Post-Harvest Operations and Processing of Fruits, Vegetables, Spices and Plantation Crop Products
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Lecture 56
Green Technologies and Near Zero Waste Processing

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Hello everyone, namaskar. Now, we will discuss about various aspects of green technologies, by-products and waste utilization. In today's lecture, we will discuss the green technology and near zero waste processing.

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The concept that we will be covered include an overview of green technology, novel green processing and extraction techniques, near zero waste management, and waste utilization in fruits and vegetable sector.

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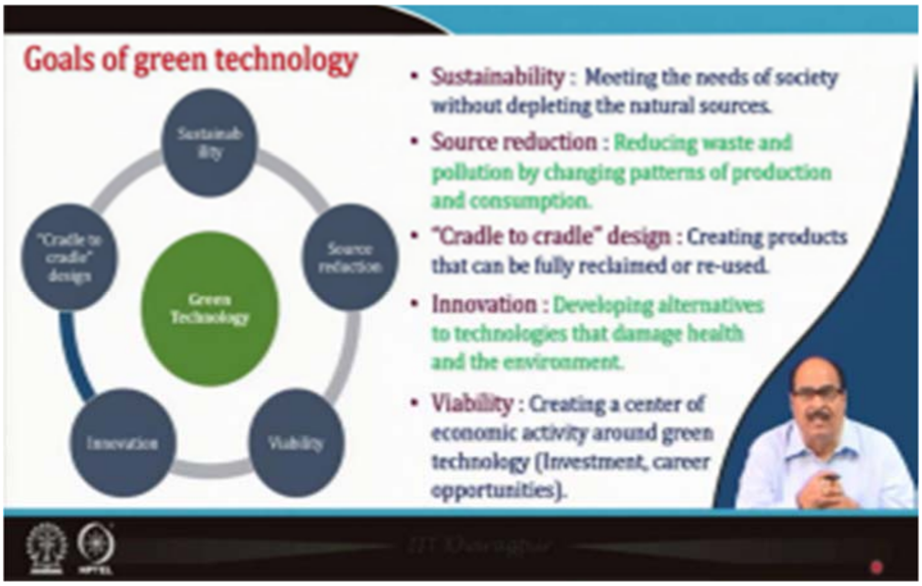

The goals of green technology are:

Sustainability: meeting the needs of society without depleting the natural sources, source reduction: reducing waste and pollution by changing patterns of production and consumption, "cradle to cradle" design: creating products that can be fully reclaimed or re-used, innovation: developing alternatives to technologies that damage health and the environment, and viability: creating a center of economic activity around green technology (Investment, career opportunities).

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Application of green technologies in food sector aims to reduce energy use, reduce environmental foot print, reduce process-induced toxins in foods, reduce waste generation, and alternative and sustainable process for analytical and processing purpose

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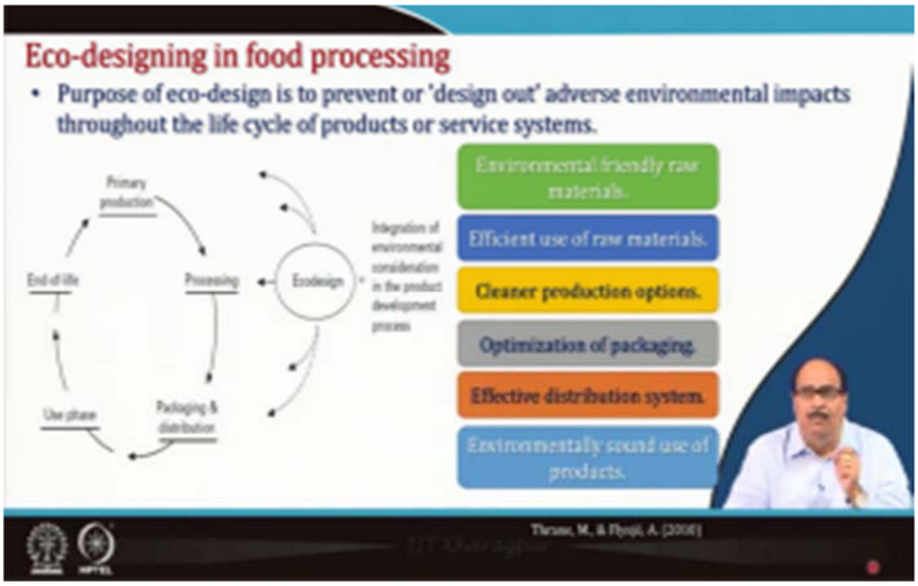

Eco-designing in food processing:

Purpose of eco-design is to prevent or 'design out' adverse environmental impacts throughout the life cycle of products or service systems. This involves environmental friendly raw materials, efficient use of raw materials, cleaner production options, optimization of packaging, effective distribution system, and environmentally sound use of products. The eco design cycle include primary production, processing, packaging and distribution, use phase and end of life.

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The novel green processing technologies, that is high pressure processing, pulsed electric field, pulsed light, Ohmic heating, ultrasound processing, cold plasma treatment, membrane processing, microwave processing, ultraviolet treatment, are considered to be green technologies because these technologies normally aim to achieve food products rich in health promoted components with appropriate shelf life and fulfill the market requirement of garden fresh and natural-like food products. They also play crucial role in product innovation, produce sophisticated and diverse food products.

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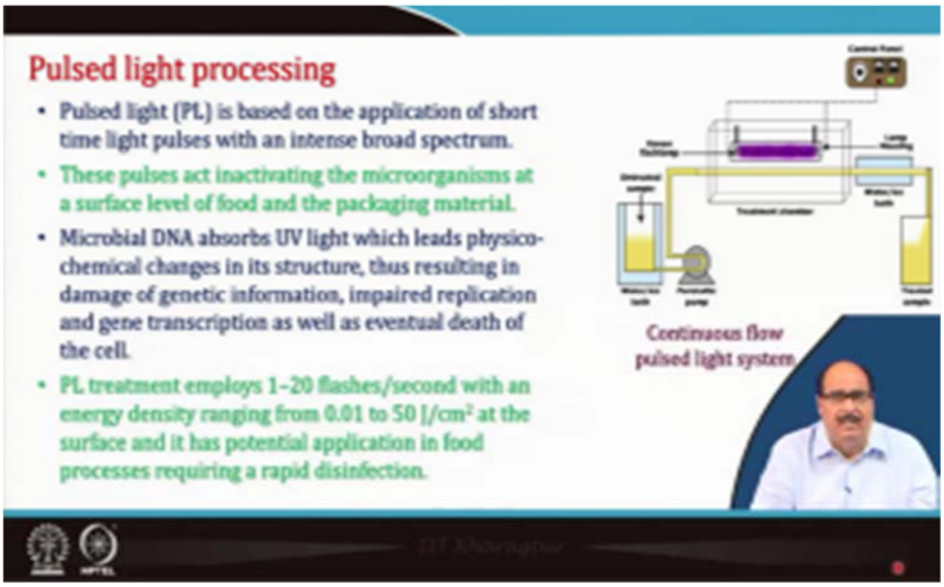

Pulsed light (PL) is based on the application of short time light pulses with an intense broad spectrum. These pulses act inactivating the microorganisms at a surface level of food and the packaging material. Microbial DNA absorbs UV light which leads physico-chemical changes in its structure, thus resulting in damage of genetic information, impaired replication and gene transcription as well as eventual death of the cell. PL treatment employs 1–20 flashes/second with an energy density ranging from 0.01 to 50 J/cm^2 at the surface and it has potential application in food processes requiring a rapid disinfection.

