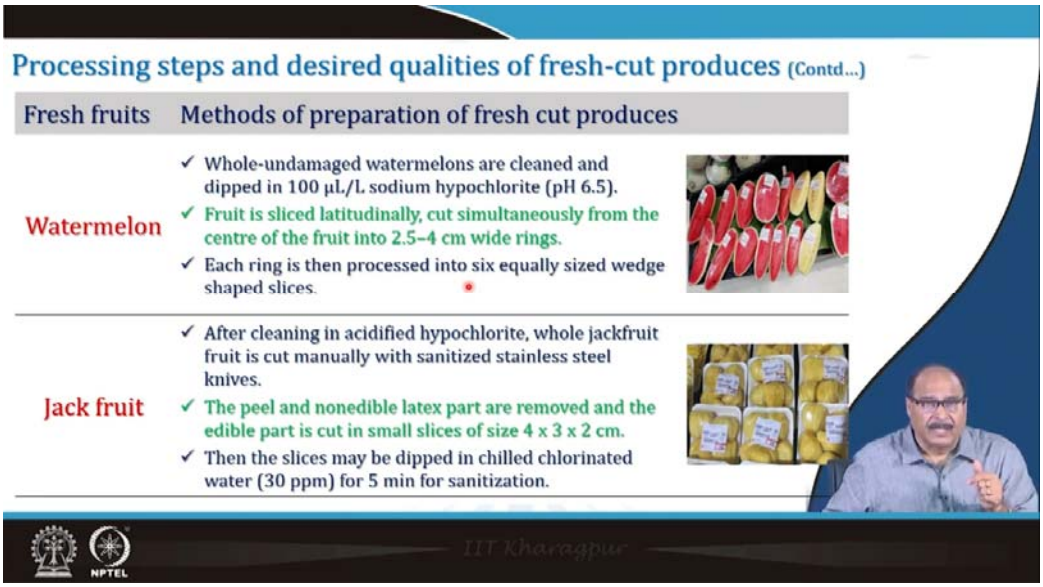
Processing steps and desired qualities of fresh-cut produces

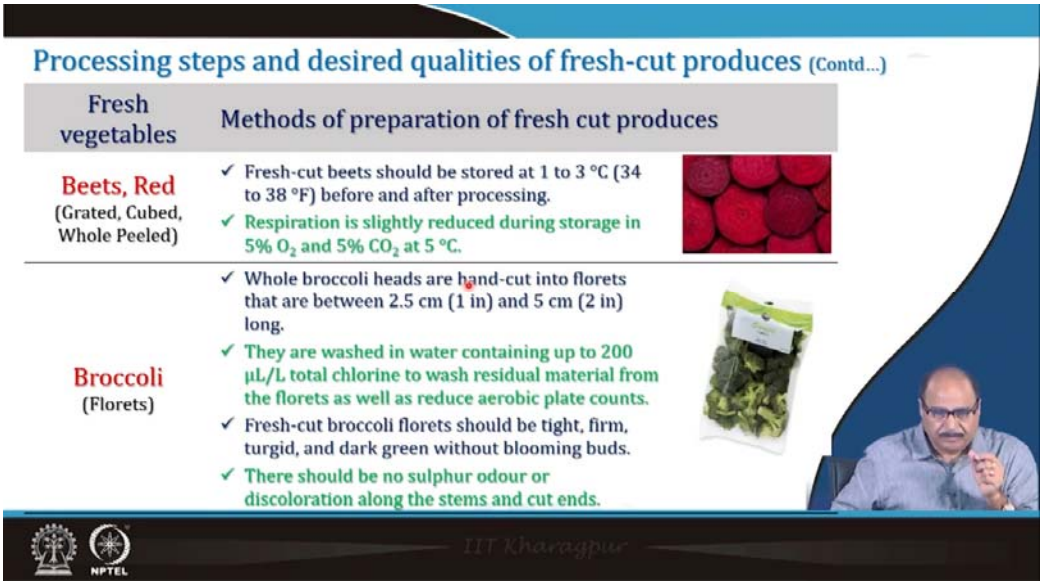
The fruit and their method for preparation of fresh-cut produce has been discussed. The commercial ripening stage for freshcut papaya is usually when its surface is 60 to 70 % yellow in colour. Thus, knife is used for slicing and cutting of papaya, which was sanitized before use with 150 µL/L free chlorine and the whole fruit is then peeled, halved longitudinally and seeds are removed.

