Waste to Worth: A Review on Utilization of Vegetable Waste

ABSTRACT

India is the world's second greatest producer of vegetables after China, however over 30% of the fruits and vegetables grown in the country are wasted. Vegetable wastes include rotten vegetables, peels, shells, scraped portions of vegetables and inedible parts discarded during collection, handling, transportation and processing. Lack of knowledge and awareness among farmers, poor infrastructure, faulty harvesting, unsuitable transport and storage facilities are major causes of loss. 5 R system of waste management including refuse, reduce, recycle, reuse and recover is an effective way of managing vegetable waste.Non-toxic, biodegradable waste of vegetables can be transformed into various valuable output products like biogas, power alcohol, biofuel, compost and vermicompost. Livestock is currently one of the agricultural subsectors in emerging countries that is expanding at the fastest rate. According to recent research, co-products from the processing of fruits and vegetables can be effectively utilized as functional feed components in farm animals' diets. Vegetable wastes are rich in vitamins and minerals and are suitable raw materials to produce high-value chemicals or metabolites such as phenolic compounds, terpenes, fatty acids, dietary fiber, saponins, pigments, food additives and phytoestrogensBio-plastic are manufactured from renewable biomass sources such as maize starch, potato starch, cassava starch, vegetable oiland have biodegradable qualities. The utilization of fruit and vegetable waste as a carbon source is an interesting alternative to reduce the production costs of microbial exopolysaccharides like xanthan and pullulan which has use in the pharmaceutical, medical, cosmetic and confectionary industries.

Keywords: Vegetable waste, valuable output, 5R system, animal nutrition and bioplastic.

INTRODUCTION

With a wide variety of climatic and geographic conditions, India is the second-largest producer of vegetables in the world (199 million metric tonnes) (1). Most of that wastage comes from fruits and vegetables. Almost 30% of the fruits and vegetables grown in India are wasted (2).Vegetable waste is a biodegradable material that is produced in vast amounts. A large portion of it is thrown on land to decay in the open, generating a nasty smell and attracting birds, rodents, and pigs that can spread illness. Vegetable waste is a biodegradable material that is produced in vast amounts. A large portion of it is thrown on land to decay in the open, generating a nasty smell and attracting birds, rodents, and pigs that can spread illness.Vegetable waste includes inedible components of vegetables such as peels, shells, scraped pieces and vegetables that rot and are wasted during collection, handling, transportation and processing (3). These wastes are currently disposed of on the outskirts of cities. However, this is not a good solution for FVW due to its high-water content, which causes microbiological instability, off-odour development, and leachate (4,5).The significant loss of fruits and vegetables is due to poor agricultural practices and a lack of regulation in the food processing sector. In order to achieve sustainability vegetable waste management by proper utilization is mandatory. Environmental pollution can be minimized by handling discarded goods properly. The high biodegradability and low toxicity of vegetable waste make them suitable for recycling. Technologies with effective low input costs are created to transform organic waste into useful goods for a sustainable environment. In addition to protecting biodiversity, natural resources, and human life, effective waste management will also have a positive economic impact by creating more work opportunities. In this review, an attempt has been made to explore and cite the various products of vegetable waste management.

PROPERTIES OF VEGETABLE WASTE (6)

Vegetable waste is different from other solid waste as it is available in cheap and available in bulk. It has defined colour & texture and Good Water binding capacity which can help in easy identification, separation and degradation. Also, it is moderate in taste & odour and contains bioactive compounds, vitamins and dietary fibers which make it suitable for reuse and compatible to processing. Also, vegetable waste is highly concentrated and easy to handle.

CAUSES OF WASTE

According to FAO estimates, the pre-consumer period is very important in terms of FVW formation (7). According to Segre and Falasconi(8), up to 87% of fruit, vegetables, and cereals are thrown before reaching the customer in Italy. The causes of waste vary from country to country. One well-known reasonfor vegetable waste isthe lack oftechnical, equipment knowledge and market information among farmers. Some farmers follow inappropriate cultural operations during the raising of crops and practicefaulty harvesting of crops*i.e*., harvesting at the inappropriate stage through unsuitable toolsand improper methods which is the major cause behind the wastage of produce. Also, Post-harvest operations have a direct effect on the shelf-life and freshness of produce. Poor handling of produce after harvesting; inappropriate storage facilities,and unavailability of cold storage can cause deterioration in product quality Lack of adequate transport facilities and open transport vehicles can add to the deterioration of quality and ultimately the loss. In developing countries, processing facilities are not adequate and demand is seasonal which leads to a glut in the market. As vegetables have a short shelf life, most of the products get wasted during the glut period. An inefficient marketing system *i.e.,* fragmented marketing channels and involvement of many intermediaries and carelessness by them is one of the potential causes of waste