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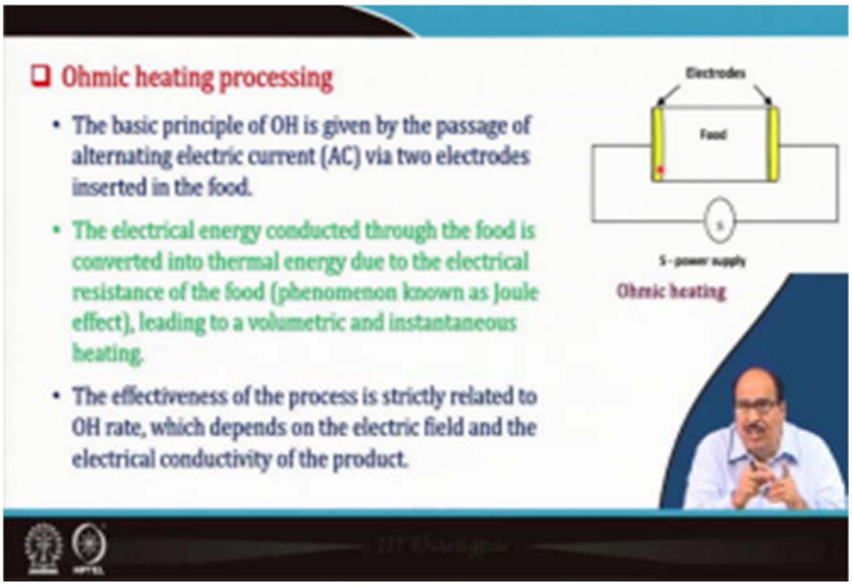

Ohmic heating processing:

The basic principle of OH is given by the passage of alternating electric current (AC) via two electrodes inserted in the food. The electrical energy conducted through the food is converted into thermal energy due to the electrical resistance of the food (phenomenon known as Joule effect), leading to a volumetric and instantaneous heating. The effectiveness of the process is strictly related to OH rate, which depends on the electric field and the electrical conductivity of the product.

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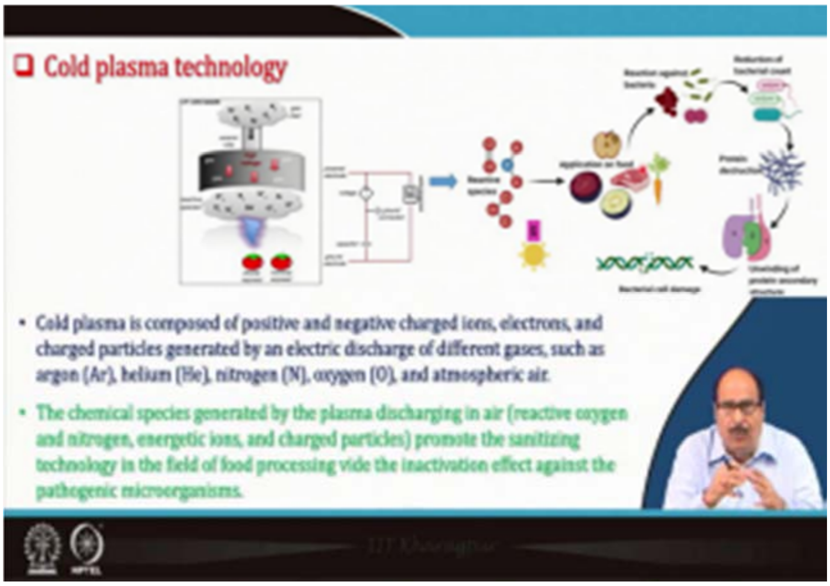

Cold plasma technology:

Cold plasma is composed of positive and negative charged ions, electrons, and charged particles generated by an electric discharge of different gases, such as argon (Ar), helium (He), nitrogen (N), oxygen (O), and atmospheric air. The chemical species generated by the plasma discharging in air (reactive oxygen and nitrogen, energetic ions, and charged particles) promote the sanitizing technology in the field of food processing vide the inactivation effect against the pathogenic microorganisms.

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Benefits of green processing:

Eliminate the local use of boilers or steam generation systems, avoid the use of non-renewable energy resources, like fossil fuels, it has good energy efficiency, water savings and reduced emissions (environmental friendly), maintain the integrity of phytochemicals & retains the nutritional quality of fruits and vegetable, inactivate oxidative enzymes & minimize browning, and minimal impact on color, flavor & volatile aroma compounds.

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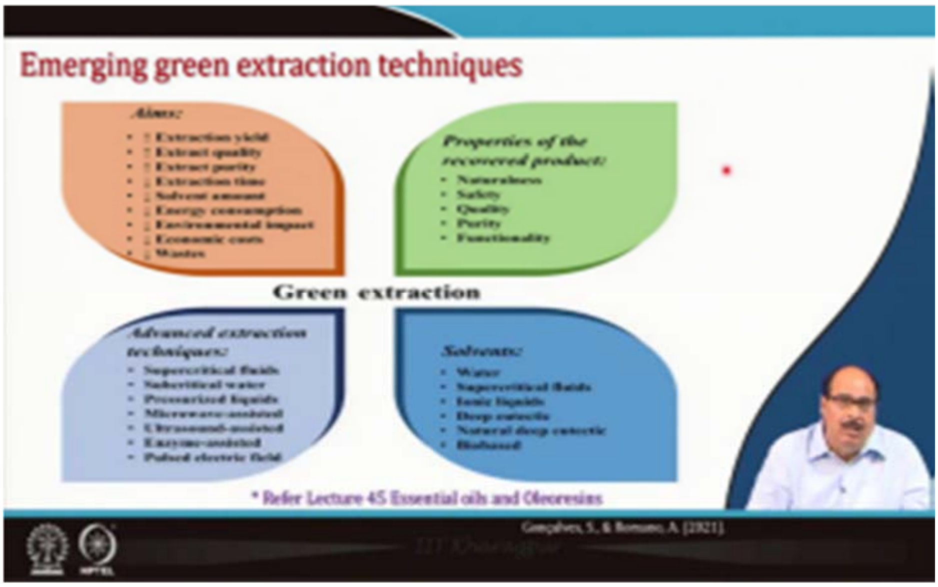

Emerging green extraction techniques

What is the green extraction technique? It aims to increase the extraction yield, extraction quality, extract purity, etc and lower down the extraction time, amount of solvent required for extraction, energy consumption, environmental impact, economic cost, waste generated, etc. The properties of the recovered product using green technology have more naturalness, safety, quality, purity, and functionality.

Various advanced extraction techniques include supercritical fluid extraction, subcritical water extraction, pressurized liquids, microwave assisted extraction, ultra sound assisted extraction, enzyme assisted extraction, and pulse electric field. The solvents used are water, supercritical fluids, then ionic liquids, deep eutectic or natural deep eutectic and even bio-based solvents.