Similarly, in mango, there is a commercial ripening stage i.e. colour break, shoulders developed, and/or shoulder bloom, should be chosen. It should be chosen properly, proper quality or grade. The selected clean fruits are peeled thoroughly to remove all visible veins and browning followed by submerging it in the clean water for 5 minutes and then cut and sliced.

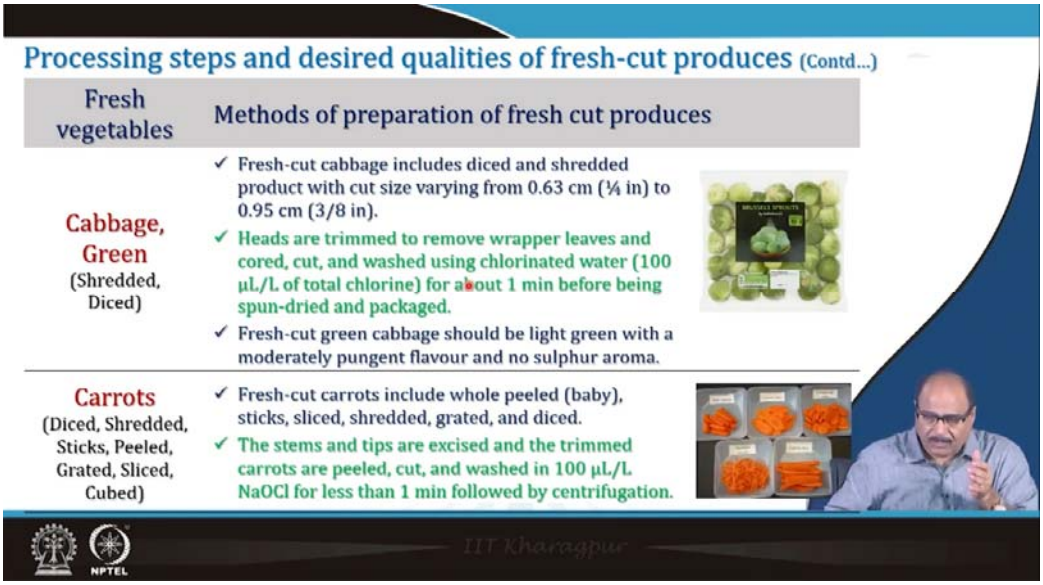
Whole undamaged watermelons are cleaned and dipped into 10 µL/L sodium hypochlorite solution having pH of 6.5 approximately. The fruit is sliced latitudinaly, cut simultaneously from the center of the fruit into 2.5 to 4 cm wide rings and each ring is then processed into 6 equally sized wedge-shaped slices.

Jackfruit i.e. after cleaning in the acidified hydrochlorite solution, whole jackfruit is cut manually with sanitized stainless steel knives. The peel and non-edible latex parts are removed and the edible part is cut into small sizes of 4 x 3 x 2 cm and these slices may be dipped in chilled chlorinated water (30 ppm) for 5 minutes for sanitization and then packaged appropriately.



