FOOD SCIENCE AND TECHNOLOGY

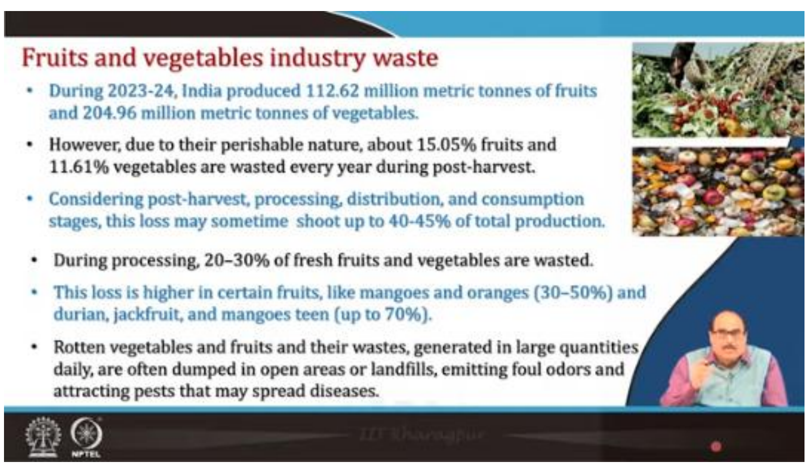
Lecture 58

Lecture 58: Fruits and Vegetables Processing Industry Waste utilization

Hello everybody, Namaste.

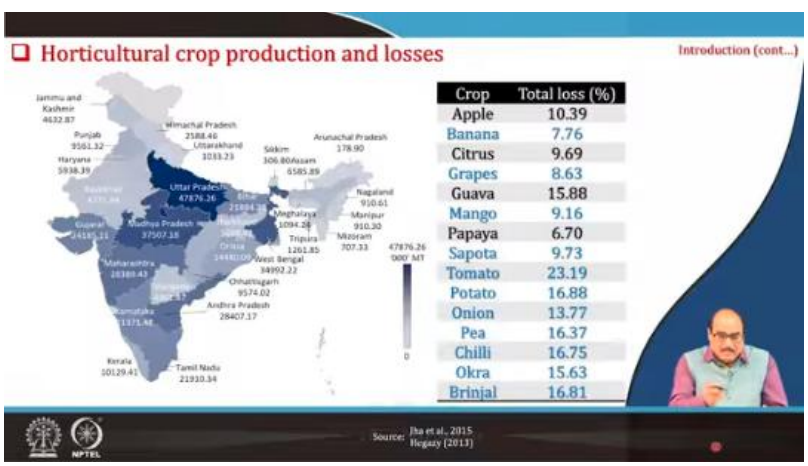
Now, we are in Lecture 58, discussing the circular economy in the food industry. In this class today, I will discuss the circular economy aspects of the fruits and vegetable processing industry, particularly waste utilization or byproduct utilization in this sector.

We will talk about What are the different types of waste generated by the fruits and vegetable industry? What are the uses of fruits and vegetable industry waste in various products? Just like in grain processing, here too, fruits and vegetable wastes or byproducts can be used for bioethanol production. Phenolics and bioactive extractions can also be done from these materials, along with citric acid production from fruit waste, cellulose and nanocellulose production, and pectin extraction from fruit processing byproducts. These are some of the products and processes we will briefly discuss here. Again, this is a very vast topic. So, I will just highlight some important aspects and major byproducts of the fruit and vegetable processing industry. This will give you a good overview of how the circular economy concept adds value to the fruits and vegetable processing industry.

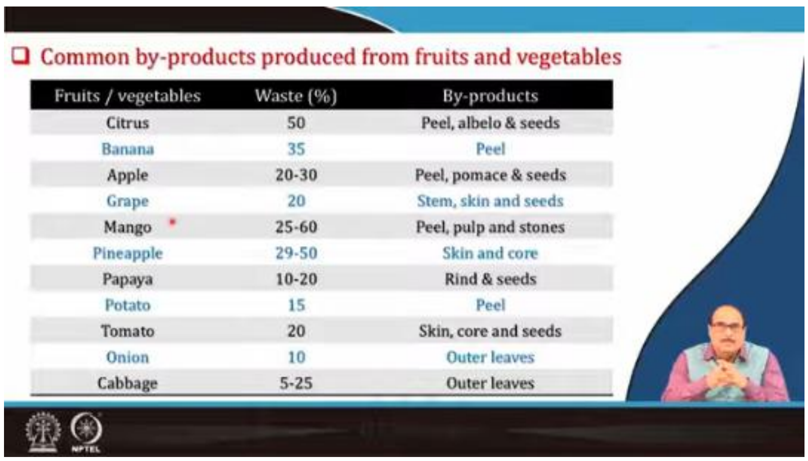


So, let us talk about the various wastes generated by the fruits and vegetable processing industry. Looking at the data from the current year, 2023-24, India produced around 112.62 million metric tons of fruits and 204.96 million metric tons of vegetables, which was the production in India during 2023 and 2024. However, these fruits and vegetables are highly perishable in nature, and because of their perishable nature about 15 percent on an average basis the fruits and around 12 percent vegetables are wasted every year during post harvest value chain. And considering the post harvest processing, distribution, and consumption stages. Even if you look at all the stages and what are the losses even this may go up to suit up to 40 to 45 percent that is in some cases some vegetables some fruits about half of their produce are wasted every year. During processing about 20 to 30 percent of the fresh fruits and vegetables are wasted and this loss is higher in certain fruits even like mango and oranges about 30 to 50 percent and durian fruit, jackfruit, mangoes teens etcetera up to 70 percent. So, that is in fact, each and every stage in the post harvest after the harvesting, then cleaning, drying, grading, processing, value processing and drying, packaging and all each and every stage, supply chain, each and every stage there is a huge potential of losses, waste generations. And then even you see the rotten vegetables and fruits and their waste generated in the large quantity daily, and often they are dumped into open area for or landfills emitting foul odors and attracting pests that may spread various diseases.

So, these are the burning problems. So, again one has to have a proper mechanism to address this is to minimize this address or collect these waste materials etcetera or byproduct and convert into its valuable various valuable products and technology is available for that only one has to have a proper collection mechanism in place and then it is a channelization into different processes.



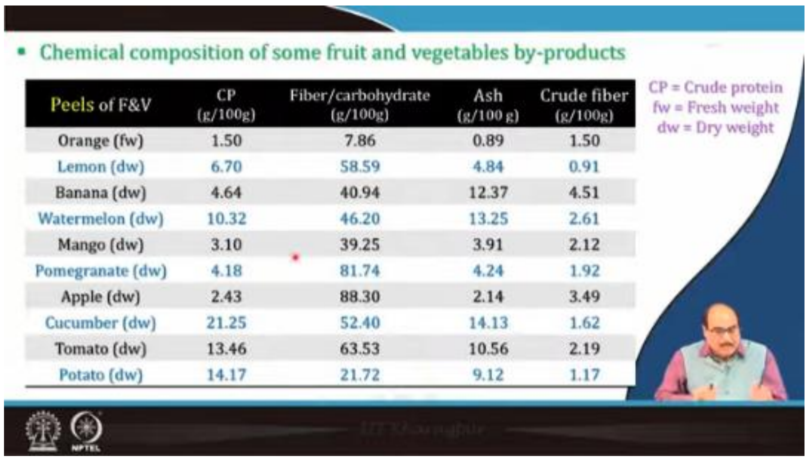
This just a horticultural crop production and losses. In the India, the production data I will not say, this is available in the net you can take it, that is in the different state UP. It is a major producer of fruits and vegetables, and then other states like West Bengal, Gujarat, Madhya Pradesh. So, there are total data, and it is available, but the losses here indicate that again, the losses in various commodities may be up to as high as 23 or 24 percent in the case of tomatoes, and in some cases even more. Or in apples, about 10 percent; in chili, about 17 percent; okra, about 16 percent; brinjal again about 16 or 17 percent. So, these are the data, but the losses may vary if proper care is not taken. So, the purpose here is just to show that yes, a lot of this amount is lost during post-harvest, and many losses take place.



