Chapter

Sustainable Horticultural Waste Management: Industrial and Environmental Perspective

Jahidul Hassan, Md. Noor-E-Azam Khan, Md. Mijanur Rahman Rajib, Maksuratun Nahar Suborna, Jiasmin Akter and Md. Faisal Ahamed Hasan

Abstract

Horticultural crops are highly nutritious and shared lion portion of our daily diet. These items are consumed in different ways according to their nature and processing processes. These days, a crucial concerning issue is arising globally to ensure nutrition security for huge population that leads to focus on production increase, quality improvement, food safety assurance, and processing strategies. Consequently, a large amount of waste generates in the processing industries, household kitchen, and supply chain of horticultural commodities that has led to a significant nutrition and economic loss, consequently creating environment pollution with extensive burden of landfills. However, these wastes showed magnificent potentiality of re-utilization in several industries owing to as rich source of different bioactive compounds and phytochemicals. Therefore, sustainable extraction methods and utilization strategies deserve the extensive investigations. This review paper extensively illustrates the horticultural waste generation options, sustainable recycling strategies, and potentiality of recycled products in different industries for betterment in population with the assurance of green environment and sustainable ecology.

Keywords: horticultural waste, management, sustainable, environment, bioactive compounds, pectin

1. Introduction

Nowadays, the horticultural field is exploring with its various utilization. An ever-demanding market is going on with its various options. Vast cultivation in field level with fabulous export potential makes the horticultural product market more outstanding. The global horticultural market value about 20.77 billion USD was estimated in 2021 and targeted to 40.24 billion USD till 2026 [1]. From the kitchen to processing industry, the uses of horticultural product are remarkable today. With its flexibility of uses, problems also arise with various means. The by-products or wastes in horticultural point of view is getting worst day by day for lack of proper utilization not taken. Both developing and developed countries such as Bangladesh, Cambodia, India, Indonesia, Malaysia, Philippines, Thailand, and Vietnam are suffering from various environmental pollutions in concern with water, soil, and air pollution. The increasing trend of population is found to be the major cause of waste generation [2]. Increased population make wastes more usual in homestead generally produced by unnecessarily.

From the production of horticultural foods, various factors involve for the hazardous environmental appearance. Uncontrolled uses of pesticide and residual effects of various chemicals initiate the primary threats to nature by creating bad impact on the wildlife, soil, human, and animal communities [3]. Sometimes these chemicals (about 5–15%) that introduced in the global market for field management are counterfeit in nature [4]. The food wastes evolved in kitchen is noteworthy in many countries such as China, containing solid food wastes between 88% and 94% [5]. Processing industries greatly influence the environment pollution as so many by-products discarded to the environment from this sector while these by-products contain some high quantities of phytochemicals that can be reusable enough for the better disposal [6]. Massive climate issues arise from the undisposed waste available in the environment [7]. Greenhouse gases increases are also introduced in nature by the inappropriate waste disposal method. So, proper and alternative process of waste disposal is compulsory for economic viability and environmental stability.

Increasing the recycling and developing various disposal methods can ensure the proper mitigation of environmental pollution. The industrial and various sources of horticultural wastes are getting importance for its valuable compositions. Recycling can develop the new opportunities with commercial benefits. Biofuels, enzymes, vitamins, antioxidants, and various important chemicals are manufactured from the industrial wastes today. Waste to wealth can be the modern thought of waste disposal. The management of these wastes can be supervised by the government with its regular monitoring, because the waste disposal with its economic benefits can bring the sustainability for both environment and industrial concern [8].

2. Nature and generation of horticultural waste

The affluence of horticulture in industrial and environmental perspective is greatly significant today. Whereas there are some phenomena arising day by day with management and utilization of horticultural wastes. The nature of wastes in horticultural end is multidisciplinary. Some create chemical hazard; some are alarming for their biological and thermal point of view also. Postharvest handling and storage occur about 54% of wastes that is upstream, while 46% happens "downstream," at the processing, distribution, and consumption stages [9]. These wastes disposal is our major concern in case of sustainable waste management.

2.1. Wastes evolving during horticultural production chain

The pragmatic scenario of waste evolving is associated with the increasing of population. With higher population, increasing rate demands the higher agricultural produce. In other words, more food demand may arise with the population increasing rate.

Agricultural production nowadays is more than three times than the last five decades [10]. With technological advancement, the productivity may increase in horticultural sectors also. On the contrary with the increasing productivity, it generates the higher quantities of wastes also. Some of them are green wastes, and some are recyclable solid wastes.

2.1.1. Farming activity in horticultural production system

Mainly this sector may generate waste most in quantities. The whole process demands lots of intercultural operations such as training, pruning, thinning, earthing up, etc., of various fruits and vegetables can provide some wastes. For example, leaf residues, debris, dead leaves. However, these wastes sometimes added the additional organic matter in the soil. But if the maintenance is not sound enough in horticultural production chain, then the waste becomes burden for the environment. If we enlighten on the data (**Table 1**) given by Gmada et al. in 2019, according to their own supervision in the farm of Almeria, there are high amount of wastes distribution in various horticultural production systems. Greenhouses have the higher wastes in 39,215 ton out of 90,738 tons of total wastes, which is 43% of the total waste. Another approach of waste getting is disinfection having the second highest waste getting percentage that is 23%. So, there are different steps and period of waste getting and without waste management of horticultural products we the environment will be depleted day by day at the negative manner.

2.1.2. Chemical wastes during cultivation

These wastes are generated from the continuous use of pesticides, insecticides, and herbicides during the cultivation. These are mainly solid wastes such as pesticides containers, bottles. The activities of using these types of chemicals in developing countries are mostly handled by the rural uneducated farmers. So, the disposal of these types of solid wastes usually gets ignorance by the farmers or the users. Such types of ignorance result in the degraded mode of the environmental balance. About 2% of pesticides usually remain unused in the containers, and then the disposal of these hazardous material is done by the throwing these into the nearest ponds or on the open field condition; the ultimate environmental issues may arise by this as food poisoning, water pollution, air pollution, etc., by this type of ignorance [12].