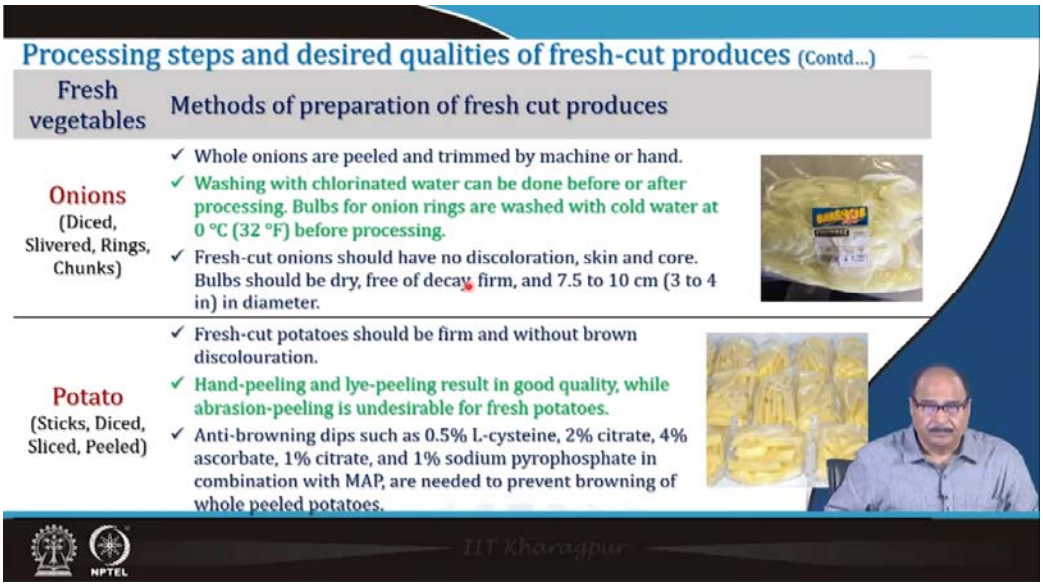


In red beet whether grated, cubed, or whole peeled. They should be stored at around 1 to 3 °C before and after processing. Respiration is slighly reduced during storage in 5 % O_2 and 5 % CO_2. Broccoli is washed in water containing up to 200 µL/L total chlorine to wash the residual material from the florets as well as to reduce the aerobic plate count. Fresh-cut broccoli florets should be tight, firm, turgid, and dark green without blooming buds. There should be no sulphur odour or discoloration along the stems and the cut ends.



Fresh cut cabbage whether it is diced and shredded products depending on cutting. They are cut with the varying sizes from 0.63 cm to 0.95 cm. Heads are trimmed to remove wrapper leaves and cored, cut and washed using chlorinated water (100 µL/L of total chlorine) for about 1 minute before being spun-dried and then packaged.

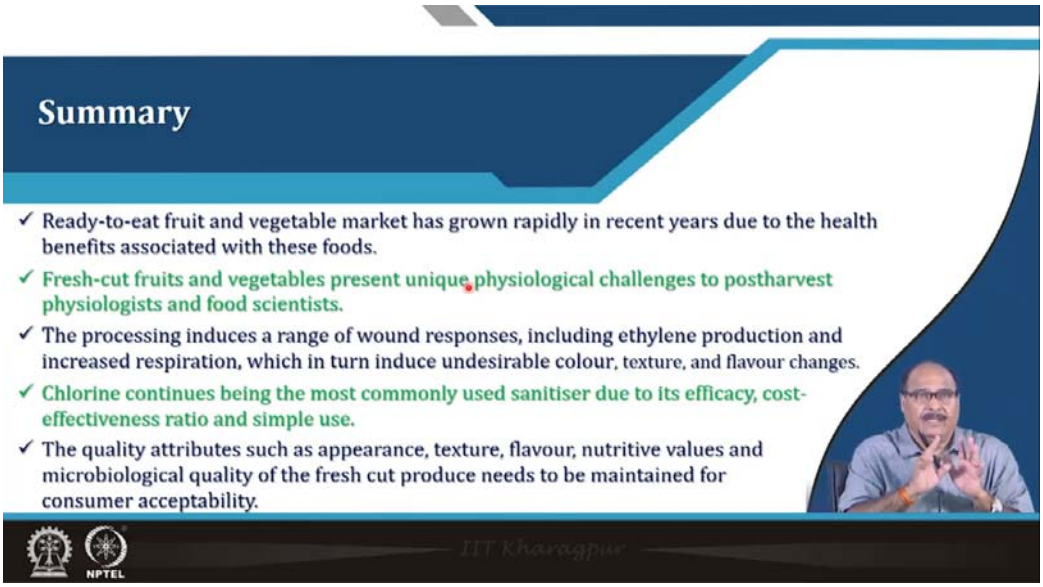
The fresh-cut carrots include the whole peeled (baby), sticks, slices, shredded, grated, and diced. The stems and tips are excised and the trimmed carrots are peeled, cut and washed in 100 µL/L sodium hypochlorite solution for the less than 1 min followed by centrifugation for the removal of surface water.