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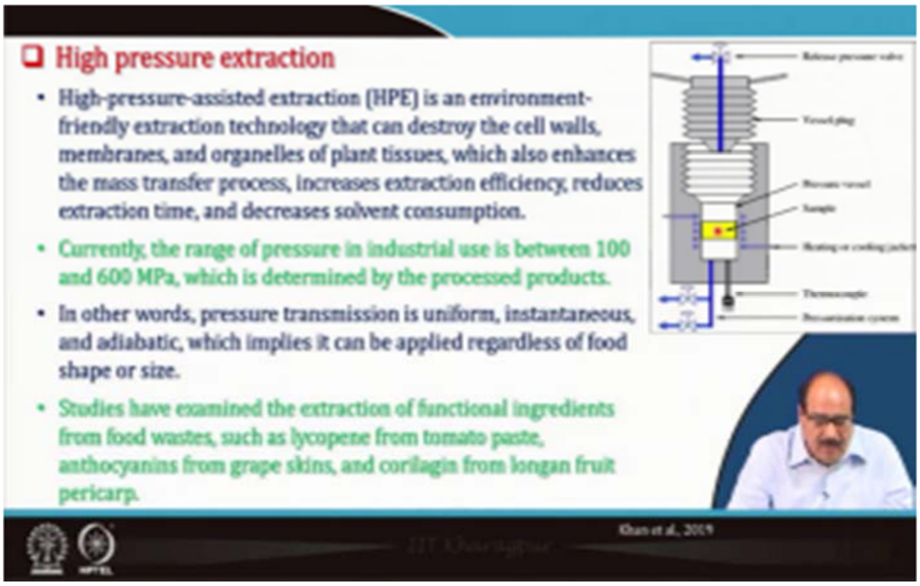

High pressure extraction:

High-pressure-assisted extraction (HPE) is an environment-friendly extraction technology that can destroy the cell walls, membranes, and organelles of plant tissues, which also enhances the mass transfer process, increases extraction efficiency, reduces extraction time, and decreases solvent consumption. Currently, the range of pressure in industrial use is between 100 and 600 MPa, which is determined by the processed products. In other words, pressure transmission is uniform, instantaneous, and adiabatic, which implies it can be applied regardless of food shape or size. Studies have examined the extraction of functional ingredients from food wastes, such as lycopene from tomato paste, anthocyanins from grape skins, and corilagin from longan fruit pericarp.

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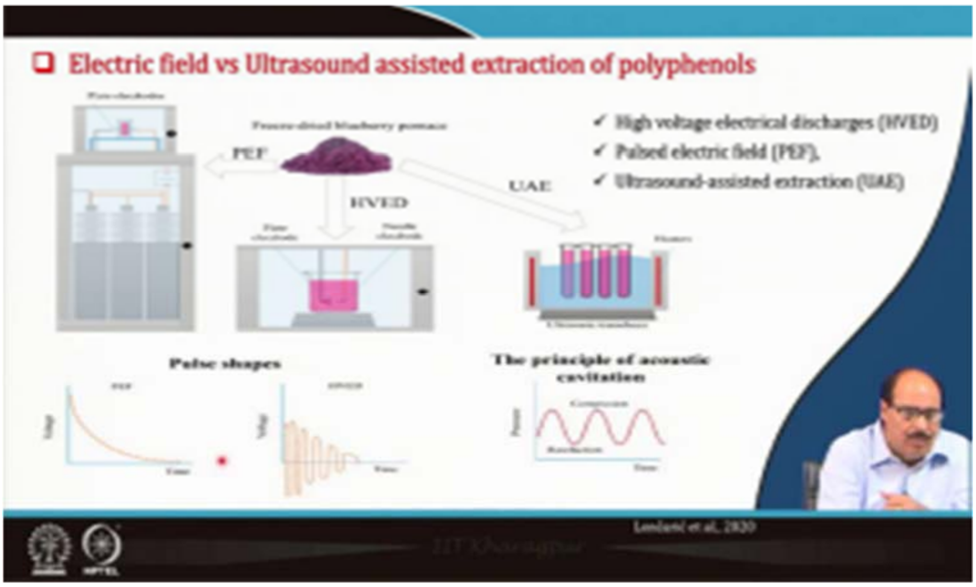

Electric field versus ultrasound assisted extraction of polyphenols:

Here the freeze-dried blueberry pomace is taken and subjected to either pulsed electric field structure or high voltage electric discharge method or ultrasound assisted extraction. In the ultrasound assisted extraction, the pomace powder is put into some liquid solvent inside the ultrasonic transducer. The extraction efficiency increases due to the principle of acoustic cavitation where, compaction and refraction, the time and pressure and the extraction rate is present. In the case of High voltage electrical discharges (HVED), commodity is kept in the plate electrode or needle electrode. The fluctuation in HVED that is how extraction pulse shapes can be observed in the figure.

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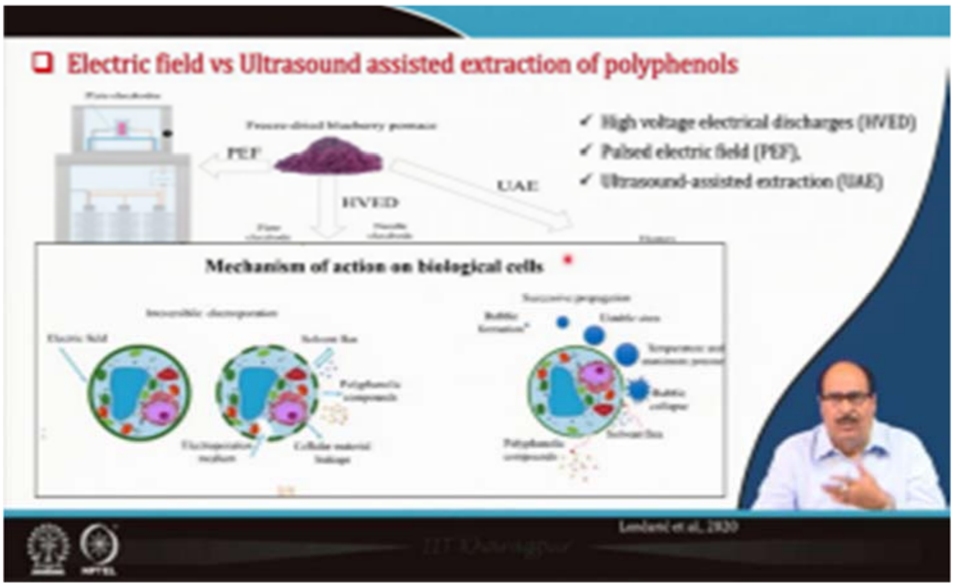

The mechanism of action basically irreversible electroporation, that is, when you are applying the electric field, then this cells are damaged, ruptured and pores are created, either existing pores are enlarged, or new pores are created. The cellular components flow to outside of cells. The solvent present in outer side penetrates into the cell and this releases polyphenolic components and cellular material. Finally, the extract component is obtained.

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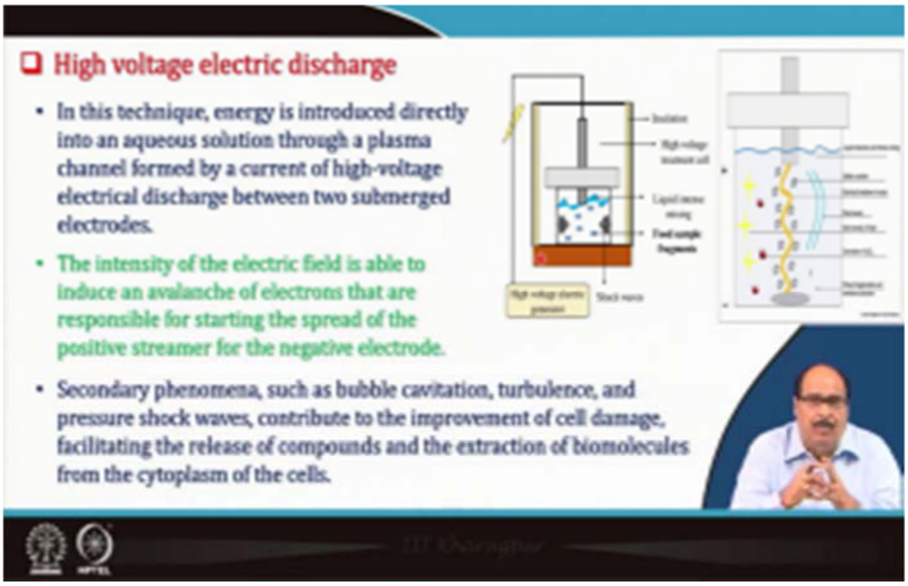

High voltage electric discharge:

In this technique, energy is introduced directly into an aqueous solution through a plasma channel formed by a current of high-voltage electrical discharge between two submerged electrodes. The intensity of the electric field is able to induce an avalanche of electrons that are responsible for starting the spread of the positive streamer for the negative electrode. Secondary phenomena, such as bubble cavitation, turbulence, and pressure shock waves, contribute to the improvement of cell damage, facilitating the release of compounds and the extraction of biomolecules from the cytoplasm of the cells.