Function	Weight		Volume	
	t	%	m^3	%
Greenhouses	39,215	43	49,798	27
Substrates	1219	1	1598	1
Water storage	576	1	730	0
Disinfection	21,061	23	24,066	13
Shading	10	0	10	0
Transplanting	698	1	40,714	22
Tunnels	2259	2	2429	1
Padding	4900	5	5065	3
Supporting system	6448	7	4891	3
Irrigation	4967	5	20,760	11
Plant protection	4034	4	17,333	9
Pollination	2469	3	26	0
Harvesting	2883	3	19,630	13
Total	90,738	100	187,050	100

Table 1.
Annual distribution of waste according to their function of Almeria [11].

2.1.3. Postharvest wastes

Postharvest food loss is any loss in physical weight, edibility, nutritional quality, caloric value, consumer adequacy happens between the period of reap and the time it reaches the consumer, while food waste is a subset of the food losses [13], and this might occur through human activity or inaction such as discarding produce, not consuming accessible food before its expiry date, or taking serving sizes beyond one's ability to consume [14]. Horticultural crops are highly perishable products. As it is perishable so that handling and the maintenance are really tough. For this kind of phenomena, the developing countries are the real sufferers of this type of problems. Postharvest loss and wastes of perishable commodities in horticulture are up to 60% depending on the seasons, commodity, and the region of production [15]. So, the wastes after harvesting threaten the sustainable environmental security with environmental pollution. Postharvest loss is not the issue of reduction of food availability for the consumers; it may cause negative externalities to the societies with the increasing cost effect of waste management, greenhouse gas production, and loss of scarce resources used in production [16].

2.1.4. Unconsumed waste foods and kitchen waste

One part of the world's population is struggling every day with the hunger and scarcity of food, whereas in some parts of the world, people waste food without thinking about the food security. Horticultural foods such as vegetables, fruits, and grain crops are wasted daily in our home and appear as the kitchen wastes. In

Biowaste	Bioactive compounds
Avocado peel and seed	Phenols, carotenoids
Tomato peel	Flavonols, phenolic acid, flanones, carotenoids
Banana peel	Phenols, carotenoids, flavonols, flavonoids
Mango peel and seed	Phenolic acids, flavonoids, flavonols, gallotanins, carotenoids, bioactive lipids
Pineapple by products	Phenols, cinnamic acid, amino acids, proteins
Citrus peel and seed	Flavonones
Pomegranate peel and seed	Bioactive lipids, anthocyanins, ascorbic acid
Orange peel	Phenolic acids
Watermelon peel	Anthocyanins
Apple peel	Flavonoids and anthocyanin
Papaya peel	Carotenoids, amino acids, proteins
Apple pomace	Flavonoid and anthocyanin
Carrot pomace	Carotenoids
Onion waste	Quercetin
Red beet waste	Betalins
Potato peel	Phenolic acids
Tomato peel	Lycopene

Table 2.
Bioactive compounds identified in different fruits and vegetables [19, 20].

America, horticultural wastages consist of fruits nearly 20%, vegetables 30%, others 25% [17]. General estimation of food waste annually is about trillion US dollars [18]. The whole world scenario is also alarming in this concern.

2.1.5. Industrial horticultural wastes

There are lots of food processing industries. These industries use some hazardous materials for food processing such as coloring agents, dyes, by-products such as banana peels, coconut husks, and other extraneous bioactive compounds phenols, flavonoids, flavanols, anthocyanins always evolved in the processing industries as by-products (**Table 2**). Heavy and rapid disposal is required for this kind of wastes. If it is not disposed with the time, then it will appear as a biggest threat for human survival and environmental balance. Higher emissions of pollutant make the environment more vulnerable. So, without utilizing these types of compounds it can be delectable enough to make our environment polluted.

3. Horticultural wastes as environmental concern

Environment day by day is threatened with the undisposed wastes derived from various sources of horticultural sectors, from both farming and industrial perspective. Air, water, and soil are major three components of the environment that get affected by the pollutants derived from the horticultural wastes.

3.1. Impact of waste on air quality

Sometimes, we disposed some waste with the burning. But these types of waste management are not fruitful always as burning of crop stubbles possesses some hazardous emissions of many harmful gaseous components. As a result, the atmosphere represents monoxide, nitrogen oxide, nitrogen dioxide, sulfur dioxide, methane associated with other toxic hydrocarbons. These types of dangerous gases and particulate matters make a negative impact on air and are harmful for both human and animal health (**Table 3**) [21–23].

Besides burning of crop stubbles, nitrous oxide is derived from microbial processes in cultivated soil and manures. Machineries used in crop cultivation require

Category	Pollutants[x]	Source
Particulates	SPM (PM100)	Incomplete combustion of in organic material, particle on burnt soil
	RPM (PM10) FPM (PM25)	Condensation after combustion of gases and incomplete combustion of organic matter
Gases	CO	Incomplete combustion of organic matter
	NO_2 and N_2O	Oxidation of N2 in air at high temperature
	O_3	Secondary pollutant, form due to Nitrogen Oxide and Hydrocarbon
	CH_4/Benzene PAH5	Incomplete combustion of organic matter Incomplete combustion of organic matter

[x]*SPM small particulate matter, PM particulate matter; FPM fine particulate matter.*

Table 3.
Major air pollutants emitted during crop residue burning [24].

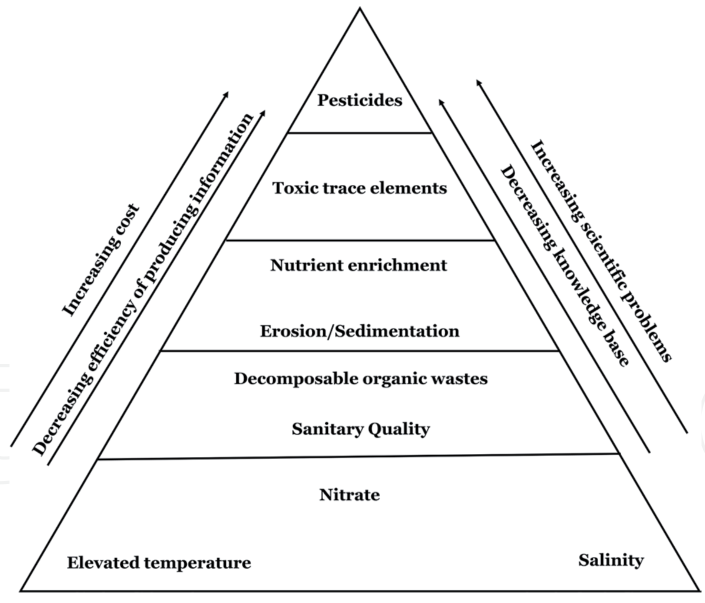

Figure 1.
Water pollution pyramid [25].