Then, let us talk about common byproducts produced from fruits and vegetables during processing. So, if you look at citrus fruits, here, they told you almost 50 percent of the material is generated as waste in the form of peel, albedo (that is albedo), seeds, and so on. Like after, let us say, the orange after the extraction of the juice. Orange juice, and almost 50 percent of the biomass is a very valuable source of various antioxidants, various bioactives, citric acid, carbolic acid, and all those things, many acids are there.

So, they can be collected, and similarly, if you look at the banana industry, it has around 35 percent waste or byproduct in the form of peel. Apple, about 20 to 30 percent in the peel, pomace, and seeds. Grape, 20 percent in the form of stem, skin, and seeds. Mango processing results in about 25 to 60 percent waste in the form of again peel, pulp, and stones. Pineapple processing again results in about 29 or 30 to 50 percent waste in the form of skin and core.

Papaya processing results in 10 to 20 percent waste in the form of rind and seeds. Tomato processing results in 15 percent waste in the form of peel, and potato processing in 15 percent in the form of peel. Tomato processing results in about 20 percent waste in the form of skin, core, and seeds. Similarly, onion and cabbage—that is, outer leaves in onion account for 10 percent, while in cabbage, it may waste from 5 to 25 percent. So, you can see these are the various byproducts of fruit and vegetable processing industries, and a significant, huge amount is wasted. But all these byproducts, as I told you about the sector, similarly in all these, they have a lot of valuable products.

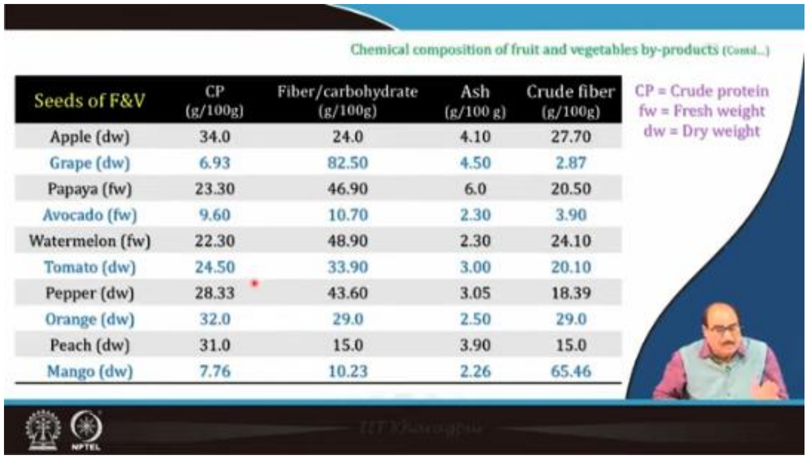


Peels of F&V	CP (g/100g)	Fiber/carbohydrate (g/100g)	Ash (g/100 g)	Crude fiber (g/100g)
Orange (fw)	1.50	7.86	0.89	1.50
Lemon (dw)	6.70	58.59	4.84	0.91
Banana (dw)	4.64	40.94	12.37	4.51
Watermelon (dw)	10.32	46.20	13.25	2.61
Mango (dw)	3.10	39.25	3.91	2.12
Pomegranate (dw)	4.18	81.74	4.24	1.92
Apple (dw)	2.43	88.30	2.14	3.49
Cucumber (dw)	21.25	52.40	14.13	1.62
Tomato (dw)	13.46	63.53	10.56	2.19
Potato (dw)	14.17	21.72	9.12	1.17

Similarly, if you look at the chemical composition of some of these fruit and vegetable byproducts, then you will get an idea of what valuable components they have. Like the peels, if you look at the peels of fruits and vegetables, such as oranges, they contain about 1.5 percent crude protein, fiber or carbohydrates around 7.8 grams per 100 grams, about 0.89 or 1 percent ash, and 1.5 percent crude fiber. The ash contains various minerals, and apart from that, they may also contain various vitamins and other nutrients.

Similarly, lemon contains around 58 or 59 percent fiber or carbohydrates, about 6.7 percent crude protein, 4.8 percent ash, and 0.9 percent crude fiber. Then mango, if you look at mango, it contains around 3.1 percent crude protein, about 40 percent fiber or carbohydrate, 4 percent ash, and 2.12 percent crude fiber. Tomato contains around 13.46 percent protein, about 63 percent fiber, 10 percent ash, and around 2.9 percent crude fiber. So, all these things like the peels of tomato. Similarly, peels of potato contain around 15 percent crude protein, about 21.72 percent fiber, 9 percent ash, and about 1.1 percent crude fiber.

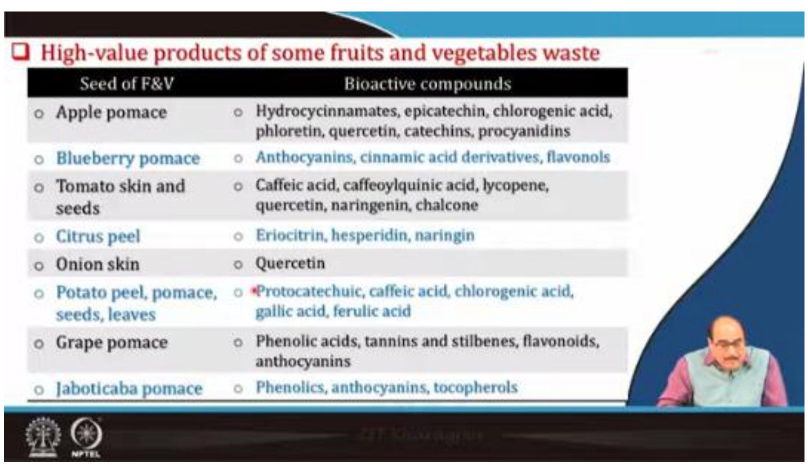
So, all these peels of all these vegetables they are very valuable as they contain very valuable component.



Seeds of F&V	CP (g/100g)	Fiber/carbohydrate (g/100g)	Ash (g/100 g)	Crude fiber (g/100g)
Apple (dw)	34.0	24.0	4.10	27.70
Grape (dw)	6.93	82.50	4.50	2.87
Papaya (fw)	23.30	46.90	6.0	20.50
Avocado (fw)	9.60	10.70	2.30	3.90
Watermelon (fw)	22.30	48.90	2.30	24.10
Tomato (dw)	24.50	33.90	3.00	20.10
Pepper (dw)	28.33	43.60	3.05	18.39
Orange (dw)	32.0	29.0	2.50	29.0
Peach (dw)	31.0	15.0	3.90	15.0
Mango (dw)	7.76	10.23	2.26	65.46

Similarly, if you look at the seeds of these products, seeds like apple seeds they contain around 34 percent protein, 24 percent carbohydrate, 4.1 percent ash and 27, 28 percent crude fiber you can see. Papaya seeds contain around 23.3% crude protein, 47% fiber, about 6% ash and 21% crude fiber. Similarly, tomato seeds, they contain around 24.5% protein, 34 percent fiber or carbohydrates, 3 percent ash and even 20 percent crude fiber.