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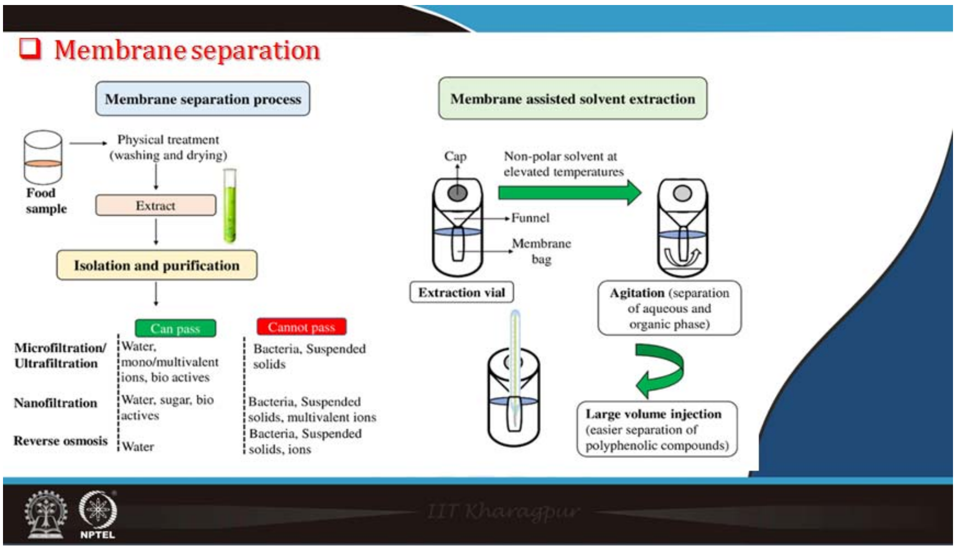

Membrane separation:

The fruit or vegetable or other sample is given physical treatment like washing, drying, then taken for extraction and then extract is subjected to isolation and purification either using microfiltration, ultrafiltration, nanofiltration or reverse osmosis which are the known technologies.

Membrane assisted solvent extraction:

An extraction vial with a cap, funnel and membrane bag, is used to obtain the non polar solvent at elevated temperatures followed by agitation (separation of aqueous and organic phase) and finally larger volume injection is done to easily separate the polyphenolic compounds.

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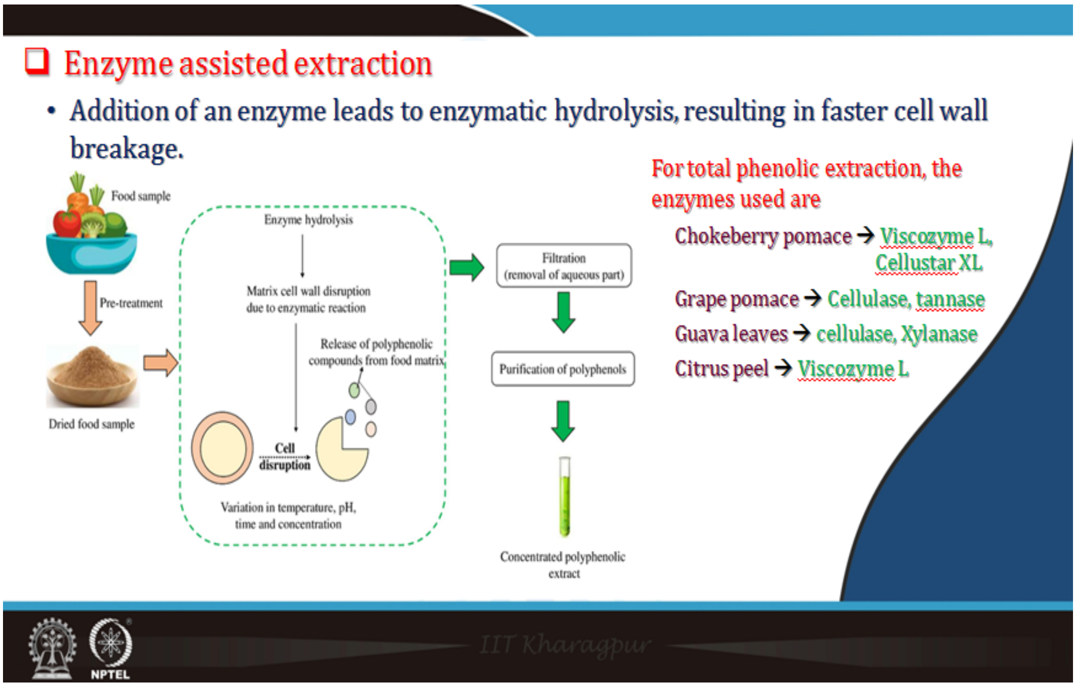

Enzyme assisted extraction:

It works on the principle that addition of an enzyme leads to enzymatic hydrolysis, resulting in faster cell wall breakage. The food dried sample is taken after pre-treatment for enzyme hydrolysis where the matrix cell wall disruption due to enzymatic reaction occurs which in turn release the polyphenolic compounds from the food matrix. Removal of aqueous part is then done by filtration followed by purification of polyphenols then finally, the concentrated polyphenolic extract is obtained. For total phenolic extraction, the enzymes used are: Chokeberry pomace → Viscozyme L, Cellustar XL, Grape pomace → Cellulase, tannase, Guava leaves → cellulase, Xylanase, and Citrus peel → Viscozyme L.

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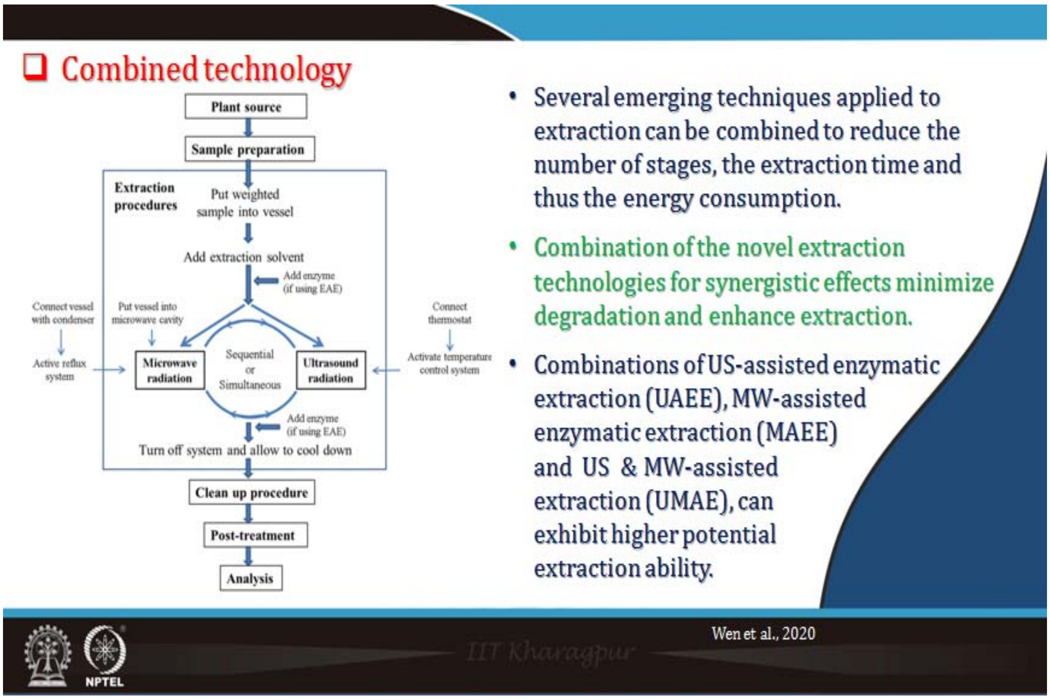