	Impacts	
Farm activities	**surface water**	**Groundwater**
Tillage/plowing	Sediment/turbidity: sediments carry phosphorus and pesticides adsorbed to sediment particles; siltation of river beds and loss of habitat, spawning ground, etc.	
Fertilizing	Runoff of nutrients, especially phosphorus, leading to eutrophication causing taste and odor in public water supply, excess algae growth leading to deoxygenation of water and fish kills.	Leaching of nitrate to groundwater; excessive levels are a threat to public health
Manure spreading	Carried out as a fertilizer activity; spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen, leading to eutrophication and potential contamination	Contamination of groundwater, especially by nitrogen.
Pesticides	Runoff of pesticides leads to contamination of surface water and biota; dysfunction of ecological system in surface waters by loss of top predators due to growth inhibition and reproductive failure; public health impacts from eating contaminated fish. Pesticides are carried as dust by wind over very long distances and contaminate aquatic systems thousands of miles away (e.g. tropical/subtropical pesticides found in Arctic mammals).	Some pesticides may leach into groundwater causing human health problems from contaminated wells.
Feedlots/animal corrals	Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also, contamination by metals contained in urine and feces.	Potential leaching of nitrogen, metals, etc. to groundwater
Irrigation	Runoff of salts leading to salinization of surface waters; runoff of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts	Enrichment of groundwater with salts, nutrients (especially nitrate).
Clear cutting	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; causes public health problems due to loss of potable water.	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; causes public health problems due to loss of potable water

Table 4.
Wastes effect in different horticultural operation on water pollution [27].

fuel combustion resulting in the rapid production of CO_2. The ultimate result of air pollution leads to the temperature rising, ecological disbalance, and degradable sustainability of the environment.

3.2. Water contamination through horticultural pollutants

Only the industrial solid wastes with heavy metals are not the headache for water contamination today. Agricultural wastes, more specifically the horticultural wastes within horticultural cultivation system and processing by-products, can hamper the water quality in various ways. Fertilizer and other pesticide chemicals are responsible for both ground and surface water contamination. Toxic trace elements make the essential nutrients unavailable, and beneficial soil-borne microorganisms become extinct. Water pollution pyramid (**Figure 1**) stated that groundwater use has become unsafe for the toxicity of the chemicals. Erosion, sedimentation, salinity are the typical after-effects of continuous cultivation system.

Only agricultural field makes the water polluted about 70% worldwide [26]. Besides, different intercultural operations have the major influence in water contamination (**Table 4**).

3.3. Impact on soil

Long-term fertilization and indecomposable plastics solid waste make the soil barren for the crop cultivation. Besides, some plant residues contain the toxic chemicals (secondary metabolites, volatile terpenes, phenolic compounds), which can suppress the growth and production of other crops. This type of phenomenon is addressed as crop-crop allelopathy. Postharvest residues are mainly the source of this kind of allelopathic effects [28].

4. Technique of horticultural waste management

Horticultural waste such as the peels, seeds, and other constituents of vegetables and fruits that contain high amount of phytochemical compounds and essential nutrients are used to produce different industrial products. It can be utilized to extract as well as obtain bioactive compounds that can be used in food, textile, and pharmaceutical industries as shown in **Figure 2**.

The techniques of horticultural wastes management consist of different applied strategies for different kinds of wastes. Generally chemical, biological, biofuels, and thermal strategies are followed throughout the world (**Table 5**).

4.1. Bioactive compound of agricultural waste

4.1.1. Pectin, starch, cellulose as biopolymers

From various by-products we find some starch, cellulose; where starch is a white granular, organic compound with soft, tasteless powdery appearance insoluble in cold water, alcohol or different solvents, and cellulose found by peeling of horticultural crops as it is available in primary cell wall of green plants [30] Amylose and amylopectin are the branched form of starch, whereas linear polymer is the simplest one [31] Starch nowadays is produced from banana peels, corn, pea, potato, cassava roots. Banana peels can be processed for bioplastic production and sometimes sodium metabisulfite used as antimicrobial agent, glycerol used for more flexibility. Degradation of bioplastics produced from starch starts after 3–4 months

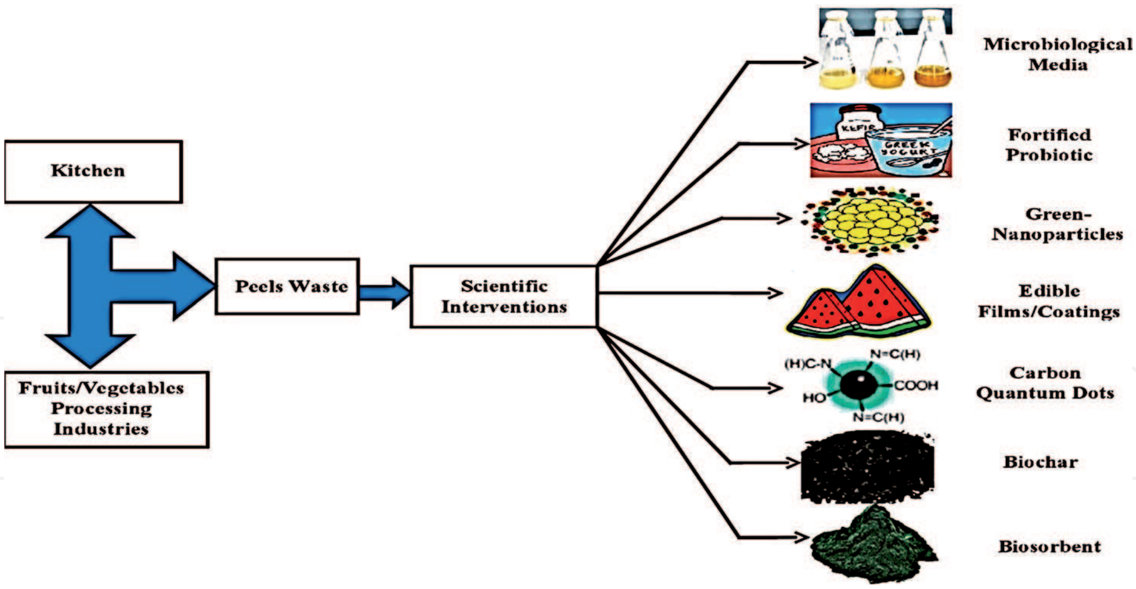

Figure 2.
Utilization of fruits and vegetable peel-based waste into novel industrial products [29].