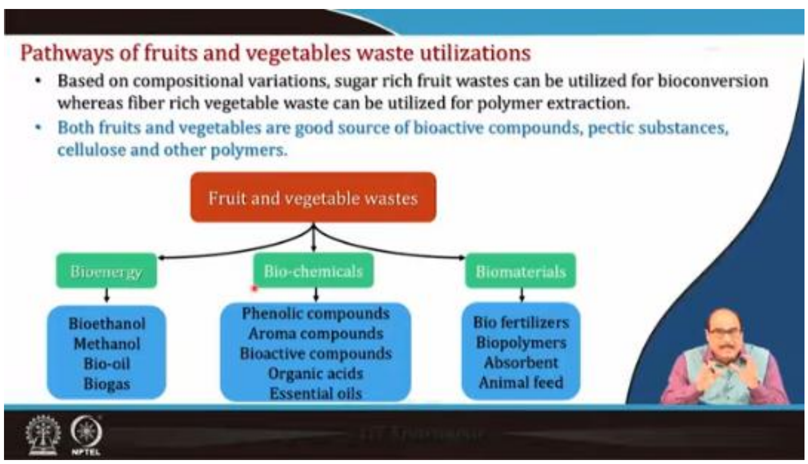
Mango seeds contain around 7.7 percent protein, 10 percent carbohydrate, 2 percent ash and even 65 percent crude fiber. All peel, pulp, seed and the peel that is the pulp and seed and peel they all valuable materials, products. They contain various valuable components.



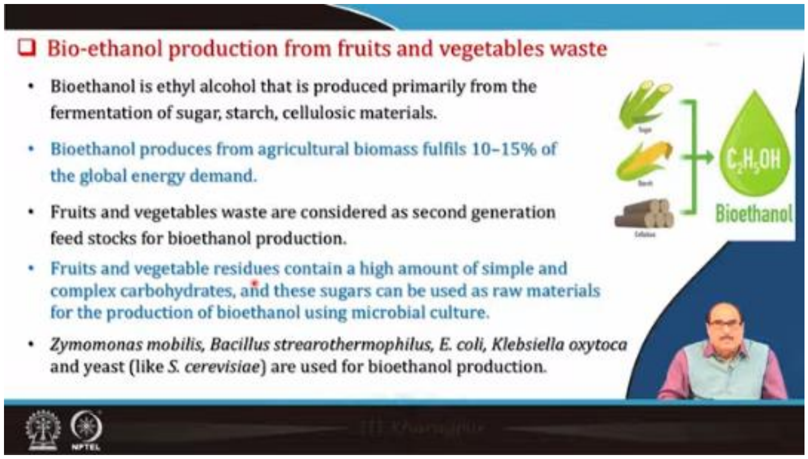
Seed of F&V	Bioactive compounds
Apple pomace	Hydrocycinnamates, epicatechin, chlorogenic acid, phloretin, quercetin, catechins, procyanidins
Blueberry pomace	Anthocyanins, cinnamic acid derivatives, flavonols
Tomato skin and seeds	Caffeic acid, caffeoylquinic acid, lycopene, quercetin, naringenin, chalcone
Citrus peel	Eriocitrin, hesperidin, naringin
Onion skin	Quercetin
Potato peel, pomace, seeds, leaves	Protocatechuic, caffeic acid, chlorogenic acid, gallic acid, ferulic acid
Grape pomace	Phenolic acids, tannins and stilbenes, flavonoids, anthocyanins
Jaboticaba pomace	Phenolics, anthocyanins, tocopherols

Then, high value products of some fruits and vegetable waste that is these which are like apple pomace after juice processing industry that gets, that is the pomace you get it gives that various bioactive compounds which can be generated. This is hydrocycinnamates, epicatechins, chlorogenic acid, phloretin, quercetin, catechins etcetera. Then blueberry pomace contains various bioactive compounds, anthocyanin, cinnamic acid derivatives, flavanol. Even tomato skin and seed contain caffeic acid, lycopene, quercetin, naringenin, chalcone. Citrus peel contains eriocitrin, hesperidin, naringin. Onion skin contains quercetin. Potato peel, pomace, seeds and leaves they contain caffeic acid, chlorogenic acid, gallic acid, ferulic acid. Even grape pomace that is the material remaining after the extraction of the juice it is a significant source of the phenolic acids, tannins, stilbenes, flavonoids. So, all these that is the various components that is the fruits and vegetable that is the various byproducts.

They contain lot of valuable bioactive compounds, antioxidants etcetera which can be extracted from them. Then, now we have so far seen that yes, what are the lot of products, by-products generated and these byproducts they have lot of valuable compounds.

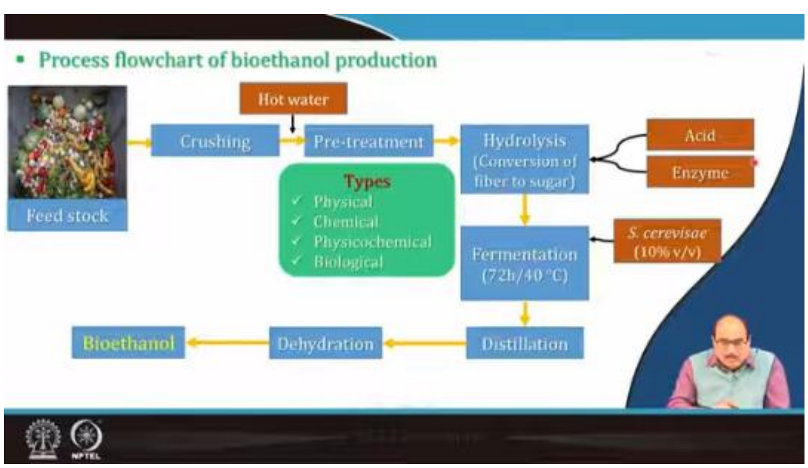


Now, what are the various pathways for utilizing these waste or byproducts of fruits and vegetable processing industry. That is, they can be methods like bioenergy, they can be used for bioenergy that is bioethanol, methanol, bio-oil and biogas production. Then they can be used for making biochemicals like phenolic compounds, aroma compounds, bioactive compounds, organic acid, essential oils, antioxidants and so on. And they can also be used for making biomaterials like bio fertilizers, biopolymers, absorbents, animal feeds etcetera. So, this all this and as you can see that is the they have various biochemical compounds, but one should have a proper mechanism in place, and then these materials can be channelized subjected to various treatment, various processes and can be used for bioenergy generation, biochemical productions, anti-oxidant production sector or various biomaterials purposes.