STEPS FOR WASTE MANAGEMENT(9)

Waste segregation is a significant problem in waste processing and management. Unfortunately, no city in India can claim 100% waste segregation at dwelling units, and on average, only 70% of the trash collection is observed, with the other 30% being mixed up and lost in the urban environment.5 R system of waste management including refuse, reduce, recycle, reuse and recover is an effective way of managing vegetable waste. Steps of waste management are cited below:-

(i) <u>Preventing and/or reducing the generation of waste at source:</u> - The waste generationshould be prevented as much as possible. If prevention of any type of waste is not possible then the quantity of waste generated should be kept minimum

(ii) <u>Improving the quality of the waste generated</u>: - The quality of waste generated should be improved by adopting variousappropriate waste treatment or disposal strategies.

(iii) <u>Encouraging reuse, recycle and recovery: -</u>

- Reuse is finding a new purpose for undesirable goods that would otherwise be discarded. It includes animal feeding. Leftover vegetables, peels and rotten vegetables can be reused for animal feeding (10).
- Recycle is the process of converting waste material into new goods in order to minimize the use of more virgin resources. Composting is a typical example of recycling (11).
- Recovery is using waste materials as input material to generate energy or create valuable new output products. Biofuel production comes under this aspect of waste management (12).

UTILIZATION OF VEGETABLE WASTE

The term "food by-products" is becoming more popular. This concept denotes that biomass and garbage can be processed appropriately and transformed into useful marketable products (13). There are various ways of utilization of vegetable waste. It can be directly used to feed animals or can be transformed into various other valuable products like compost, vermicompost, biogas, biofuel, etc. Various bioactive compounds including phenolic compounds, essential oil, dietary fibers, metabolites, nutraceutical products and enzymes can be extracted from it. Exopolysaccharides and bioplastics are other transformational products of this waste. So, it must not be wasted and should be converted into various products of economic value. Various economic products of vegetable waste are discussed below.

1.) ANIMAL FEEDING

Vegetable production, packing, distribution, and consumption produce a significant amount of waste, which is often disposed of by composting or dumping into landfills or rivers, polluting the environment. Due to the enrichment of useful substances including polyphenols, carotenoids, and dietary fiber, such resources can serve as a good supply of nutrients. In addition to turning waste into silage, this has the potential to be employed in the manufacturing of animal feeds, particularly for cattle and dairy cows (14). However, there are significant limitations to this reuse strategy as well. These wastes are susceptible to microbial contamination due to their high-water content, which frequently exceeds 80%. As a result, some drying is frequently required. Furthermore, low protein content and a significant presence of indigestible chemicals may not always make a product acceptable for animal feed (15). Furthermore, the content of vegetable items fluctuates by season, necessitating manufacturers to often adjust feed compositions.

In most developing nations, feed supplies are already very limited. India has a shortage of 25, 159 and 117 million tonnes of concentrates, green forages and crop residues respectively. Thus, constituting 32% concentrates, 20 % green forages and 25 percent crop residues shortage of the estimated requirement (16).

Pulp residue left after extraction of juice from bottle gourd is sundried and ground to feed to animals as it contains 24.3% protein. Grade-out carrots are used to feed rabbit and horse diet as it contains 10% CP and 60% sugar. Cabbage leaves and waste is used to feed poultry as a nitrogenous and high-caloric diet which increases egg production. Feeding goats with 12.5% tomato waste could replace 35% cereal-based concentrate in their diet and improve milk quality (17).