Combined technology:

From the plant source, the sample preparation is done for the extraction procedures, where, weighted samples are put into vessels; extraction solvent is added along with enzyme addition before subjecting it to micro wave and ultra sound radiation. The system is then turned off and allowed to cool down followed by clean up procedures, post-treatments and analysis. Several emerging techniques applied to extraction can be combined to reduce the number of stages, the extraction time and thus the energy consumption. Combination of the novel extraction technologies for synergistic effects can minimize the degradation and enhance extraction. Combinations of US-assisted enzymatic extraction (UAEE), MW-assisted enzymatic extraction (MAEE) and US & MW-assisted extraction (UMAE), can exhibit higher potential extraction ability.

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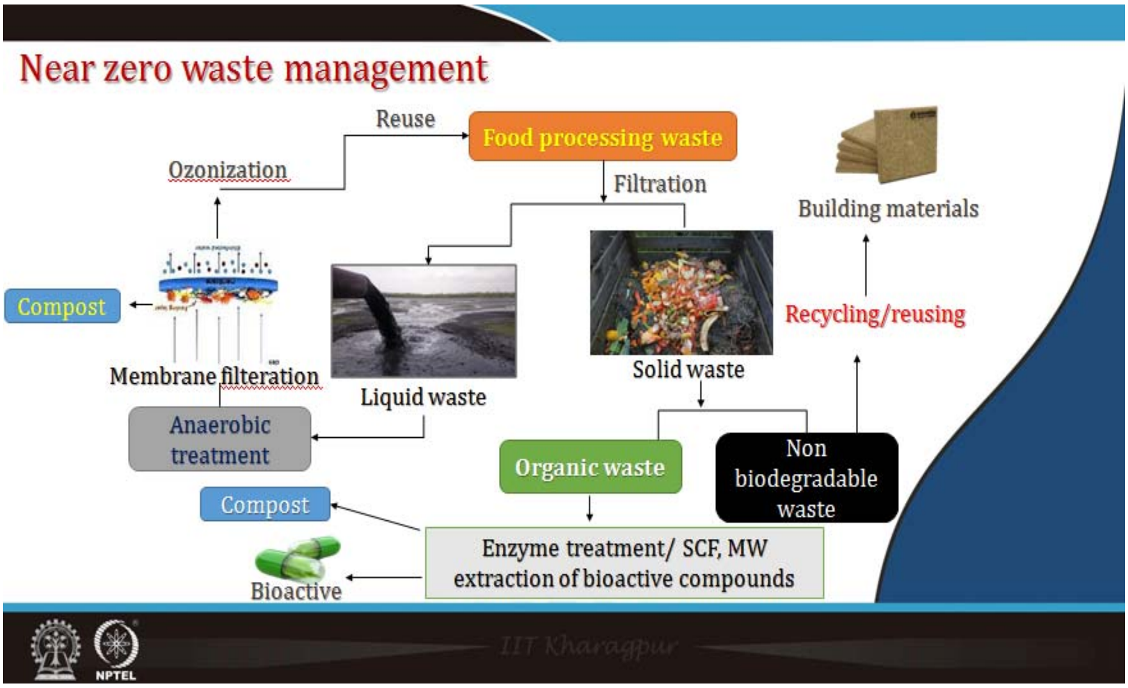

Near zero waste management:

Food processing waste after filtration is of two types: liquid and solid wastes. The organic wastes and solid biodegradable waste are taken for enzyme treatment/ SCF, MW extraction bioactive compounds, to obtain the bioactives and compost. However, the liquid waste is taken for anaerobic treatment, membrane filtration to obtain the compost on one side and the other part is ozonized for the reuse.

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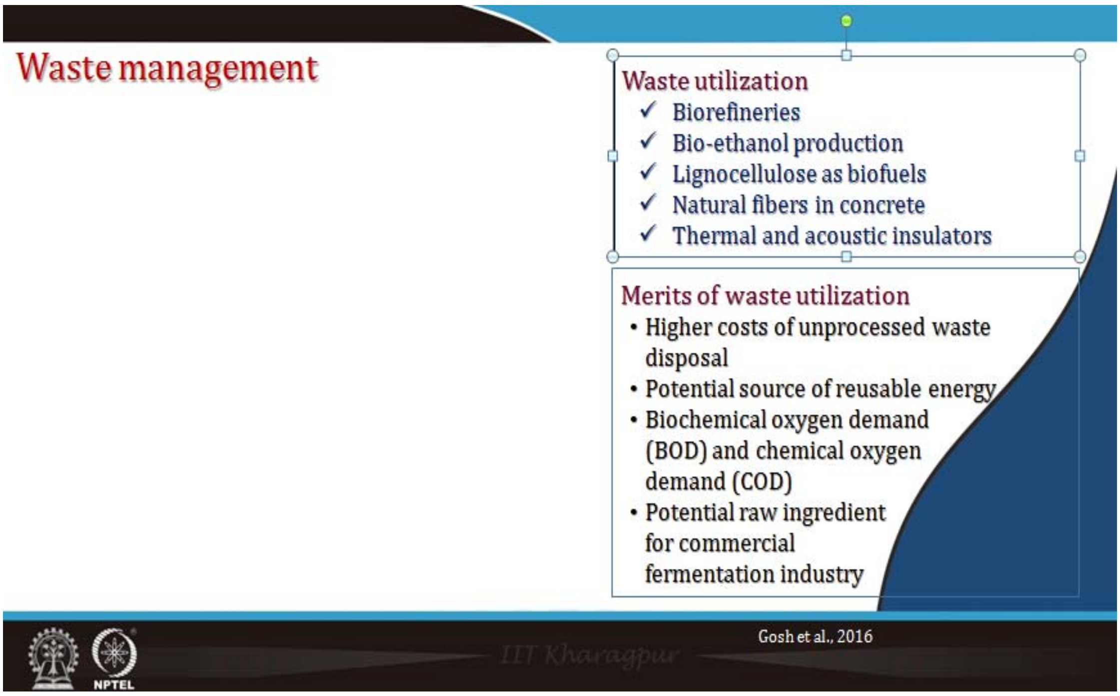

Waste management:

Waste utilization involve the biorefineries, bio-ethanol production, lignocellulose as biofuels, natural fibers in concrete, and thermal and acoustic insulators. merits of waste utilization include higher costs of unprocessed waste disposal, potential source of reusable energy, biochemical oxygen demand (BOD) and chemical oxygen demand (COD), and potential raw ingredient for commercial fermentation industry.