Whole onion are peeled and trimmed by machine or hand, then washed with chlorinated water before and after processing for sanitization purpose. The bulbs of onion rings are washed with cold water at around 0 °C before processing. Fresh-cut onions should have no

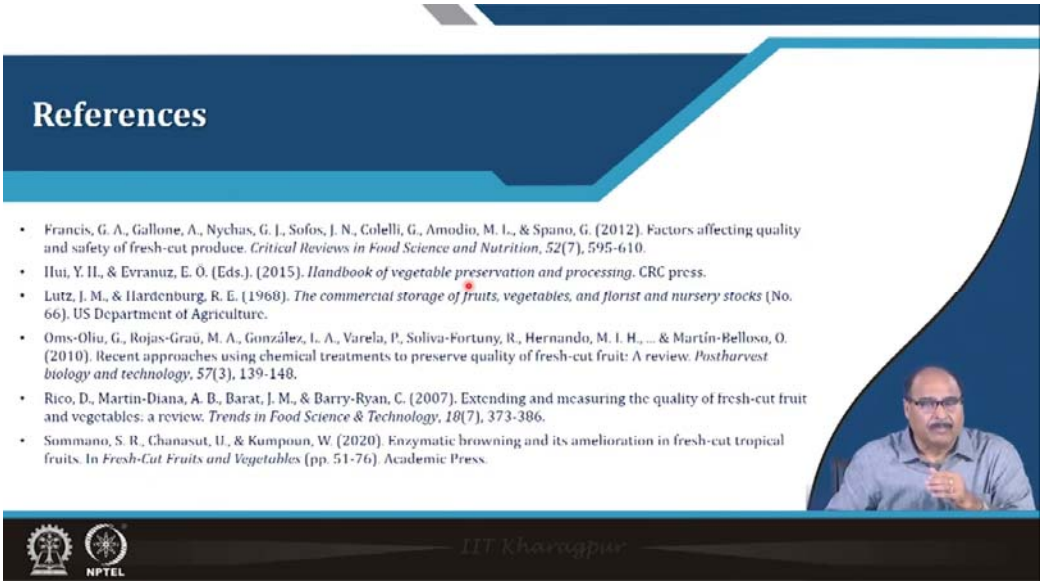
discoloration, skin and core. Bulbs should be dry, free of decay, firm, and they may be about 7.5 to 10 cm in diameter.

Fresh cut potatoes (sticks, diced, sliced, or peeled) should be firm and without brown discoloration. Hand peeling and lye peeling result in good quality, although abrasion peeling is more common in the freshed potatoes. However, it is not recommended for making cut potato, diced potato. An antibrowning dips such as 0.5 % L-cysteine, 2 % citrate, 4 % ascorbate, 1 % citrate, 1 % sodium pyrophosphate or even 1 to 2 % brine solution in combination with modified atmospheric packaging (MAP) are needed to prevent the browning of the peeled potatoes as browning occurs very fast in them.



Summary

The market for ready-to-eat fruits and vegetables is growing at a rapid rate. Fresh cut fruits and vegetables present unique physiological opportunity in the market. But at the same time, maintaining the quality, freshness and shelf life in the fresh cut fruits and vegetables is a challenge. Because the physiological and other biochemical reactions are there. So, appropriate care such as anti-enzymatic or anti-browning, antimicrobial steps, either by dipping or blanching, appropriate packaging and edible coating, etc. operations need to be taken cae of. Moreever, this should be done at lower temperature. In the supply chain management, the low temperature should be maintained in both the supply chain as well as storage. The quality attributes such as appearance, texture, flavour, nutritive values and microbiological quality of the fresh cut produce needs to be maintained for consumer acceptability.



These are the references for further study. Thank you.