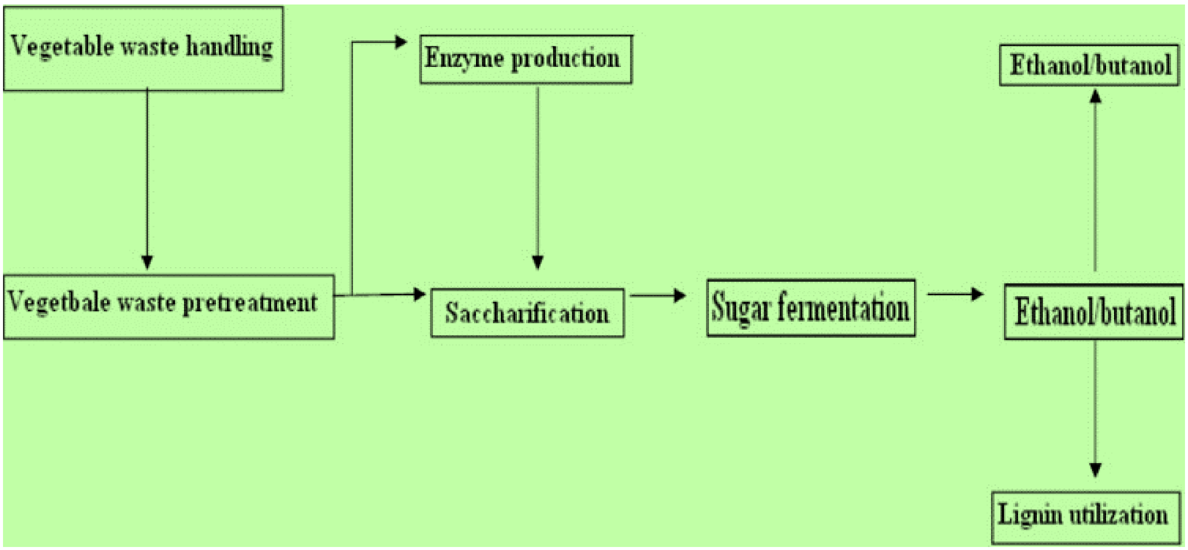
2.) BIOFUEL

It is a type of fuel derived from biomass sources having a low carbon footprint and is documented as a significant component of a sustainable energy system. It includes bio-hydrogen, biogas, bioethanol and biobutanol. Bi-hydrogen is produced through fermentation by anaerobic microorganisms such as clostridium either in the presence (photo fermentation) or absence of light (non-phototrophic). Many parameters affect its productions which include the kind of microorganism involved, metabolic pathways followed, the substrates used as inoculum and feedstock, the presence of inhibitors, and process conditions such as pH, temperature, and nutrient availability. Due to their abundance, high cellulose and starch content, and non-competitiveness with our food chain, monosaccharides produced from the hydrolysis of polysaccharides found in vegetable waste are the optimal substrates. Pumpkin waste yielded 55 mL H_2/g-VS (18).

It has been reported that utilizing carrot waste as a substrate, 71 mL H_2/g-VS and 38 mL H_2/g-using FVW made of cabbage, celery, and cauliflower have both been achieved (19).

Alkyl esters with large levels of fatty acids and less aliphatic alcohol make up biodiesel. The best biomass to use for making biodiesel is one with a high lipid content. Fresh or used vegetable oil waste, animal fats, and oilseed plants are all effective and potent substrates for the synthesis of biodiesel.

Fig. 1: Flow diagram for bioethanol/biobutanol production from vegetable wastes (20)



3.) BIOGAS

It is one of the most valuable outcomes of anaerobic digestion of organic waste. India has the second-largest biogas program in the world. Biogas is a mixture of Methane (60%), Carbon dioxide (20-30%), Hydrogen (5-10%) and Hydrogen Sulphide (Trace), Nitrogen (1-2%), Water vapor (0.3%). Biogas can be used to different purposes, including heat, electricity, production of compressed or liquefied natural gas, while the AD digestate, rich in nitrogen, can be used as a fertilizer (21).Methane fermentation is a complex process. The general process of anaerobic digestion is a series of processes like enzymatic hydrolysis, acidogenesis, acetogenesis and methanogenesis (22) and each metabolic stage is assisted by a series of microorganisms. Amongst the four stages, hydrolysis is the rate-limiting stage for FVW (23). Methane production from waste depends on substrate composition. Among vegetables cabbage and carrot peels give the highest methane yield *i.e.,*250-310 ml Methane/kg of vegetable waste (24). According to a report published on 10th Jan 2021 in the Times of India, a biogas plant was set up with the assistance of the Indian Institute of Chemical Technology to utilize vegetable waste from the Bowenpally market of Tamil Nadu. It generated 500 units of electricity daily and cut down electricity bills by 50%.

Since the methane content in the upgraded biogas must typically be over 95%, biogas upgrading to biomethane is one of the most widely used technologies for biogas exploitation today because it offers the chance to obtain a valuable biofuel that can be used directly as vehicle fuel in compressed natural gas (CNG) engines. Technologies for membrane separation, water or amine scrubbing (absorption procedures), and pressure swing adsorption (PSA) are employed. Additionally, the creation of syngas from the reforming of biogas has drawn interest since it may be utilized as a raw material to create chemicals and synthetic fuels (25).