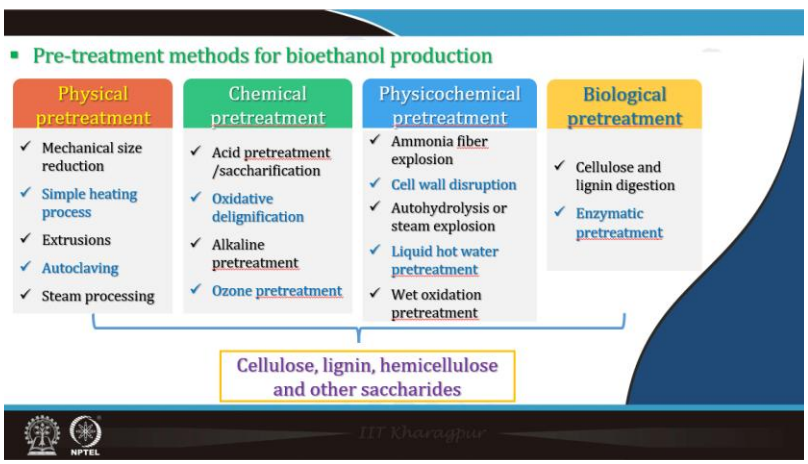


So, let us talk about bioethanol production from the fruits and vegetable waste. In the earlier case also in the green processing briefly we discussed. So, here basically bioethanol is nothing, but ethyl alcohol. Ethyl alcohol that is produced primarily from the fermentation of sugar, starch and cellulosic materials. So, bioethanol produces from agricultural biomass fulfils about 10 to 15 percent of the global energy demand. Fruits and vegetable waste are considered as second generation feed stock for the bioethanol production.

Fruits and vegetable residues contain a high amount of simple and complex carbohydrates and these sugars can be used as a raw material for the production of bioethanol using microbial culture. That is the here *Zymomonas mobilis*, *Bacillus strearothermophilus*, *E coli*, or yeast like *Saccharomyces cerevisiae*, they are used for fermentation of this by agricultural or fruits and vegetable biomass for production of bioethanol.

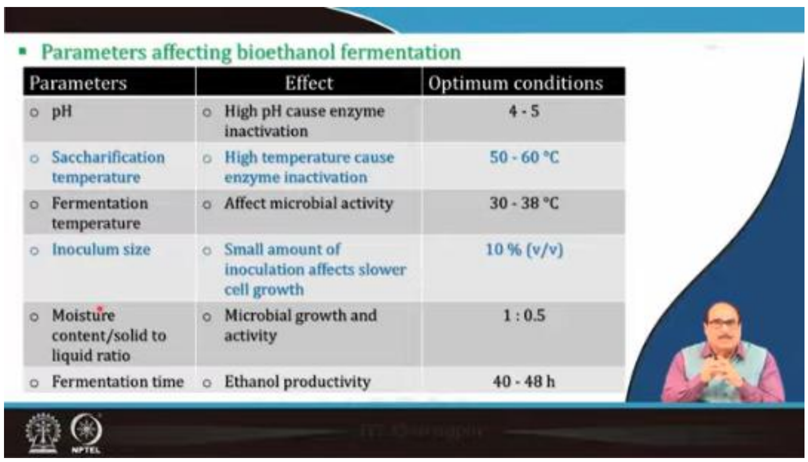


So, the process flow chart if you can see here that is this is a feed stock you can see the various fruits and vegetable biomass byproducts. They are crushed in the given hot water treatment that is the pretreatment you get the various that is hot water treatment to form in the slurry and thus this slurry is given various pre-treatment like physical treatment, pre-treatment chemical, physicochemical and biological pre-treatment and this is subjected to after this. Of course, this pre-treatment one has to decide depending upon the type of the biomass which is used, waste material which is used. Then it is subjected to hydrolysis that is the conversion of fiber to sugar and this may be acid hydrolysis or enzyme hydrolysis as the case may be. So, after they are hydrolyzed, this is added to the microorganism concerned microorganism. For example, Saccharomyces cerevisiae is added 10 percent to volume-by-volume basis and it is allowed in the fermentation reaction for about 72 hours reaction time at 40-degree Celsius temperature also. So, once all these sugars are converted into alcohol, then this is distilled dehydrated and you get the bioethanol alcohol. So, this is the process flow chart.



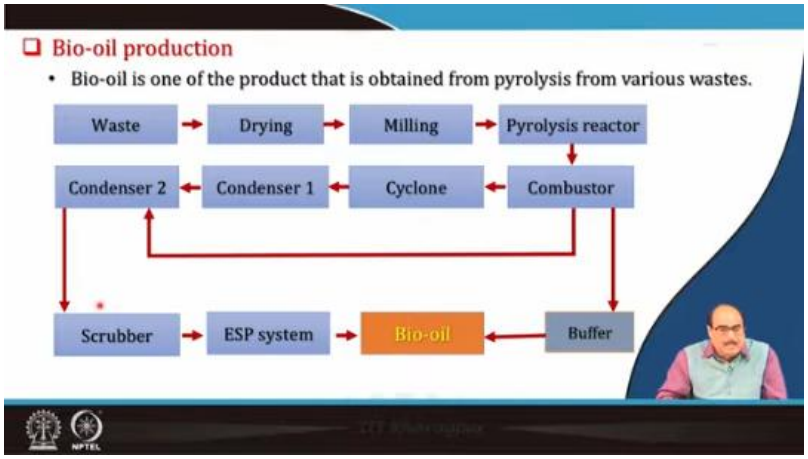
Now, let us briefly talk about this various pretreatment like the pretreatment which are there. Physical treatment like mechanical size reduction, simple heating, extrusion, autoclaving and steam processing that is the slurry which you got and made that is given various pre-treatment. So that it becomes suitable for the action of these enzymes or microorganisms. Chemical treatment may be acid pre-treatment, saccharification or oxidative delignification, alkaline pre-treatment or ozone pre-treatment.

Physicochemical pretreatment may include ammonia fiber explosion, cell wall disruption, auto hydrolysis or steam explosion, liquid hot water pretreatment, or wet oxidation. Biological pretreatment may include cellulose and lignin digestion, or enzyme pretreatment. So, all this, whether the material is to be subjected to physical, chemical, or biological pretreatment, will obviously depend upon the nature of the biomass and the process required. The idea here is to obtain end products like cellulose, lignin, hemicellulose, and other saccharides, which are derived from the bio-pretreatment of this material. These are then further allowed to react in the fermentation process, etc., yielding bioethanol.

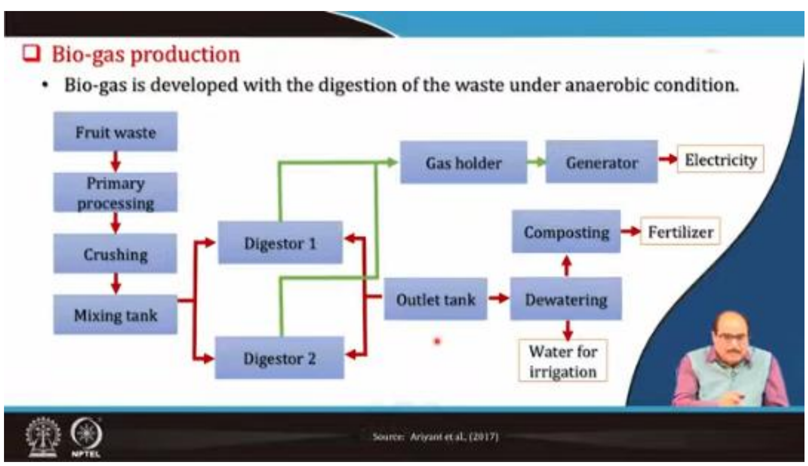


So, the parameters that affect the bioethanol fermentation process include the pH. High pH causes inactivation, so the optimum pH range is 4 to 5. Saccharification temperature: if too high, it will cause enzyme inactivation. The proper temperature range is 50 to 60 degrees Celsius. Fermentation temperature affects microbial activity, so the optimum range is 30 to 38- or 40-degrees Celsius maximum.