Chemical	Biological	Biofuels	Thermal
• Starch, pectins, cellulose • Natural colorants Dietary nutrients or fiber • Bioactive compounds	• Animal feeding • Composting • Vermiculture • Substrate for microbial growth	• Bioethanol • Biogas	• Incineration • Pyrolysis

Table 5.
Strategies for horticultural wastes management [19].

date of production [32] By this, starch-producing strategies can give the commercial aspects for many emerging entrepreneurships. This is also nonhazardous for the environment because it is readily disposable after a short period of time. Not only banana but also cassava will completely be degraded on the ninth day after production of bioplastic [33] On the contrary, plastic materials are nondegradable products that can hamper the balance of the environment. Cellulose sometimes coverts into starch or glucose by decomposing called cellulolysis with the help of microbes such as *Trichoderma reesei* and *Aspergillus terreus*. Then it is used as a material for bioplastic production (**Table 6**) [34].

4.1.2. Utilization of wastes as coloring agent, dietary fiber, and prebiotic compounds

4.2. Biological approaches for wastes mitigation

4.2.1. Animal feed

Animal feed can be the good approach for productive waste disposal. That can provide manures, which influence reduction of synthetic fertilizer use tendency. Fermentation industries are established on the basis of wastes types (**Table 7**). This provides the ultimate economic outcome without creating the environment hazards in nature.

Food product	By-product	Formulation/Storage conditions	Dietary fiber/prebiotic compound	Optimal dosage (s)	Impact on senzorial characteristics	Other impacts
Cake	Potato peels	Powder (drying- > grinding)	Dietary fiber	5%	No major changes in the product were noticed, just more darkness color.	Increasing the strength and elasticity of the dough.
Donut	Carrot pomace	Powder (drying- > grinding- > sift)	Dietary fiber: pectin, lignin, cellulose, hemicellulose	6.45%	The sample showed a smaller volume. Consumers have suggested adding a glaze.	Significant impairment of physico- chemical properties.
Biscuits	Carrot pomace	Powder (whitening-grinding-sif)	Dietary fiber: pectin, lignin, cellulose, hemicellulose	10%	—	Neutralization of free radicals
Eriste (Turkish noodle)	Grapes, pomegranates, rosehips seeds	Powder (grinding- > sift)	Dietary fiber	10%	The sample enriched with pomegranate seed powder obtained the highest appreciations from a sensory point of view.	Increase in antioxidant activity.
Corn chips	Mango peels	Powder (freeze drying)	Dietary fiber	10–15%	Improving and maintaining the smell, texture, color and aroma.	Increasing the content of total phenolic compounds.
Ice cream	Red pitaya peels	Powder (grinding- > sift)	Dietary fiber: pectin, lignin, cellulose, hemicellulose	1%	Melting rate and color were not affected.	Improving rheological qualities and increasing nutritional value.
Ice cream	Grapefruit peels	Stem-shaped crystals	Nanofibril cellulose	0.4%	Texture improvement.	Reducing caloric intake.
Agitated type yogurt	Carrot pomace	Powder	Dietary fiber: pectin, lignin, cellulose, hemicellulose	1%	The color and smell of the sample were affected and strawberry flavor was added to improve them.	Reducing syneresis.
Chocolate	Grapes pomace	Powder (drying- > grinding- > sift)	Dietary fiber and prebiotic compound: lignin, cellulose, oligosaccha- ride	3–5%	At a higher dosage there is a slightly bitter taste due to phenols. The greatest impact on the product occurred in the particle size.	Water activity and stability increased.

DOI: http://dx.doi.org/10.5772/intechopen.101689

Food product	By-product	Formulation/Storage conditions	Dietary fiber/prebiotic compound	Optimal dosage (s)	Impact on senzorial characteristics	Other impacts
Instant drinks	Mango peels	Powder (bleaching- > drying with hot air)	Prebiotic compound	5 g/250 mL	During storage, the sensory characteristics decrease.	Improvement of phyto- chemical parameters and stability increases during storage.
Vienna sausages	Pineapple pomace	Powder (pressure steaming– + lyophilized or hot air dried)	Dietary fiber: lignin, cellulose, hemicellulose			The educing effect on nitrites, moisture, shear strength and shrinkage was obtained in sausages, while carotenoids and antioxidant polyphenols increased. Increased
Buffalo meat	Apple pomace	Powder	Dietary fiber: lignin, cellulose, hemicellulose	6%	The firmness increased, and the color became redder and darker.	Cooking efficiency, water retention capacity, pasta diameter.
Flour	Feijoa peels	Steam discoloration-rice bath- > drying in a convective oven- > grinding	Dietary fiber: lignin, cellulose, hemicellulose	—	—	Alternative source of bioactive ingredients.
Powder	Olive pomace	Liquid-enriched pomace powder (the liquid fraction was lyophilized and the solid fraction was dried)	Dietary fiber: pectin, lignin, cellulose, hemicellulose		—	Food preservative and source of mannitol.

Table 6.
Recent (last 5 years) report of utilization of fruits and vegetable wastes, dietary fibers, and prebiotic compounds in different food products [35].

Plant origin	Fermentation industry
Bran	Grain
Waste flour	Sugarcane industry (molasses, bagasse)
Wastes from grain-cleaning process	Potato distillers soluble
Wheat	Brewery waste
Corn	Bacteria and fungi biomass
Rye germs	Winemaking industry (grape pomace)
By-products of oil industry	Citrus by-products (molasses, citrus-activated sludge)
By-products of sugar and starch industry	Anthocyanins
By-products of fruit and vegetable industry	Effluents from biogas production
Plant by-products (husk and pods)	Dairy industry

Table 7.
Horticultural wastes were used in animal feed [19].