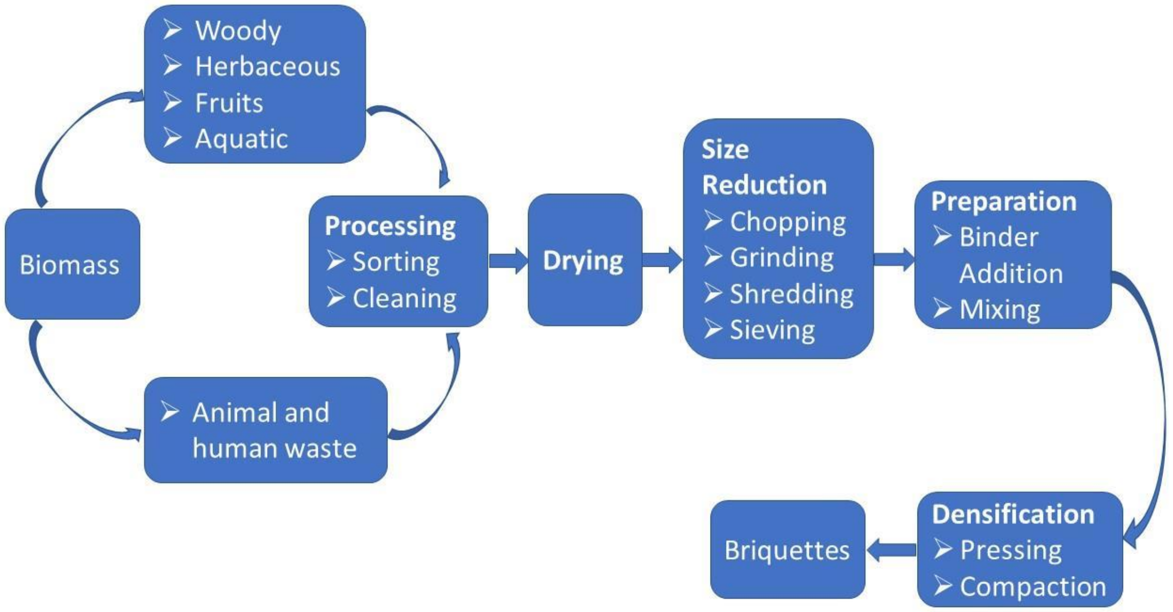
4.) BRIQUETTING

It is a process for turning solid vegetable waste into high-density briquettes that increases the volumetric calorific value while also allowing for flexible storage and transportation. Vegetable waste is thermochemically transformed into affordable, environmentally friendly biofuel. Waste biomass can be directly compacted, ground and mixed with a binder, or brought to a specified moisture content before converted to briquettes. Without employing an external binder,Srivastava*et al*manufactured and assessed briquettes using four different types of VMW. According to the findings, the price of briquettes, including the price of raw materials, varied between $24.68 and $28.90 per tonne. The study concluded that the briquetting of VMW may be a viable option for generating useful energy instead of being allowed to rot and cause environmental concerns because the cost is equivalent to the cost of wood that is available at the market rate (26).

Fig.2: Diagrammatically representation of the Process of Briquetting(27)

1) Collection of vegetable waste
2) Segregation of waste into different grades based on composition and size

3) Drying of waste material to appropriate moisture content
4) Size reduction
5) Briquetting (Formation of briquettes/ blocks using briquette press)