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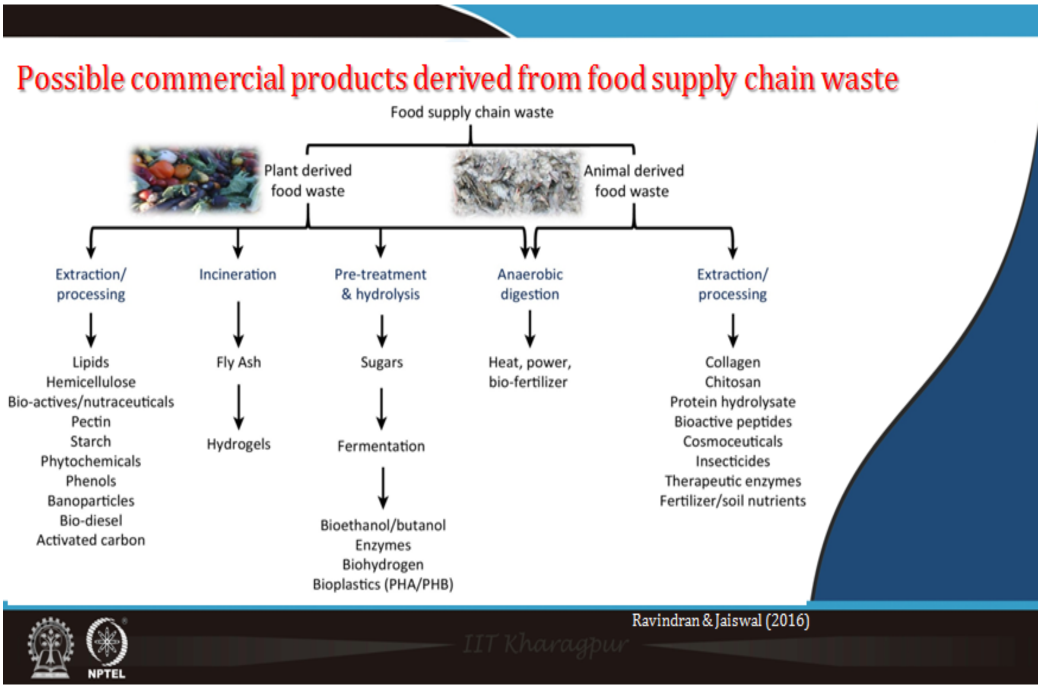

Food supply chain waste is mainly plant derived or animal derived. Particularly the plant derived waste material are subject to extraction and processing technology where, various molecule like lipids, hemicellulose, bio actives, pectin, starch, phytochemical, phenols etc can be made or by incineration we can get fly ash and hydrogels. From pretreatment and hydrolysis one can get sugars, which can be fermented to obtain products like bio ethanol, butanol, enzymes etc. Anaerobic digestion can be used for obtaining the heat, power, biofertilizers, etc. These are the some of the main commercial value products can be obtained from these wastes. Similarly, Animal derived waste after extraction can give us collagen, chitosan, protein hydolysate, bioactive peptides, insecticides and therapeutic enzymes tc.

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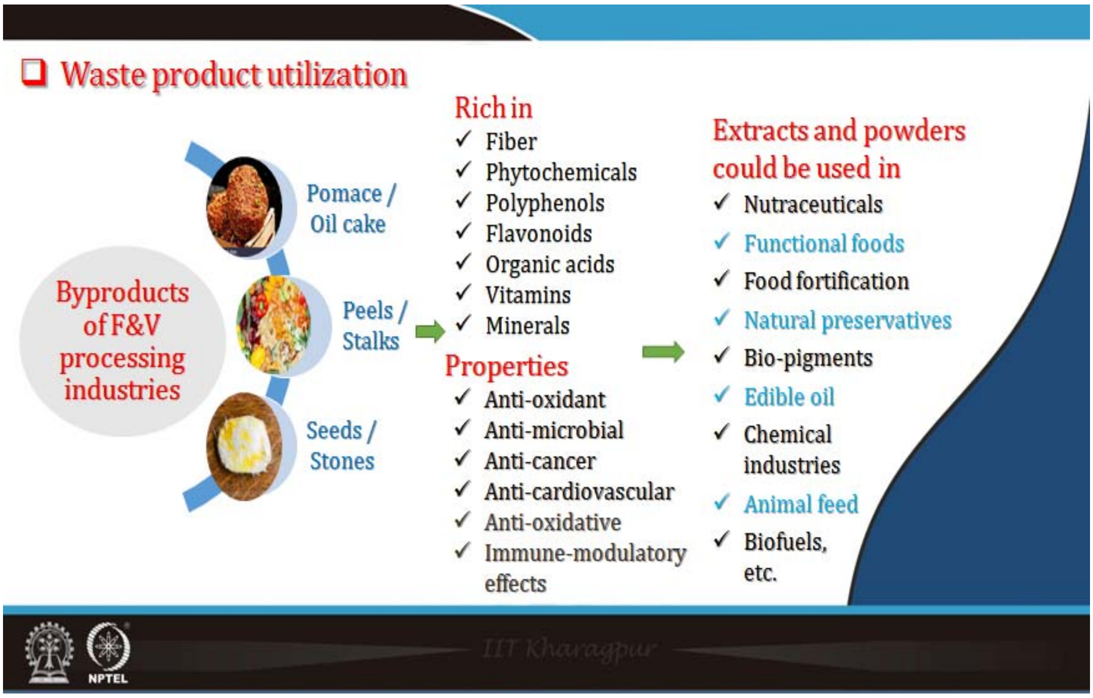

Waste product utilization:

Byproduct of fruit and vegetable industries are pomace, oil cakes, peels, stalks, seeds and stones. They are often rich in Fiber, Phytochemicals, Polyphenols, Flavonoids, Organic acids, Vitamins, Minerals and exhibits various important properties such as Anti-oxidant, Anti-microbial, Anti-cancer, Anti-cardiovascular, Anti-oxidative , Immune-modulatory effects. The extracts and powders could be used in Nutraceuticals, Functional foods, Food fortification, Natural preservatives, Bio-pigments, Edible oil, Chemical industries, Animal feed, Biofuels, etc.

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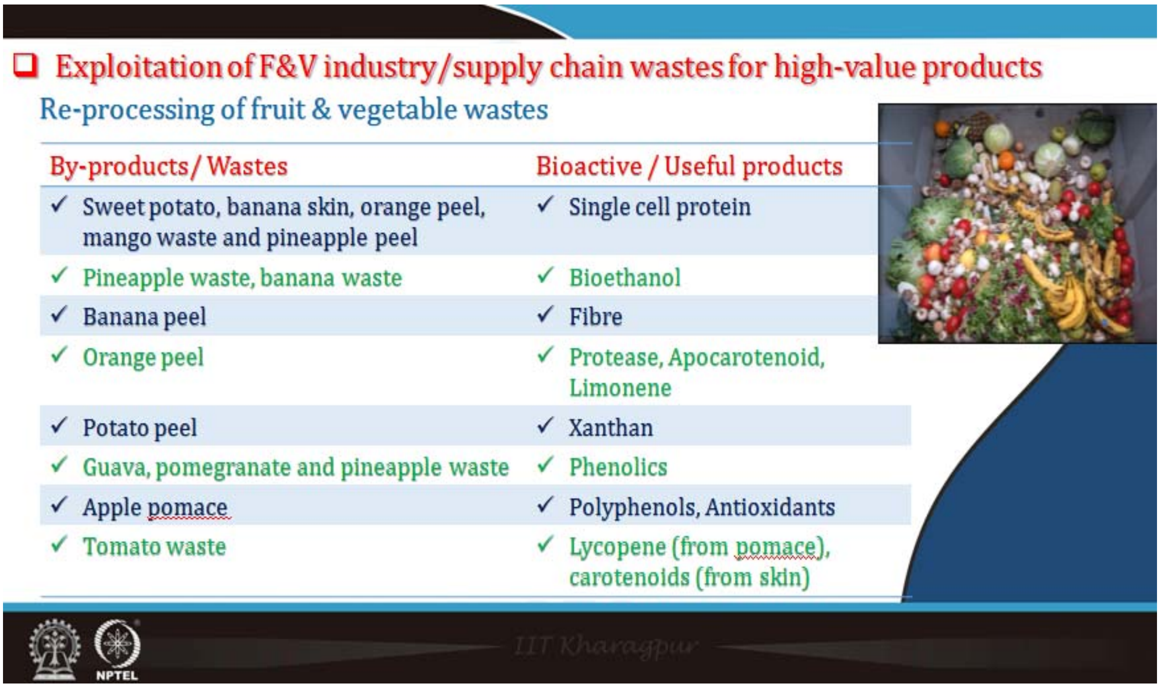