The inoculum size should optimally be 10 percent, but if too small, it affects the microorganism's growth rate. It results in a slower growth rate. Moisture content or solid-to-liquid ratio should be 1:0.5, as this ratio affects microbial growth and activity. So, the optimum is a 1:0.5 solid-to-liquid ratio. Fermentation time affects ethanol productivity, and the optimum duration is about 40 to 48 hours.

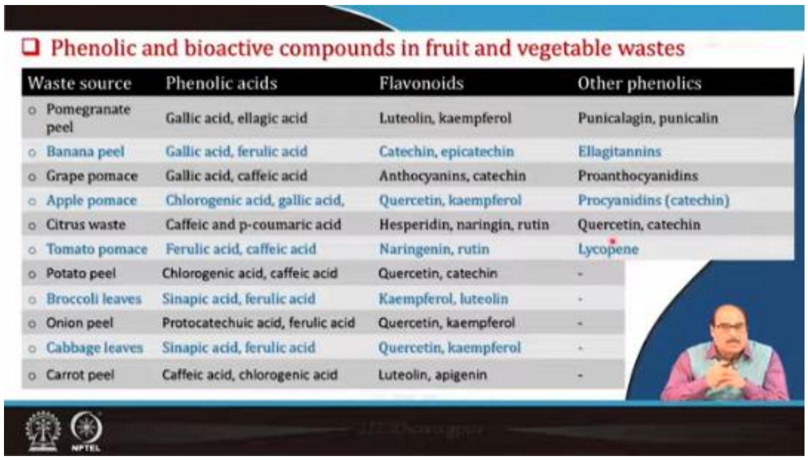


Then next is the bio-oil production, bio-oil is one of the products that is obtained from pyrolysis from citrus wastes. So, here the citrus food, after the citrus juice concentration of the juice preparation the material other material you are getting the waste material. The residue from the juice processing industry that may be collected and dried, milled and then sent to the pyrolysis reactor and where it is combusted. So, after combustion it may be directly one way, that is you can get the treatment and you get the bio-oil. Or this from the material from the combustion it can be cyclone, condenser 1 or directly to condenser 2 and then it is passed through a scrubber and ESP system and you get bio-oil. So, this is a schematic of the bio-oil production.



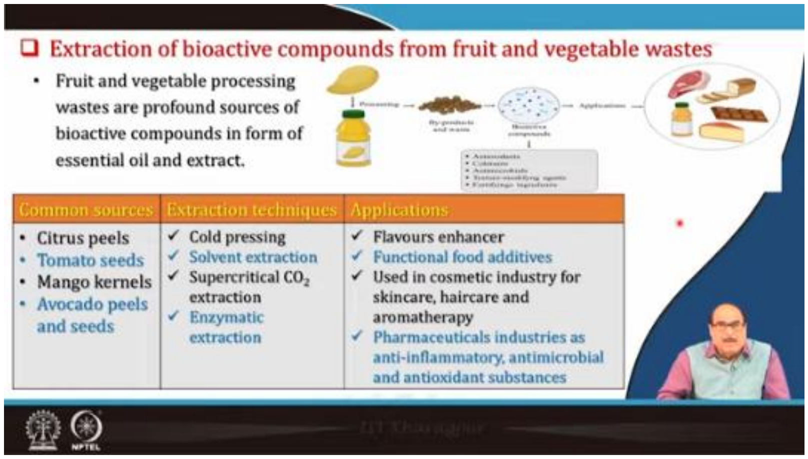
Similarly, schematic of the biogas production, it is developed with a digestion of waste under anaerobic conditions. Though you take fruit waste, it is subjected to primary processing, crushing, mixing and then sent to the digester 1 or digester 2 and then from this either both digester 1 and digester 2, it can go to the outlet tank and dewatering, you get water for irrigation etcetera after dewatering. And the residue after dewatering it sent to composting that is the fertilizer. And other thing both the it may be gas holders and gas generators electricity.

So, they can be used the biogas can be used for and the remaining residue can be used for fertilizer or water for irrigation all these bioproducts.

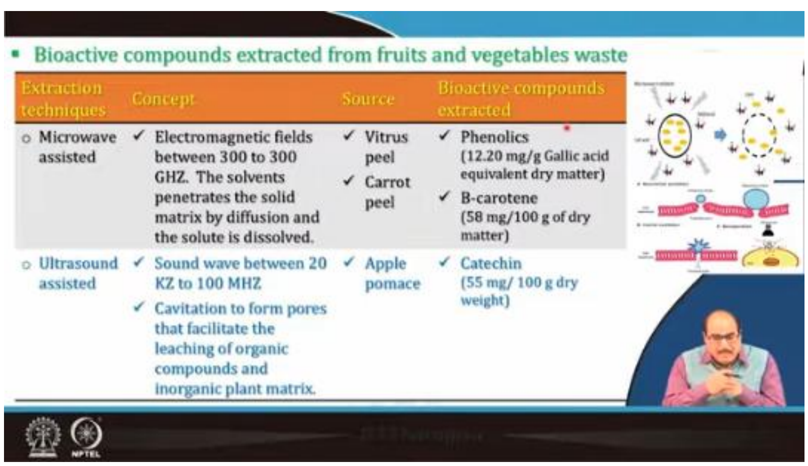


So, here I just try to give you phenolic and bioactive compounds in fruits and vegetable waste. Like in the pomegranate peel waste source that is the phenolic is gallic acid, ellagic acid, banana peel: gallic acid and ferulic acid. Grape pomace: gallic acid, caffeic acid, tomato pomace: ferulic acid, caffeic acid, potato peel: chlorogenic acid, onion peel: photocarcinogenic acid, ferulic acid, carrot peel: caffeic acid, chlorogenic acid. Similarly, even they also contain flavonoids like luteolin, catechin, anthocyanins, quercetin, naringenin, even luteolin, quercetin or other compound like punicalagin, punicalin, procyanidins that is catechins, quercetin, catechins, lycopene.