5.) POWER ALCOHOL

Despite the world's energy supply inevitably depleting, there is a growing global interest in alternative energy sources (28). In recent years, increased research and development efforts have been concentrated onthe commercial production of ethanol as the most promising renewable biofuel.Power alcohol is the mixture of ethyl alcohol and petrol in the ratio of 20:80 + a small quantity of Benzene. Ethyl alcohol is the main component of Power alcohol and its main advantage is that it can also be prepared from agricultural waste. Power Alcohol has high octane number which possesses better antiknock properties and the ability to burn completely.Therefore, many countries have initiated, or are in the midst of implementingprograms that allow ethanol to be added to petrol. Fuel ethanol production has expanded dramatically as a result of the global need to cut oil imports, helping to enhance rural economies and improve air quality. The world ethyl alcohol production has reached approximately 27.34 billion gallonsin 2022, whereas the USA and Brazil are the main producers i.e., 82 % of total production. The raw materials used for the manufacture of the power alcohol or ethyl alcohol are saccharine materials (such as sugarcane, and molasses), starchy materials (potatoes, cereal grain, etc.) and cellulose materials. While potato consumption has declined, processed items such as French fries, chips, and puree have grown in popularity. Potato peeling losses range from 15% to 40%, depending on the process used, *i.e.* steam, abrasion, or lye peeling. The PPW has enough starch, cellulose, hemicellulose, lignin, and fermentable sugars to be used as an ethanol feedstock. Although starch is a high-yielding feedstock for ethanol production, hydrolysis is necessary to make ethanol through fermentation.Previously, acids were used to hydrolyze starch, but due to the specificity of the enzymes, their inherent mild reaction conditions, and the absence of side reactions, amylases are now widely used as catalysts in this process. Starch processing is a method that uses enzymatic liquefaction and saccharification to produce a relatively clean glucose stream that is digested to ethanol by Saccharomyces yeasts. Enzymes have several advantages over acidic hydrolysis since they act under mild circumstances, are biodegradable, improve yields, and reduce energy, water consumption, and by-products (29). The technique for using enzymes to produce bio-ethanol from starch consists of two stages: liquefaction and saccharification. In liquefaction, -amylase, which is derived from thermo-resistantbacteria such as *Bacillus* *licheniformis* or modified strains of *Escherichia coli* or *i*, is used to reduce slurry viscosity or create dextrins. Enzymes in saccharification employ dextrins to produce glucose(30).

The procedure of making ethyl alcohol from vegetable peelings (Potato)

i. The potato skins are removed
ii. The potato peels are carefully washed, dried outside in the sun, then processed in a food processor. The obtained powder was kept in airtight containers.
iii. The powder is mixed with distilled water and cooked in an autoclave for a while.
iv. The mixture is well mixed in the stirrer
v. With the addition of the yeast, the substance undergoes additional fermentation.
vi. Following fermentation, distillation was done at a temperature of about 70 degrees Celsius to speed up ethanol evaporation.
vii. Ethanol is produced after distillation.

6.) COMPOST

It is the oldest way of stabilising organic waste and is a natural process of rotting or breakdown of organic matter by aerobic and anaerobic bacteria. Organic material that contains humic substrate and has been composted and used as a fertilizer and soil amendment is referred to as compost (31). It is a helpful tool for farmers who practise organic farming. In addition to N, P, and K, it also includes micronutrients like Fe, Cu, Zn, and Mn. By 2025, there would be a requirement for 10 MMT of organic and bio-fertilizer in addition to 35 MMT of chemical fertilizer, according to the Ministry of Urban Development Department of the Government of India. Only 6–7 MMT of NPK nutrients can now be produced in the nation. As a result, there will be a huge discrepancy between supply and demand. This gap can be closed by producing usable manure from the organic waste generated by all cities (32).

Benefits of composting

- Reduce the volume of waste and the need for chemical fertilizer
- Promotes higher yield of the crop and generates additional revenue
- Kill pathogen and weed seed
- Facilitates reforestation and habitat revitalization by amending contaminated, compacted and marginal soil
- Reduce pollution
- Provide at least 50% cost savings over conventional soil, water and air pollution technologies.

7.) VERMICOMPOSTING

Vermicomposting is a practical waste management method. The stabilization of waste organic matter through the cooperative activity of earthworm microorganisms has recently been developed as vermicomposting of food wastes for the generation of bio-fertilizers. Vermicompost is compost that has been created with the aid of earthworms(33). Earthworms eat biomass and expel it as wormcast, which is the digested form. It is a stable, fine-grained organic manure that enhances the physiochemical and biological qualities of the soil. For better vermicomposting, the material should have amoisture of 60-70%, aeration-50%, pH-6.5-7.5 and a temperature of 18-35 ^{0} C. It contains N-(1.2-1.6%), P-(1-1.2%) and K-(0.5-0.75%).When it comes to nutrient availability in soil, the finished product (vermicompost) has greater qualities than traditional compost. Its application improves mycorrhizal symbiotic relationships with the roots and legume nodulation. One could draw the conclusion that vermicomposting is better suited than composting for the creation of soil fertilizers since it can effectively reduce bacterial pathogenic load (34).

8.) BIOACTIVE SUBSTANCES

Fruits and vegetables are the simplest forms of functional foods, due to their high content of bioactive components and non-nutrient secondary metabolites such as phenolic compounds, terpenes, fatty acids, dietary fiber, saponins and phytoestrogens. Both their structural parts (stems, leaves, peels, pulps, seeds, shells, brans and roots) and the residues remaining after the extraction of juice, oil, starch and sugar contain these compounds in large quantities (35).