Exploitation of F&V industry/supply chain wastes for high-value products:

Re-processing of fruit & vegetable wastes

Sweet potato, banana skin, orange peel, mango waste and pineapple peel are used for the preparation of single cell protein; Pineapple waste, banana waste are used for bioethanol formation; Banana peel can be used for fibre generation; Orange peel is used to prepare Protease, Apocarotenoid, Limonene; Potato peel is used for xanthan formation; Guava, pomegranate and pineapple waste forms phenolics; Apple pomace helps in Polyphenols, Antioxidants formation; Tomato waste is used to extract Lycopene (from pomace), carotenoids (from skin).

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Similarly, the fruits and vegetable they can also be exploited for making packaging materials from the peels, skin leaf, kernel, pomace etc. After the bioactive extraction, the residue which is coming can be used for renewal and bio-degradable biopolymers, composite film with good instability and barrier properties, and active films as carrier of antioxidant, antimicrobial properties.

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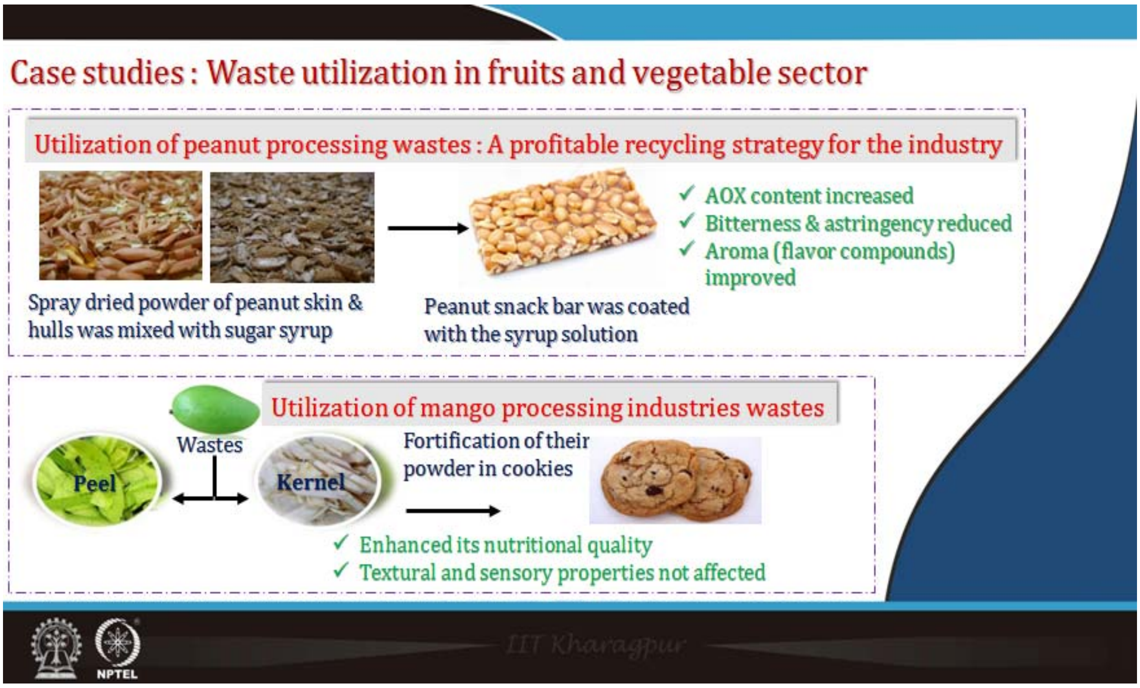

Case studies: Waste utilization in fruits and vegetable sector

This case study represents the waste utilization in fruits and vegetable sector. Utilization of peanut processing waste involves the collection of spray dried powder of peanut skin & hulls was mixed with sugar syrup, peanut snack bar was coated with the syrup solution, it was found that antioxidant content of the snack bar increased bitterness and astringency was reduced and aroma was improved. Similarly, the fortification of mango kernel powder in cookies improved its nutritional, textural and sensory qualities.

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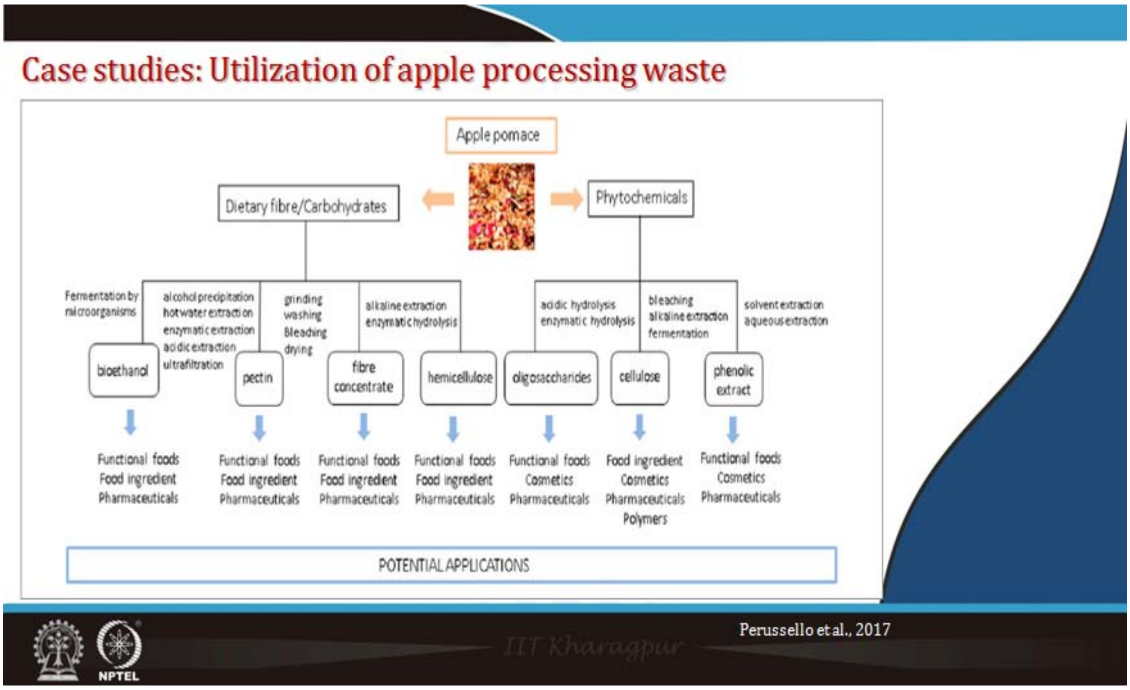

Utilization of apple processing waste:

Apple pomace is rich in dietary fibres/carbohydrates and phytochemicals and are utilized for the production of bioethanol, pectin, fibre concentrate, hemicelluloses, oligosaccharides, cellulose, and phenolic extract, which are further used for the production of functional foods, food ingredients, pharmaceuticals, cosmetics, polymers etc.