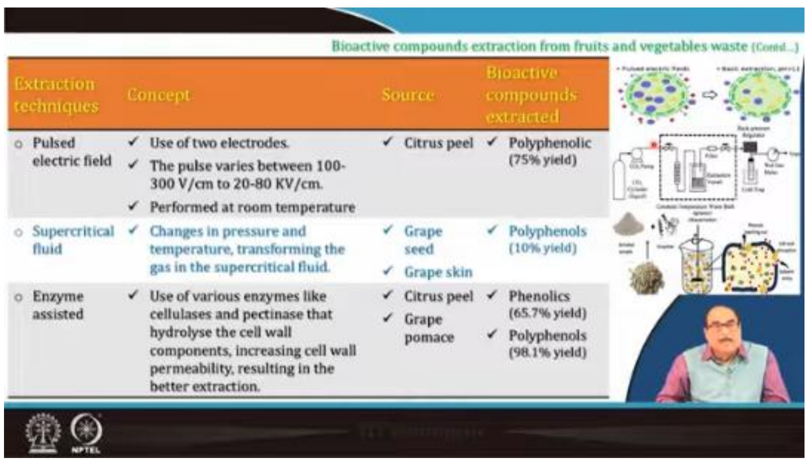
So, all these fruits and vegetable compounds are storehouses of various phenolic acids, flavonoids, and other phenolics as well. And in the earlier classes, we have seen how they are important in giving flavor, antioxidants, and other purposes. These bioactives regulate various processes. So, they become very useful sources, and these wastes or byproducts can be channelized and extracted using suitable technology.



Then, if you talk about the extraction of bioactive compounds from fruits and vegetable wastes, they can be processed byproduct wastes containing various bioactive compounds. Common sources include citrus peels, tomato seeds, mango kernels, avocado peels, seeds, etcetera. They can be subjected to various techniques like cold pressing, solvent extraction, supercritical carbon dioxide extraction, enzymatic extraction, etcetera. And you get various bioactive compounds that can be used as flavor enhancers, functional food additives, or in the cosmetic industry for skincare, haircare, and aromatherapy, or in pharmaceutical industries as anti-inflammatory, antimicrobial, and antioxidant substances, etcetera. So, there is a lot of potential in these byproducts as they can be made into bioactives and utilized.



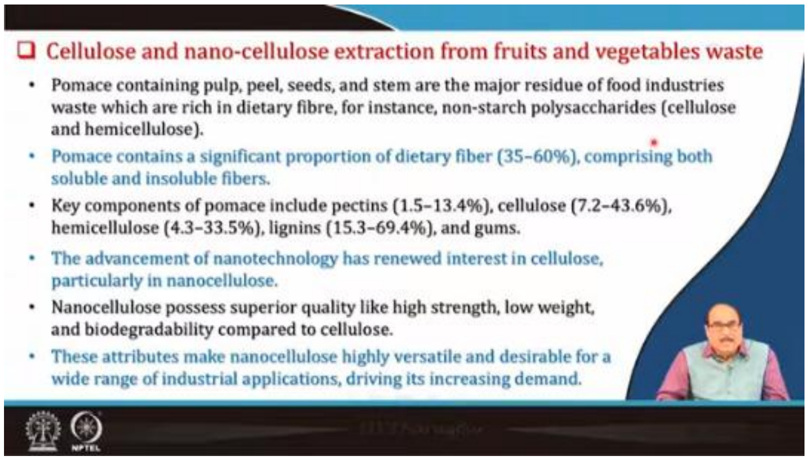
Then, even the bioactive compounds extracted from fruits and vegetable waste can use techniques like microwave-assisted or ultrasound-assisted extraction. In microwave-assisted techniques, the waste material is given microwave treatment. This microwave treatment uses electromagnetic fields between 300 gigahertz to 3000 gigahertz. They are applied, and the solvent penetrates the solid matrix by diffusion, dissolving the solute. And here source may be even vitrus peel, carrot peels etcetera, by this microwave when penetrates it into and then they can be. So, even bioactive compounds using this process can be this phenolics about 12.2 percent milligram per gram gallic acid equivalent. or beta carotene about 58 milligrams per 100 grams. Then ultrasound assisted technique extraction technique, here sound wave between 20 kilohertz to 100 megahertz they can be used. And even the ultrasound which creates cavitation, which form pores that facilitate the leaching of organic compounds and inorganic plant matrix. So, basically here apple pomace can be given to this treatment and the catechin etcetera can be removed from that.



Then even pulse electric field technology can be used. Here, in the pulse electric field treatment, there are it uses 2 electrodes, the pulse varies between 100 to 300 volt per centimeter to 20-80 kilovolt per centimeter and the citrus fruit peel can be used in this process and polyphenolic compounds maybe you get up to 75 percent yield.

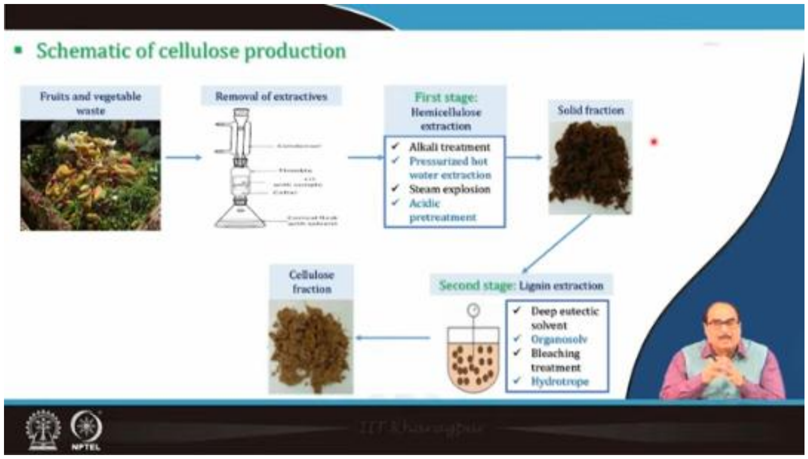
Then grape seed or that grape skin after the byproduct of the wine making industries, they can be subjected to supercritical fluid extraction process and it can result in the changes in the pressure and temperature during supercritical extraction process, transforms the gas in the supercritical fluid and then it is used to extract the phenolics etcetera phenols and 10 percent yield is reported in this case.

Similarly, citrus peels, grape pomace etcetera they can be used extraction technique various enzyme assisted extraction technologies can be used in this case and here use of various enzymes like cellulose, pectinase etcetera and these enzymes hydrolyze the cell wall components and increasing the cell wall permeability resulting in the better extraction. And here phenolics, polyphenols etcetera even 65.7 percent yield of phenolics or even 98 percent yield of polyphenols are reported by the enzyme in assisted extraction of citrus peels or grape pomace etcetera.

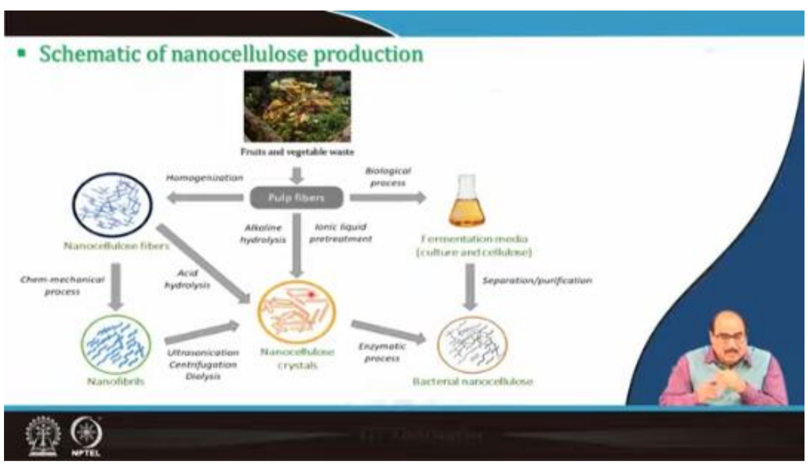


Then another is the cellulose and nanocellulose extraction from fruits and vegetable waste. The pomace containing pulp, peel, seed, and stem are the major residues of food industry waste, which are rich in dietary fiber. For instance, non-starch polysaccharides, etcetera, that is cellulose, hemicellulose, they are major components in the peel, pulp, and seeds of the material, fruits and vegetables both. Even pomace contains a significant proportion of dietary fiber, about 35 to 60 percent dietary fiber, and comprises both soluble and insoluble fibers. Key components of pomace include pectins, about 1.5 to 13.4 percent pectin, about 7.2 to 43.6 percent cellulose, 4.3 to 33.5 percent hemicellulose, and 15.3 to 69.4 percent lignins, and significant amounts of gums.