Phenolic compounds

Phenolic compounds derived from vegetable waste have many uses, including food functionalization, use as natural antioxidants in the personal care and cosmetics industries, dietary supplements or nutraceuticals with health advantages, and the pharmaceutical sector. Brassica vegetables (broccoli, cabbage, cauliflower, etc.) and their by-products are the principal sources of glucosinolates and isothiocyanates, which are produced during their breakdown. These substances have been linked to the reduction of cardiovascular illnesses and their anti-cancer properties, particularly against lung, bladder, and colon cancer. Capsaicinoids are reported in pepper by-product. The main capsaicinoids present in pepper wastes are capsaicin and dihydrocapsaicin. They exhibit quite potent antiproliferative and antioxidant properties. Capsaicin has also been extensively researched for its potential to relieve neurological pain. Capsaicin has actually received FDA and EU approval as a medication for the topical management of neuropathic pain.

Dietary fibres

Vegetable waste is also an excellent feedstock for the recovery of nutritional fiber. The word "dietary fiber" refers to a complex combination of non-digestible polysaccharides, waxes, and lignin present in plant-based foods. Insoluble fibres include cellulose, hemicellulose, and lignin, whereas soluble fibers include pectins, -glucans, fructans, and arabinoxylans (36).

Advantages

Insolublefiber improves laxation and promotes the growth of intestinal microflora, whereas soluble fiber helps to lower blood cholesterol and regulate blood glucose levels (37). In the agri-food industry, pectin has been traditionally used as a gelling and thickening agent, and as a stabilizer of fruit juices. However, in recent years pectin has been used in innovative applications such as fat replacer agent through encapsulation or as a carrier molecule for antimicrobial and/or antioxidant compounds in edible packages Citrus peel and sugar beet pulp are the main sources for the recovery and production of commercial pectin.

Pigments

Tomato peel has a high concentration of carotenoids, including lycopene (38). It aids in the treatment of coronary heart disease and cancer. Carrot pomace is similarly high in carotenoids. Beetroot root peel contains excellent water-soluble nitrogenous pigments known as betalains, which are divided into two groups: red betacyanins and yellow betaxanthins. They are free radical scavengers that protect biological molecules from being oxidized by active oxygen and free radicals. In the current food sector, betalains are employed as natural colourants (39).

Food Additives

Synthetic antioxidants such as butylatedhydroxyanisole (BHA) and butylatedhydroxytoluene (BHT) have long been employed as antioxidant additives in the food industry to protect and stabilize the freshness, nutritional value, flavour, and colour of foods. However, BHT has the potential to be hazardous, particularly at large dosages. As a result, interest in replacing synthetic dietary antioxidants with natural ones has grown in recent years. Carrot pomace may be utilized in bread cake, dressing, and pickles, as well as functional beverages (40)and onion pomace in snacks.

Methods of extraction of Bioactive substances

The extraction process for these chemicals is determined by various aspects, including the technique used, the raw material, and the organic solvent. Conventional processes often require significant amounts of organic solvents, a lot of energy, and a lot of time, which has stimulated interest in emerging technologies known as green technologies. These can help to reduce or eliminate the usage of harmful solvents, preserving the natural environment and its resources. Soxhlet, maceration, and hydro-distillation are the main conventional extraction techniques for bioactive chemicals, however green technology includes pulsed electric field, microwave-assisted extraction, high hydrostatic pressure, and solid-state fermentation. A brief explanation of the above-mentioned techniques is given below.

Soxhlet technique

In this technique, asmall quantity of dry sample is placed on the equipment through which the solvent travels. The procedure is repeated until the extraction is complete. However, this approach necessitates a lengthy extraction time as well as a substantial volume of solvent. (41)

Maceration

It involves chopping the sample into smaller particles in order to enhance the surface area for a desirable solvent mixture. The agitation in the maceration process facilitates extraction in two ways: it increases diffusion and removes the concentrated solution from the sample's surface. This method has long been used to extract essential oils and bioactive substances. (42)

Hydro-distillation

It is used to extract the volatile fraction and is accomplished with distilled water. This process typically takes 6-8 hours and does not use organic solvents. This method employs three major physicochemical processes: hydro-diffusion, hydrolysis, and heat breakdown. High temperatures during extraction can damage chemicals, limiting their application.Hydro-distillation is a comprehensive method in which volatile and non-volatile organic molecules can be extracted and physically separated in a single stage. The volatile organic components are removed from the matrix by azeotropic distillation; they are then condensed, collected, and separated in a Florentine flask. Boiling water in contact with the matrix inside the alembic extracts the soluble non-volatile organic molecules. However, hydro-distillation requires sufficiently high levels of energy and is time-consuming. (43)