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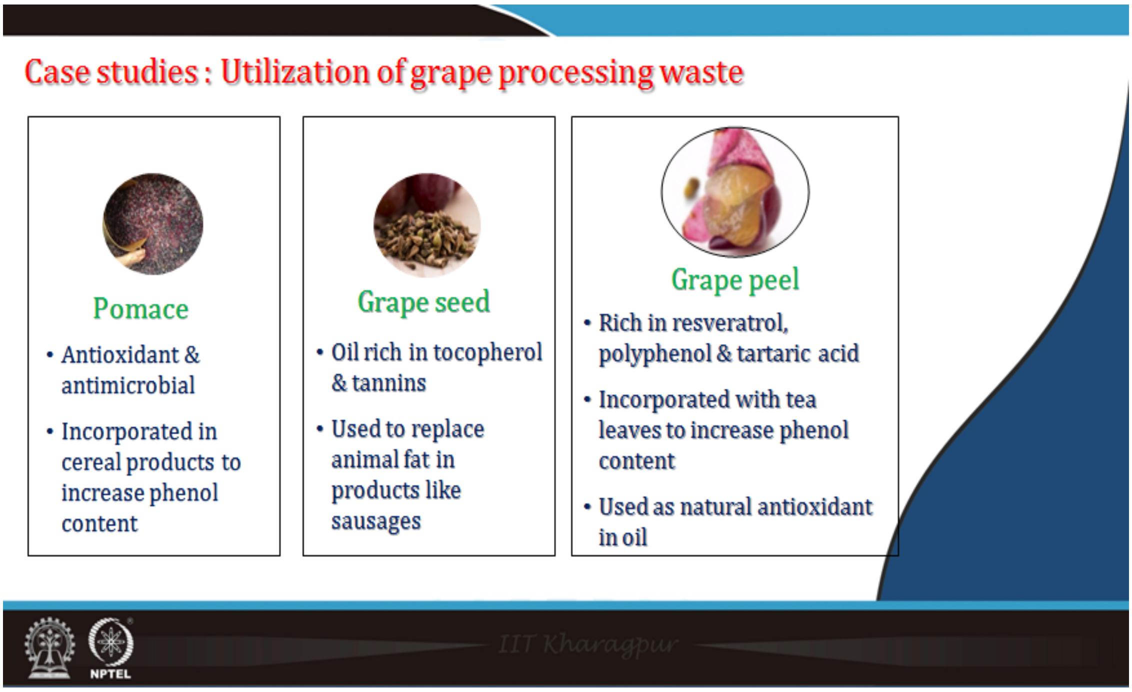

Utilization of grape processing waste:

The grape pomace is rich in Antioxidant & antimicrobial and can be Incorporated in cereal products to increase phenol content. Grape seed oil is rich in tocopherol & tannins and Used to replace animal fat in products like sausages. Grape peels are rich in resveratrol, polyphenol & tartaric acid which can be incorporated with tea leaves to increase phenol content and used as natural antioxidant in oil.

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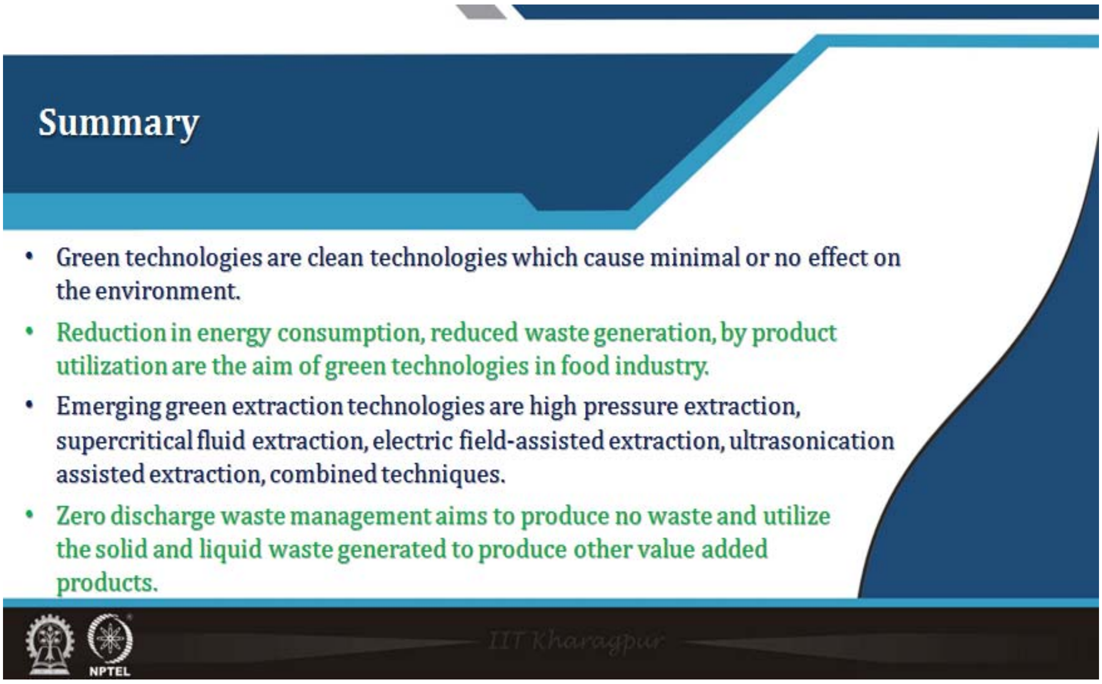

Summary:

Green technologies are clean technologies which cause minimal or no effect on the environment. Reduction in energy consumption, reduced waste generation, by product utilization are the aim of green technologies in food industry. Emerging green extraction technologies are high pressure extraction, supercritical fluid extraction, electric field-assisted extraction, ultrasonication assisted extraction, combined techniques. Zero discharge waste management aims to produce no waste and utilize the solid and liquid waste generated to produce other value added products.

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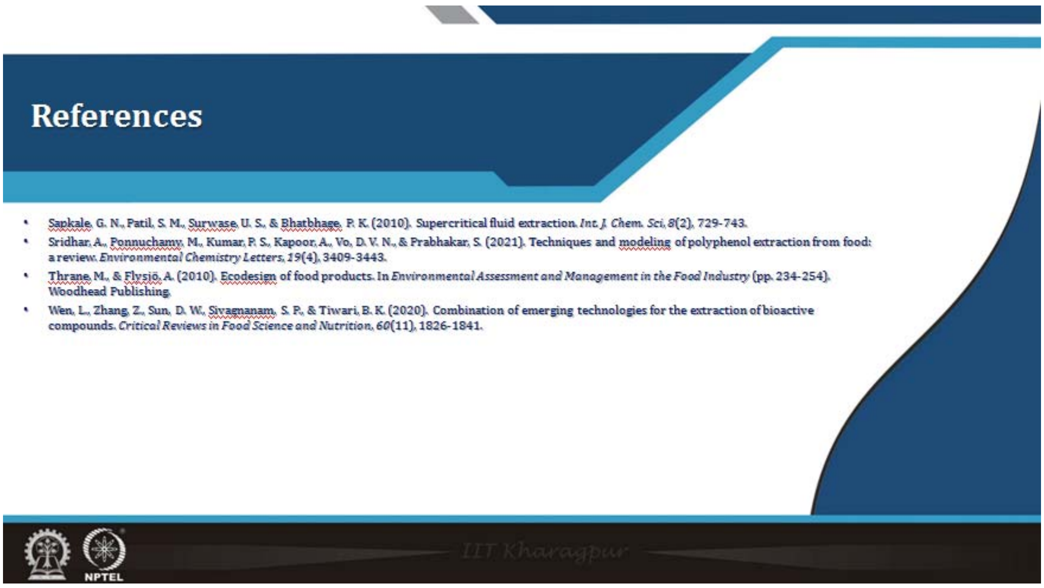

So, this is all. These are the references used in this lecture.

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Thank you very much for your time.