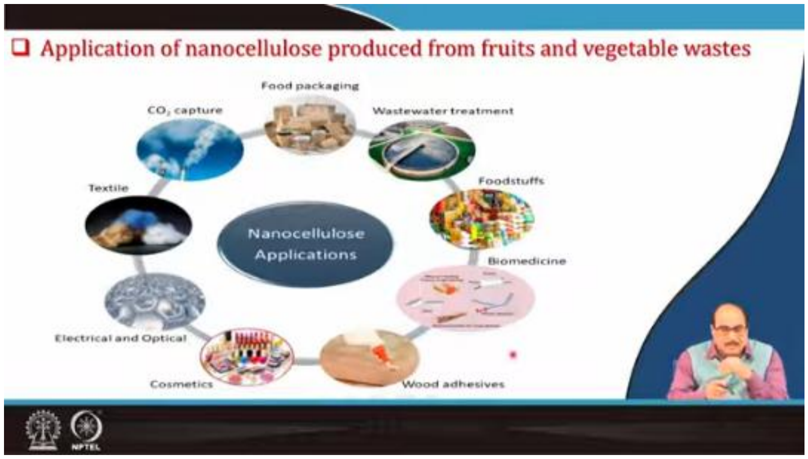
So, the advancement of nanotechnology has renewed interest in cellulose, particularly nanocellulose. Nanocellulose possesses superior qualities like high strength, low weight, and biodegradability compared to cellulose. These attributes make nanocellulose highly versatile and desirable for a wide range of industrial applications, driving its increasing demand.



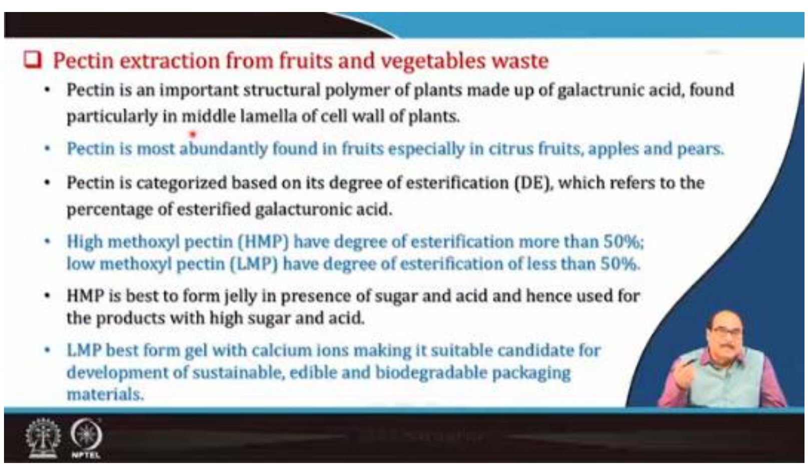
So, here is the schematic of cellulose production. If you look at the fruits and vegetable waste, they are subjected to the removal of extractives, that is, the Soxhlet apparatus. Then, in the first stage, hemicellulose extraction occurs by alkali treatment, pressurized hot water extraction, steam explosion, acid pretreatment, etcetera. So, after this, you get a solid mass, and then the solid mass is again subjected to the second stage, lignin extraction. That is, it may be deep eutectic solvent extraction or organosolv, bleaching treatment, hydrotrope, and so on, to get the cellulose fraction.



Then, the schematic of nanocellulose production. If you look at fruits and vegetable waste, this pulp fiber may be homogenized or it may be a biological process. This biological process it is also the fermentation media (culture and cellulose) and separation and purification process; it gives the bacterial nanocellulose. This after homogenization one get the nanocellulose fibers, these nano cellulose fibers can be chemical mechanical process you get nano fibrils. Or this nanocellulose fiber can be subjected to acid hydrolysis get nanocrystal, nanocellulose crystals or these nanofibers also on ultrasonication and centrifugation or dialysis you can get nanocrystal. Even pulp fibers by alkaline hydrolysis or ionic liquid pretreatment you get nanocellulose crystals. So, this nanocellulose crystals, nanofibres or bacterial nanocellulose etcetera.



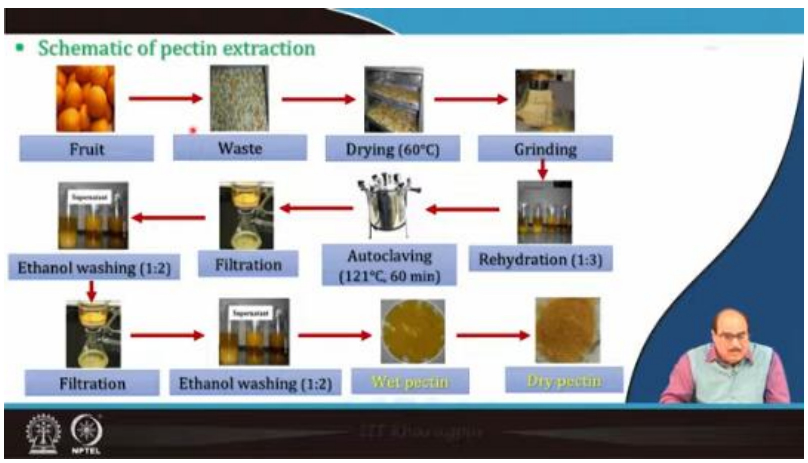
These are the major product and which has even lot of industrial application nowadays. Then these nanocellulose produced from the fruits and vegetable waste. It can be used suitably for food packaging, it can be used for wastewater treatment, for food stuffs, manufacturing and packaging etcetera. It can be used in biomedicines even wood adhesives, cosmetics, in electrical and optical purposes, in the textile industry, or even for the carbon dioxide capture CO_2 capture. So, they can be these nanocellulose can be applied for various purposes.