4.2.2. Composting for waste disposal

Compost is most demandable nutrient source in the crop field. This approach allows growers to spend less money for their initial cultivation inputs. Also, higher yield will be observed by using compost instead of synthetic fertilizer [36]. Different types of composting methods are used on the basis of grower's choice and wastes types (**Figure 3**).

4.2.3. Biofuels (bioethanol, biogas)

Waste can be disposed through converting the wastes and by-products into biofuels. Bioethanol and biogas production nowadays appears as the most sustainable waste management program, which has some significant economic values.

Bioethanol can be processed through horticultural by-products such as carrot peels, banana peels, and other crops parts, which previously can be dried in the sun. The product can be ground and sieved for further processing. After that, the products can be pretreated with 1 N NaOH for 2 hours. Then draining or in other words alkali subsequent washing can be done. Enzymatic hydrolysis by cellulase enzyme leads to saccharification. Then the inoculation of *Saccharomyces cerevisiae* is required. Then the fermentation and distillation are done for bioethanol production (**Figure 4**).

The other way for wastes disposal as the biofuel source is biogas production. Nowadays we can see the rapid adaptation of this disposal system in our rural areas also.

In case of biofuel products, horticultural by-products can be utilized in effective way. Different content of organic matters can yield the sufficient amount of methane gas (**Table 8**).

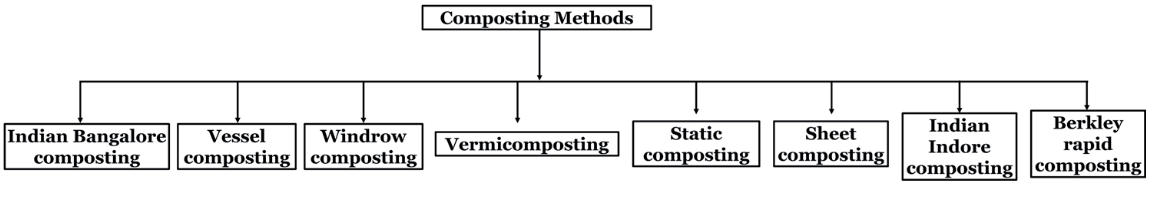

Figure 3.
Different composting methods [37].

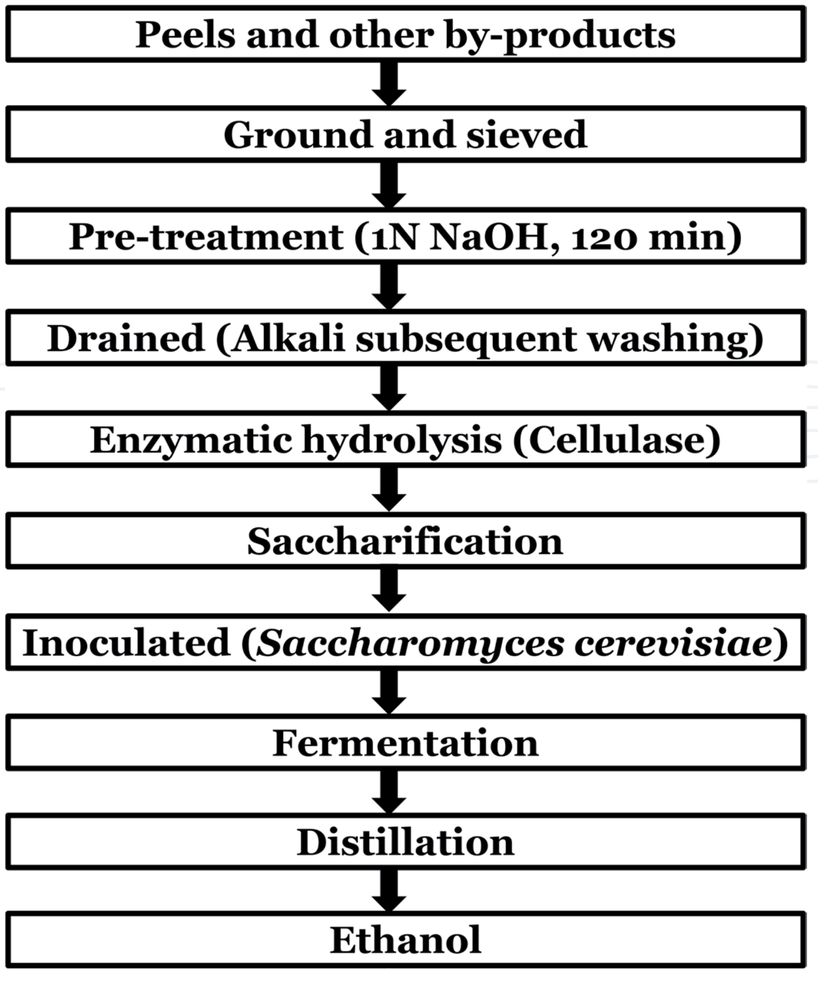

Figure 4.
Flow chart for bioethanol production by cellulase enzyme [38].

Substrate	Organic dry matter in %	Methane yield in Nm^3/t ODM
Banana peel	87–94	243,322
Citrus waste	89–97	433,732
Coriander waste	80–86	283,325
Mango peel	89–98	370–523
Oil palm fiber	94	183
EFB	79–84	200–400
Onion peels	88	400
Pine apple waste	93–95	355,357
Pomegranate	87–97	312–430
Sapot peels	96	244
Tomato waste	93–98	211–384
Water hyacinth	81	211–310
Coffee waste (pulp)		380 (biogas yield)

Table 8.
Biogas generation rate from the horticultural by-products [39].

5. Negative consequences of traditional disposal operations

5.1. Incineration

Combustion of wastes materials to achieve waste to energy is called incineration. High-temperature thermal treatment converts wastes into ash, flue gas, and heat. It requires localized combined heat and power facilities to encourage its heating process. Japan, Denmark, Singapore, and Netherlands follow this technique usually to dispose the wastes [40]. This method can reduce wastes up to 90%; but this is one type of waste reduction process rather than the disposal process as it is associated with the fire disaster and production of greenhouse gases [41]. Energy produced as coal could save about 2.26 MT of CO_2 eq/year [42].