Pulsed electric field (PEF)

The idea behind pulsed electric field extraction is to cause electroporation of the cell membrane, which increases extraction yield. An electric potential travel through the cell membrane, separating molecules based on their charge. This repulsion causes pores to develop, enhancing permeability. PEF is a useful method for economically and sustainably recovering important compounds from various fruit and vegetable tissues, owing to its capacity to soften and rupture cell membranes, enabling the release of intracellular molecules(44). Vallverdú-Queralt*et al.,* (45)extracted bioactive compounds from tomato juice by this method by applying 5-30 pulses of the electric field with a strength of (0.4–2 kV/cm).

Microwave-assisted extraction (MAE)

Microwaves are electromagnetic fields with perpendicular oscillating fields, such as electric and magnetic field frequencies, that span from 300 MHz to 300 GHz. The solvent diffuses into the solid matrix and dissolves the solute to a concentration restricted by the solid's properties.Microwaves are a non-contact heat source that can provide more efficient heating by increasing energy transfer and decreasing temperature gradient. This approach can efficiently separate several kinds of chemicals, including essential oils, antioxidants, pigments, flavourings, and other organic compounds (46).A domestic microwave oven, which can operate at a maximum input power of 850W at a frequency of 2450MHz was used by Hiranvarachat and Devahastin, (47) to extract bioactive compounds from carrot peels.

High hydrostatic pressure (HHP)

It evolved as an alternative to thermal methods in order to get microbiologically safe food products while avoiding undesired changes in food sensory, physicochemical, and nutritional qualities. This technique runs at pressures ranging from 100 to 1,000 MPa (48). Strati, Gogou, &Oreopoulou, (49) extracted lycopene pigment and other volatile compounds from tomato peels by setting a pressure range of 100–800 MPa for 1–30 min. Temperature prior to pressurization was 25°C and was elevated during compression, due to adiabatic heating, approximately 3°C/100 MPa.

Solid-state fermentation(SSF)

Fermentation using different microorganisms is another technique for the extraction of various enzymes and bioactive compounds. Among existing technologies in the fermentation industry, solid-state fermentation (SSF) shows many advantages over fermentation in submerged culture, such as lower cost and much lower reactor volumes. Additionally, this cultivation technique permits the use of different agricultural and agro-industrial residues as substrates Different enzymes and some other products extracted from vegetable waste are given in the table below.

Enzyme	**Substrate**	**Microorganism used**	**References**
	Cabbage waste	*Pseudomonas spp.*	(50)

Amylase	Cassava waste	*Bacillus spp.*	(51)
	Potato peel	*Bacillus subtilis*	(52)
Cellulase	Cabbage waste	*Pseudomonas spp.*	(50)
Laccase	Potato peeling	*Trametes hirsute*	(53)
Xylanase	Melon peel	*Trichodermaharzianum*	(54)
	Watermelon rind	*Trichoderma spp.*	(55)
	Tomato waste	*Aspergillusawamori*	(56)

Table 1: Some enzymes extracted from Vegetable Waste

Product	**Substrate**	**Microorganism used**	**References**
Isoamyl acetate	Carrot pomace	*Ceratocystisfimbriata*	(57)
Vanillin	Carrot pomace	*Pycnoporuscinnabarius*	(6)
Vanillin	Sugar beet pulp	*Aspergillusniger*	(6)
Organic acids			
Citric acid	Cassava bagasse	*Aspergillusniger*	(58)
Lactic acid	Green pea and potato peel	*Lactobacillus plantarum*	(59)

Table 2: Some other Products Developed from Vegetable Waste

9.) EXOPOLYSACCHARIDES

These are biopolymers synthesized extracellularly or secreted into the extracellular medium by the microorganism during its growth. Their synthesis is generally favoured by the presence of a carbon source in excess, associated with limitation by another nutrient (e.g., nitrogen or oxygen) (60).Depending on their structure and composition, they can be divided into two groups: homopolysaccharides and heteropolysaccharides. Homopolysaccharides consist of identical monosaccharide units (D-glucose or D-fructose) and can also be divided into two major groups: glucans and fructans. Heteropolysaccharides are formed mainly by glucose, galactose and rhamnose, in different ratios (61). However, their production becomes quite expensive since the preferred substrates in the industrial production of these biopolymers are glucose and sucrose. The utilization of fruit and vegetable waste as a carbon source is an interesting alternative to reduce the production costs of microbial exopolysaccharides. The optimization of the cultivation conditions (temperature, pH, aeration, micronutrients, etc.) and selection of the different strains responsible to produce these polysaccharides and adequate downstream processing, such as the separation processes are very demanding to improve the exopolysaccharide yields and quality. (62)