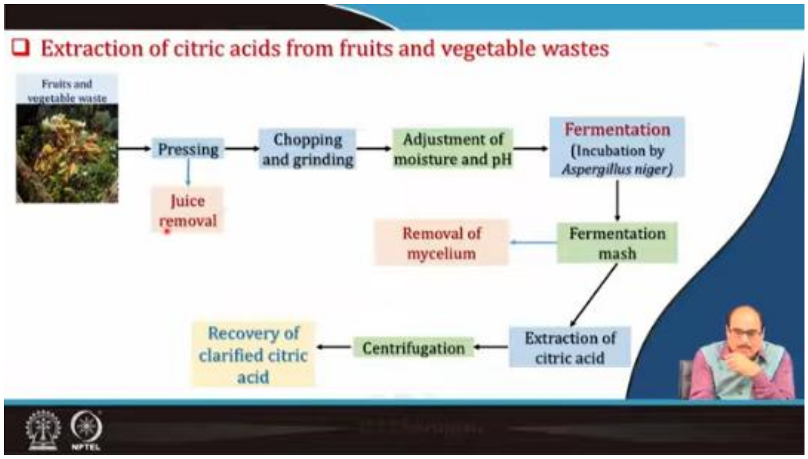
Then, another very very important process that is the pectin extraction from fruits and vegetable waste. Like again apple that is after juice processing you can get the apple pomace or even that is a guava after guava juice extraction that is the residue which is remaining it contains lot of valuable components amount of pectins etcetera. So, they can be channelized. It is a, pectin is an important structural polymer of plant made of galacturonic acid, which is found particularly in the middle lamella of cell walls of plants.

So, pectin is most abundantly found in fruits, especially in citrus fruits, apples, pears, guava, and so on. So, pectin can be categorized based on the degree of esterification, which refers to the percentage of esterified galacturonic acid. And it is the pectin which, in the presence of suitable acid and sugar, gives the proper set of jelly, etcetera. So, high methoxyl pectin has a degree of esterification of more than 50 percent.

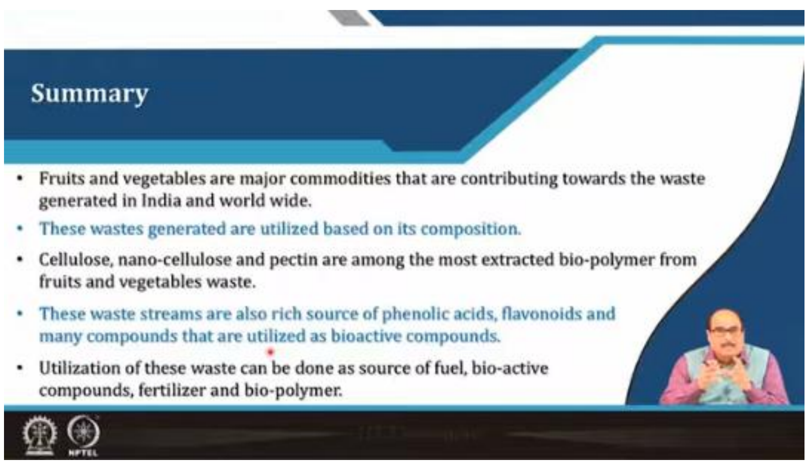
Low methoxyl pectin has a degree of esterification of less than 50 percent, and it is the high methoxyl pectin that forms jelly in the presence of sugar and acid. And low methoxyl pectin forms a gel with calcium ions, making it a suitable candidate for the development of sustainable, edible, and biodegradable packaging materials.



Schematic of the pectin production: fruits like mango, guava, or apple, whatever it is, you get the waste after juice processing, after the product processing, which is biomass waste. It is dried, ground, and then rehydrated with a rehydration ratio of 1 to 3 percent water to solid. It is autoclaved at 121 degrees Celsius for 60 minutes, filtered, and then ethanol-washed once, followed by filtration again. Ethanol-washed twice again at a 1:2 ratio, one gets wet pectin, and this is dehydrated dry pectin. This is just a schematic of the pectin extraction.



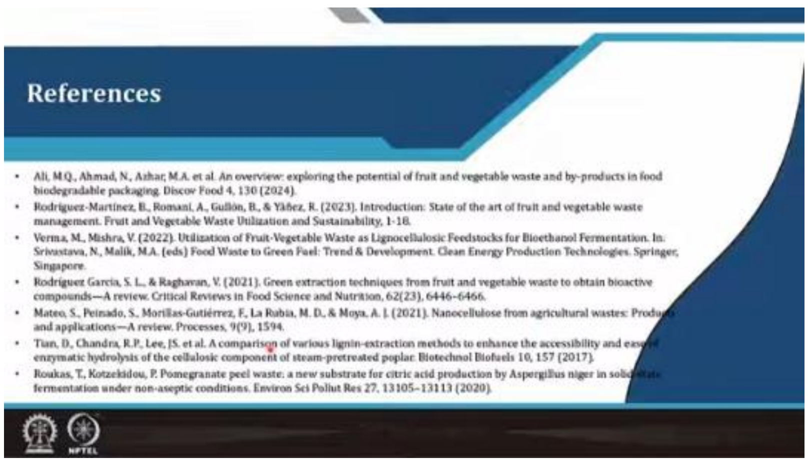
Then, even extraction of citric acid from waste like fruits and vegetable waste. They can be pressed after juice removal, after the juice, whatever the material gives, chopping and grinding, adjustment of moisture and pH. Then fermentation by *Aspergillus niger*, then you get the fermentation mash from where mycelium can be removed, and then the remaining can be extraction of citric acid, centrifugation, and recovery of clarified citric acid. So, this is the schematic of citric acid production.

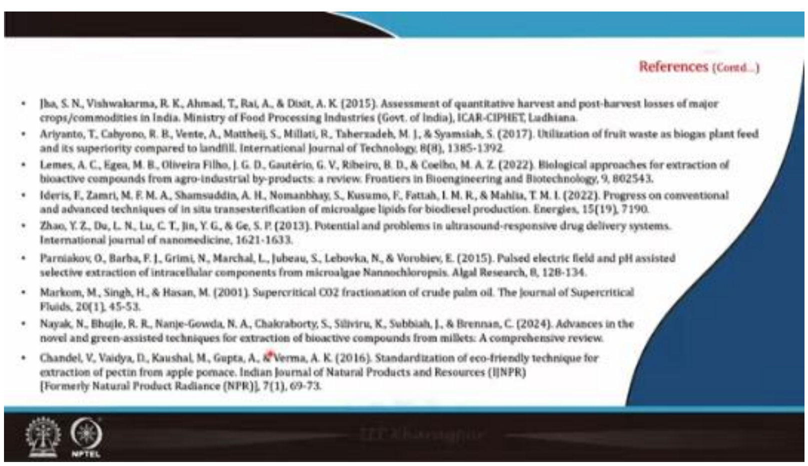


So, finally, I will summarize this lecture by saying that fruits and vegetables are the major commodities contributing to the waste generated in India and worldwide. These wastes generated are utilized based on their composition, like cellulose, nanocellulose, and pectins, which are among the most extracted biopolymers from fruit and vegetable waste. These waste streams are also rich sources of phenolic acids, flavonoids and many compounds that are utilized as bioactive compounds.

Utilization of these wastes can be done as a source of fuel, bioactive components, fertilizers, and biopolymers, etcetera. So, this is a very important area again, having a proper mechanism in place to collect these byproducts or bioproducts and then channelize them again into various bioproduct extractions, meaning they can be extracted and used for various purposes like gas production, ethanol production, or bioactive extraction, etcetera.

Then, the residue again can be used as a source of fiber or for other purposes. So, this will not only result in better economic output or various products and bioproducts for various industries, but it will also result in a cleaner environment because otherwise, when these fruit and vegetable wastes spoil, they generate a lot of gases and create environmental pollution or greenhouse gas emissions, etcetera. So, that can also be minimized.





So, these are the references which were used in this lecture.

Thank you very much for your patient hearing. Thank you.