5.2. Pyrolysis

Waste composition can determine the effectiveness of pyrolysis. It has several advantages comparing the incineration process. Lower temperature is preferable, and the plant for pyrolysis more flexible enough; product derived from pyrolysis can be converted through alternating the temperature and heating performance [43]. The pollutant emissions are lower in this disposal process as there is absence of oxygen and with low processing temperature, although emissions of other compounds simultaneously could increase with lower oxygen ratio [44]. Biochar production can be done by fruits and vegetable peels and other residues from, for example, spinach, bananas, peas, and tomatoes [45]. There are two types of pyrolysis, i.e., slow and fast. For biochar and gas production, slow pyrolysis is preferable, and bio-oil can be produced better in fast pyrolysis (**Figure 5**).

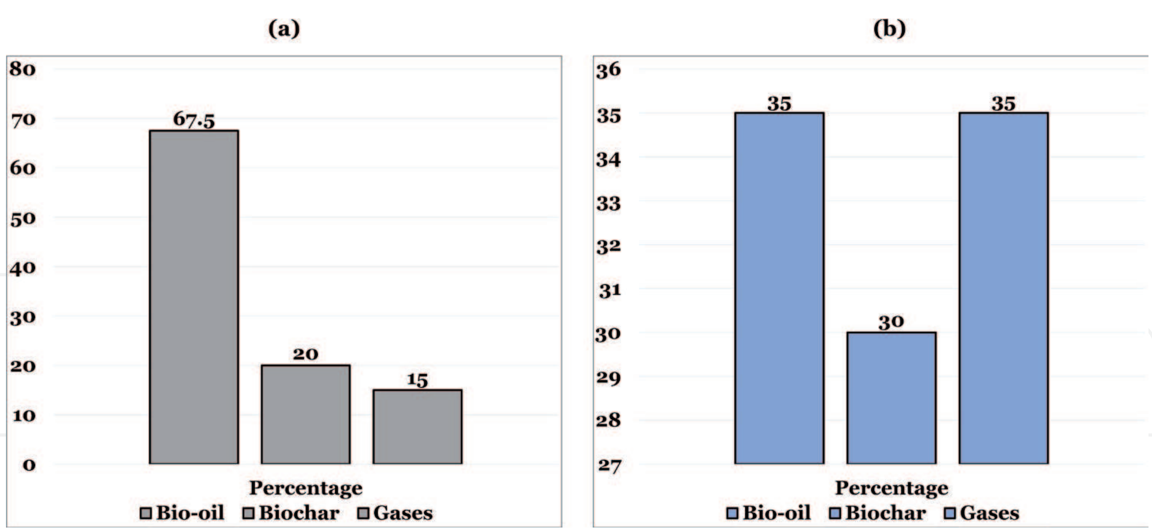

Figure 5.
Bar diagram of pyrolysis produced product. (a) Fast pyrolysis and (b) slow pyrolysis [46–47].

6. Prospects of horticultural waste management

It is obvious that waste disposal is not an easy task as it requires bigger margin of resources and right methods to minimize its after-effects. All the techniques or methods of repealing wastes are not efficient enough always. Food recovery hierarchy published by US EPA showed that there are different methods or approaches are proficient at different level. Landfilling and incineration (combustion of the waste materials) are the last resort of wastes disposal, because sometimes it is harmful for our environment. Soil pollution and abundance of toxic gases are visible by this kind of disposal system. Then the composting creates a nutrient-rich soil amendment. It requires specialized area away from the home, and it requires more time for disposal. Industrial uses of wastes are just above from the composting in that pyramid as it provides waste oils for rendering and duel conversion and food scraps for digestion to recover energy. Lots of commercial industries are developing today with the new hope with horticultural by-product establishing. Although some wastes also are considered developing the industries but commercial exposure may be spread rapidly. Main effective approach will be the source reduction and sometimes we waste food more than we consume so that extra food can be donated to food banks, shelters can reduce the possibility food wasting. Public awareness is the big thing for food waste management in horticultural sectors also (**Figure 6**).

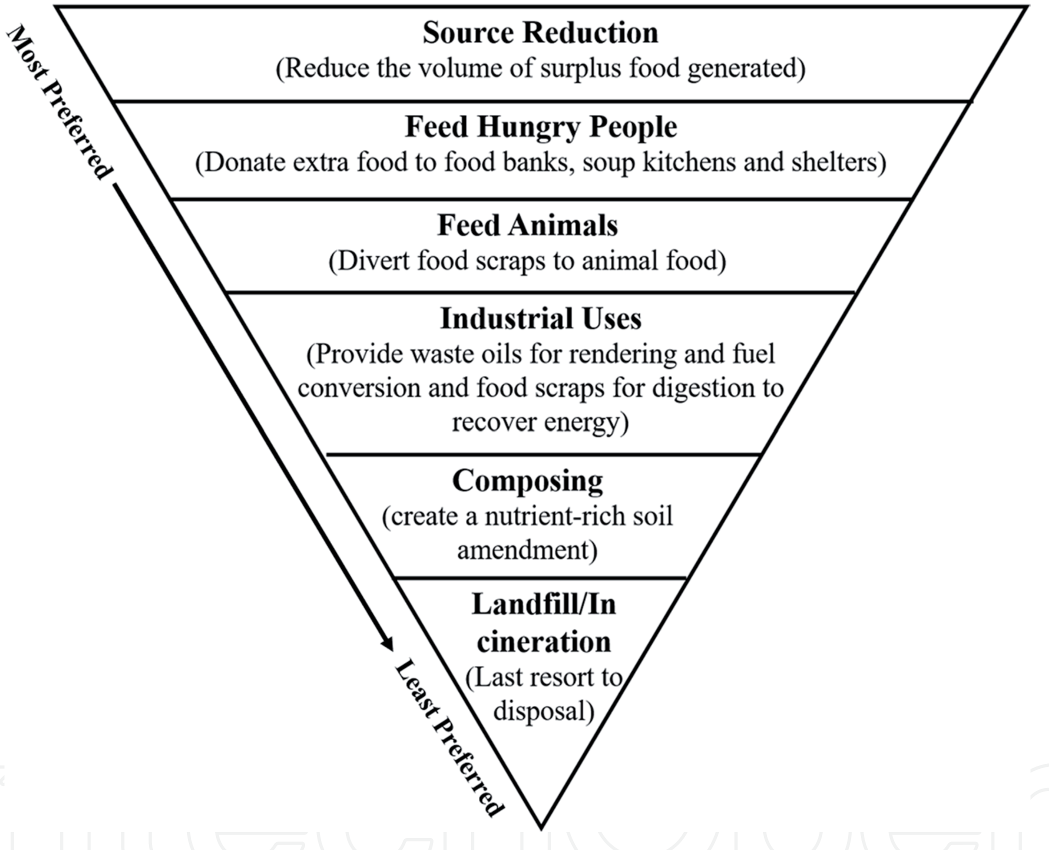

Figure 6.
Food recovery or management hierarchy [48].