Xanthan was the first biopolymer to be approved by the Food and Drug Authority (FDA) as a food additive in 1969 and since then, the demand for xanthan gum produced from *Xanthomonascampestris* has progressively increased, at an annual rate of 5–10% (63). It is used as gelling, thickener, stabilizer and suspending agent in creams, fruit juices, and sauces, as well as in syrups, ice cream and dessert coverings. It is also used in oil drilling, pharmaceutical products, cosmetics, paints (ceramic glazes), textile printing, pastes and slurries, explosive formulations, rust removers and agricultural products (as stabilizing agent for herbicides, pesticides and fertilizers.

Pullulanis another interesting biodegradable exopolysaccharide obtained from the fermentation medium of yeasts like fungus *Aureobasidiumpullulans*(64). In the food industry, pullulan is used in food coatings and can be molded in edible, biodegradable and oxygen-impermeable films. Pullulan also has medical and pharmaceutical applications such as drug delivery, gene delivery, plasma expander, tissue engineering, wound healing, vaccinations and capsule coating. (65)

10.) BIOPLASTIC

Bio-plastic refers to polymers manufactured from renewable biomass sources such as maize starch, potato starch, cassava starch, vegetable oil, and so on. Bio-plastics are plastic materials that are either bio-based, biodegradable, or have both qualities. Biodegradable medical implants, computer and mobile phone casings, foil, moulds, tins, cups, bottles, and packaging devices are only a few of the uses. There are no substantial disparities in the cost scales since the rapidly growing price of crude oil will compensate for the variances in production costs in the future.

Advantages of Bioplastic

i.) Reduced use of fossil fuel resources
ii) Environmentally friendly
iii.) Biodegradable
iv.) Recycled
v.) Non-toxic

Types of Bioplastic

Starch-based polymersaccount for almost half of the bioplastics industry, with thermoplastic starch being the most extensively used bioplastic. As pure starch absorbs humidity, flexibiliser and plasticizers such as sorbitol and glycerine are added so that the starch may also be treated thermoplastically.

Cellulose bioplastics**: -** Plastics derived from cellulose are primarily composed of cellulose esters (cellulose acetate and nitrocellulose) and their derivatives, such as celluloid. These types of cellulose can be found in plant materials such as forestry leftovers and agricultural by-products**.**

The aliphatic polyester plasticsPolyhydroxyalkanoates (PHA), poly-3-hydroxybutyrate (PHB), and polylactic acid bioplastic (PLA) are the most common aliphatic polyester plaster. Sugarcane and sugar beetroot are used as feedstock.

Bioplastic now accounts for roughly 1% of overall output out of 368 million tonnes of total plastic; however, the bioplastic industry is expanding rapidly and will reach 4.7 million tonnes by 2025.

CHALLENGES IN VEGETABLE WASTE MANAGEMENT

The Ministry of Environment, Forests, and Climate Change oversees waste management in India. However, most urban local governments lack suitable action plans for implementation. Unfortunately, no city in India can claim to have 100% trash segregation at dwelling units, and on average, only 70% of garbage is collected, with the other 30% being mixed up and lost in the urban environment. Only 12.45% of total garbage collected is scientifically handled, with the remainder disposed of in open landfills (66). An efficient waste management system must be environmentally friendly, cost-effective, and acceptable to the local population. The following are the major waste management challenges: -

- Absence of segregation and characterization of waste at the source
- Dearth of awareness
- Lack of technical expertise and appropriate institutional arrangement
- Lack of public involvement in waste management and sanitary conditions
- Indifferent attitude of citizens toward waste management
- Lack of Regulation at ground level
- Lack of funds for processing

CONCLUSION

In today's world, waste management is the most serious issue. Due to the worldwide increase of food production, there has recently been significant societal and environmental demand for the effective use of vegetable and fruit waste. The massive waste of food is caused by a lack of oversight over such agri-economy practices. Converting vegetable wastes into bioenergy and by-products can produce cash from food processing waste. Vegetable wastes are abundant in vitamins and minerals, making them ideal raw materials to produce high-value compounds or metabolites. So, the strategies stated above are some of the productive approaches for using and managing vegetable waste in industrial and residential settings.

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