7. Conclusion

Various environmental concerns and some economic benefits demand the appropriate disposal of horticultural wastes. Minimizing of wastes can maximize the environmental stability. However, people are not so aware about the impact of horticultural wastes. So, the proper awareness with the effective implementation of wastes is a crying need for today. Meanwhile, sustainability can be brought through adapting the modern disposal methods with longer effects and economic flexibility. In addition, the growth of the wastes disposal industries also gives the new dimension for the sustainable waste management. Finally, it can be enunciated that waste management provides green ecology, which can serve environmental stability with industrial prosperity.

Author details

Jahidul Hassan*, Md. Noor-E-Azam Khan, Md. Mijanur Rahman Rajib, Maksuratun Nahar Suborna, Jiasmin Akter and Md. Faisal Ahamed Hasan
Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

*Address all correspondence to: jhassan@bsmrau.edu.bd

References

[1] Global Market Estimates. (2021). Global Horticulture Market Analysis | Size & Forecasts. Global Market Estimates Research & Consultants. Retrieved November 1, 2021, from: https://www.globalmarketestimates.com/market-report/horticulture-market-3414

[2] Bhat RA, Nazir R, Ashraf S, Ali M, Bandh SA, Kamili AN. Municipal solid waste generation rates and its management at Yusmarg forest ecosystem, a tourist resort in Kashmir. Waste Management & Research. 2014;**32**(2):165-169

[3] Sánchez-Bayo F. Impacts of agricultural pesticides on terrestrial ecosystems. Ecological Impacts of Toxic Chemicals. 2011;**2011**:63-87

[4] UNICRI (2016) (United Nations Interregional Crime and Justice Research Institute, 2016) Illicit Pesticides, Organized Crime and Supply Chain Integrity. Retrieved from: http://www.unicri.it/in_focus/on/Illicit_ Pesticides. [Accessed: November 2, 2021]

[5] Li Y, Jin Y, Li J, Chen Y, Gong Y, Li Y, et al. Current situation and development of kitchen waste treatment in China. Procedia Environmental Sciences. 2016;**31**:40-49

[6] Rao RK. Agricultural, Allied Sciences & Biotechnology for Sustainability of Agriculture, Nutrition & Food Security. Mahima Research Foundation and Social Welfare, 194, Varanasi, UP, India: Karaundi, Banaras Hindu University; 2017

[7] Sadh PK, Duhan S, Duhan JS. Agro-industrial wastes and their utilization using solid state fermentation: A review. Bioresources and Bioprocessing. 2018;**5**(1):1-15

[8] Ahuja V, Macho M, Ewe D, et al. Biological and Pharmacological Potential of Xylitol: A Molecular Insight of Unique Metabolism. Foods. 2020;**9**(11):1592. DOI: 10.3390/foods9111592

[9] FAO. Food Waste Harms Climate, Water, Land and Biodiversity – New FAO Report. 2013. Available online at: http://www.fao.org/news/story/en/item/196220/icode/ [Accessed: August 13, 2021]

[10] Adejumo IO, Adebiyi OA. Agricultural solid wastes: Causes, effects, and effective management. In: Strategies of Sustainable Solid Waste Management. Rijeka: IntechOpen; 2020

[11] Sayadi-Gmada S, Rodríguez-Pleguezuelo CR, Rojas-Serrano F, Parra-López C, Parra-Gómez S, García-García MDC, et al. Inorganic waste management in greenhouse agriculture in almeria (SE Spain): Towards a circular system in intensive horticultural production. Sustainability. 2019;**11**(14):3782

[12] Dien BV, Vong VD. (2006). Analysis of pesticide compound residues in some water sources in the province of Gia Lai and DakLak. Vietnam Food Administrator

[13] Buzby JC, Jeffrey H. Total and per capita value of food loss in the United States. Food Policy. 2011;**37**:561-570

[14] Aulakh J, Regmi A. Post-harvest Food Losses Estimation - Development of Consistent Methodology. In: Paper presented at the Agricultural & Applied Economics Associations 2013. Washington DC, USA: AAEA & CAES Joint Annual Meeting, Purdue University, 4-6 August 2013. 2013

[15] Yahia EM (Ed.). Postharvest Technology of Perishable Horticultural Commodities. Woodhead Publishing, Elsevier, 2019. pp. 43-69. ISBN: 9780128132760

[16] FAO (2011) Global Food Losses and Food Waste: Extent, Causes and Prevention. Gustavsson, J, Cederberg, C, Sonesson, U, van Otterdijk, R and Meybeck, A. Rome: FAO. pp. 38

[17] Rescuing Leftover Cruisine. 2020. Available from: https://www.rescuingleftovercuisine.org/challenge [Accessed: August 10, 2021]

[18] World Food Programme. 2020. Available from: https://www.wfp.org/zero-hunger [Accessed: August 11, 2021]

[19] Lobo MG, Dorta E. Utilization and management of horticultural waste. In: Postharvest Technology of Perishable Horticultural Commodities. Woodhead Publishing; Elsevier 2019. pp. 639-666

[20] Ajila C, Brar SK, Verma M, Prasada Rao U. Sustainable Solutions for Agro Processing Waste Management: An Overview. In: Malik A, Grohmann E. (eds) Environmental Protection Strategies for Sustainable Development. Strategies for Sustainability. Dordrecht: Springer; 2012. DOI: 10.1007/978-94-007-1591-2_3

[21] Gupta PK, Sahai S. (2005). Residues Open Burning in Rice-Wheat Cropping System in India: An Agenda for Conservation of Environment and Agricultural Conservation. by IP Abrol, RK Gupta and RK Malik. Centre for Advancement of Sustainable Agriculture, National Agriculture Science Centre: New Delhi, 50-54

[22] Agrawal S, Trivedi C, Sengupta R. Air pollution due to burning of residues. In proceeding of the workshop on air pollution problems due to burning of agricultural residues, held at PAU, Ludhiana Organized by the Indian Association for Air Pollution Control in collaboration with the Punjab State Pollution Control Board. New Delhi: Patiala and the Central Pollution Control; 2006

[23] Lal MM. An overview to agricultural burning. In: proceeding of the workshop on air pollution problems due to burning of agricultural residues, held at PAU, Ludhiana organized by the Indian Association for Air Pollution Control in collaboration with the Punjab State Pollution Control Board. New Delhi: Patiala and the Central Pollution Control Board; 2006

[24] Singh RP, Dhaliwal HS, Humphreys E, Sidhu HS, Singh M, Singh Y, et al. Economic assessment of the Happy Seeder for rice-wheat systems in Punjab, India. In: 52nd Annual Conference of the Australian Agricultural and Resource Economics Society (AARES 2008), Canberra, ACT, Australia. 2008

[25] Rickert D. Water Quality Assessment to Determine the Nature and Extent of Water Pollution by Agriculture and Related Activities. Informes sobre Temas Hidricos (FAO), Rome (Italy); 1993. pp. 187-210

[26] Zhongming Z, Linong L, Wangqiang Z, Wei L. Agriculture: Cause and Victim of Water Pollution, but Change Is Possible, GSTDTAP, China; 2017

[27] Sagardoy JA. [An Overview of Pollution of Water by Agriculture]. [Spanish]. Vol. No. 1. Informes sobre Temas Hidricos (FAO), Rome (Italy); 1993

[28] Breś W, Politycka B. Contamination of soils and substrates in horticulture. In: Soil Contamination-Current Consequences and Further Solutions. Rijeka: IntechOpen; 2016

[29] Kumar H, Bhardwaj K, Sharma R, Nepovimova E, Kuča K, Dhanjal DS, et al. Fruit and vegetable peels: Utilization of high value horticultural waste in novel industrial applications. Molecules. 2020;**25**(12):2812

[30] Shrirakshaya SS, Vignesh M, Dhananandhini M, Kavya N, & Poongothai M. Cellulose and Starch as the Source of Bioplastic, IJRASET, India. 2020. DOI: 10.22214/ijraset.2020.6089

[31] Jane JJMS. Starch properties, modifications, and applications. Journal of Macromolecular Science, Part A: Pure and Applied Chemistry. 1995;**32**(4):751-757

[32] Prasad S. Bioplastics-utilization of waste banana peels for synthesis of polymeric films. Journal of Polymers. 2014;**4**:38-45

[33] Wahyuningtiyas NE, Suryanto H. Analysis of biodegradation of bioplastics made of cassava starch. Journal of Mechanical Engineering Science and Technology (JMEST). 2017;**1**(1):24-31

[34] Goswami G. Bio-plastic from waste newspaper. In: Conference Paper, JIET, Jodhpur. February 2014

[35] Pop C, Suharoschi R, Pop OL. Dietary fiber and prebiotic compounds in fruits and vegetables food waste. Sustainability. 2021;**13**(13):7219

[36] Rominger A. The 15 benefits of composting for the environment, the economy, & our communities. In: Grow Ensemble, Boston, USA. 2020. Retrieved November 2, 2021, Available from: https://growensemble.co

[37] Ayilara MS, Olanrewaju OS, Babalola OO, Odeyemi O. Waste management through composting: Challenges and potentials. Sustainability. 2020;**12**(11):4456

[38] Mushimiyimana I, Tallapragada P. Bioethanol Production from Agro Wastes by Acid Hydrolysis and Fermentation Process, NISCAIR-CSIR, India. 2016;**75**(6):383-388

[39] Barz M, Delivand MK, Dinkler K. Agricultural wastes-a promising source for biogas production in developing countries of the tropical and subtropical regions. Revista Forestal Mesoamericana Kurú. 2019;**16**(38):2-12

[40] Kleis H, Dalager S. 100 Years of Waste Incineration in Denmark. Denmark: Heron Kleis and Soren Dalager; 2004

[41] Ji L, Lu S, Yang J, Du C, Chen Z, Buekens A, et al. Municipal solid waste incineration in China and the issue of acidification: A review. Waste Management & Research. 2016;**34**(4): 280-297

[42] Jeswani HK, Azapagic A. Assessing the environmental sustainability of energy recovery from municipal solid waste in the UK. Waste Management. 2016;**50**:346-363

[43] Czajczyńska D, Anguilano L, Ghazal H, Krzyżyńska R, Reynolds AJ, Spencer N, et al. Potential of pyrolysis processes in the waste management sector. Thermal Science and Engineering Progress. 2017;**3**:171-197

[44] Conesa JA, Font R, Fullana A, Martin-Gullon I, Aracil I, Gálvez A, et al. Comparison between emissions from the pyrolysis and combustion of different wastes. Journal of Analytical and Applied Pyrolysis. 2009;**84**(1):95-102

[45] Soltan M, Elsamadony M, Mostafa A, Awad H, Tawfik A. Harvesting zero waste from co-digested fruit and vegetable peels via integrated fermentation and pyrolysis processes. Environmental Science and Pollution Research. 2019;**26**(10):10429-10438

[46] Moneim MA, El Naggar AM, El Sayed HA, Mostafa MS, Khalil NM, Hassan MED. Direct conversion of an agricultural solid waste to hydrocarbon gases via the pyrolysis technique. Egyptian Journal of Petroleum. 2018;**27**(4):991-995

[47] Kung CC, Kong F, Choi Y. Pyrolysis and biochar potential using crop residues and agricultural wastes in China. Ecological Indicators. 2015;**51**:139-145

[48] Reduce Wasted Food by Feeding Animals. 2021. US EPA. Available from:https://www.epa.gov/sustainable-management-food/reduce-wasted-food-feeding-animals