Waste Utilization in Horticulture : An Overview

Abstract : Waste management in horticulture plays a pivotal role in achieving environmental sustainability and optimizing resource utilization. One of the primary methods for waste utilization is composting, which involves the decomposition of organic waste materials to produce nutrient-rich compost. Compost serves as an excellent soil amendment, enhancing soil fertility and promoting plant growth. Additionally, anaerobic digestion offers a valuable approach for converting organic waste into biogas, a renewable energy source that can be used for heating, electricity generation, and vehicle fuel. Furthermore, fermentation processes can be employed to convert fruit and vegetable waste into valuable products such as animal feed and biofuels. The by-products of fermentation, including yeast and enzymes, have applications in various industries, contributing to the circular economy model. Advancements in precision agriculture and smart waste management systems have revolutionized waste utilization in horticulture. Technologies such as GPS, GIS mapping, wireless sensor networks and big data analytics enable data-driven, decision-making and optimize resource allocation. Precision planting, targeted spraying, automated pruning/harvesting and variable rate irrigation are among the innovative practices facilitated by these technologies, leading to increased productivity and efficiency in horticultural operations. Moreover, waste utilization in horticulture contributes to mitigating environmental pollution and reducing greenhouse gas emissions. By diverting organic waste from landfills and incineration, the emission of methane, a potent greenhouse gas, is minimized. Instead, organic waste is repurposed into valuable resources, thereby closing the loop on waste streams and promoting a circular economy.

Keywords : Utilization, compost, biofuels, automated and diverting.

Introduction

In contemporary times, the horticulture sector is undergoing exploration and diversification to meet the demands of an ever-growing market. The expansive cultivation at the field level, coupled with impressive export potential, elevates the prominence of the horticultural product market. Horticultural products find remarkable applications ranging from household kitchens to processing industries. Despite the versatility of their uses, challenges emerge in the form of by-products or wastes, exacerbating due to inadequate utilization practices.The horticultural sector's waste management is a growing concern as both developing and developed countries grapple with various environmental pollutions, including water, soil, and air pollution. The escalating global population emerges as a primary contributor to the increasing generation of waste (Bhat *et al*., 2014). The rise in population levels results in the routine production of waste in households, often unnecessarily.A substantial volume of peel waste is a by-product generated by fruit and vegetable-based industries and household kitchens, leading to significant nutritional, economic, and environmental repercussions (Kumar *et al*., 2020). The improper management of these wastes not only results in substantial losses but also poses environmental challenges. Addressing these waste-related issues is imperative for creating sustainable practices in the horticultural sector and mitigating the adverse impacts of waste generation on both the economy and the environment.

The production of horticultural foods introduces various factors contributing to detrimental environmental effects. Unregulated pesticide usage and the lingering impacts of diverse chemicals pose primary threats to nature, causing adverse effects on wildlife, soil, human, and animal communities (Sánchez-Bayo *et al*., 2011). The environmental pollution from processing industries exacerbates the situation, as numerous by-products are discarded into the environment. Interestingly, these by-products contain substantial quantities of phytochemicals that could be effectively reused, offering a more sustainable disposal method.Improper waste disposal methods contribute to an increase in greenhouse gas emissions, further negatively impacting the environment. Therefore, it becomes imperative to adopt proper and alternative waste disposal processes to ensure both economic viability and environmental stability. Such practices not only address the issue of waste generation but also harness the potential of valuable compounds present in the by-products, contributing to a more sustainable and environmentally friendly horticultural production system.

Enhancing recycling efforts and exploring diverse disposal methods are crucial for effectively addressing environmental pollution. The industrial and diverse sources of horticultural wastes are gaining significance due to their valuable compositions. Recycling opens up new opportunities with commercial benefits, leading to the production of biofuels, enzymes, vitamins, antioxidants, and various essential chemicals from industrial wastes. Embracing the concept of "waste to wealth" represents a modern approach to waste disposal.Government supervision and regular monitoring play a pivotal role in waste management, as effective waste disposal not only contributes to economic benefits but also ensures sustainability for both the environment and industrial sectors (Ahuja *et al*., 2020). This approach aligns with the contemporary notion that waste materials can be transformed into valuable resources, emphasizing the need for responsible waste management practices to achieve both environmental conservation and economic prosperity.

Wastes evolving during horticultural production chain

The practical situation of waste generation is linked to the rising global population. The higher population growth rate correlates with an increased demand for agricultural produce, indicating a surge in food demand. Current agricultural production exceeds that of the last five decades, amplified by technological advancements that enhance productivity in the horticultural sector (Adejumo and Adebiyi, 2020). However, the downside of increased productivity is the generation of larger quantities of waste, including green wastes and recyclable solid wastes.

1. **Floricultural waste**

   Following the harvest of flowers, the entire plant, along with any damaged or unsold flowers, is considered waste. However, the remaining flowers can undergo a process of drying and grinding, while cut flowers can be utilized for creating dried flower arrangements, contributing to a burgeoning industry. These dried flowers offer versatile possibilities, as they can be painted, colored, or dyed. Various floral products, including cards, pictures, wall hangings, arrangements, potpourris, and pomanders, can be crafted from these processed flowers (Sehrawat *et al*., 2015).
2. **Mushroom waste**

   Mushroom are cultivated using natural materials sourced from agriculture, woodlands, animal husbandry, and manufacturing sectors. Following the harvest of mushroom crops, there are millions of tons of utilized mushroom substrate that can be repurposed for various applications. The spent growing medium remains valuable and has been repurposed in different ways, such as serving as animal feed, acting as an ingredient in cultivating different mushroom species, being utilized as fuel, serving as a medium for vermin culture, enriching soils, and acting as a matrix for bioremediation.

3. **Chemical wastes during cultivation**

   These waste materials stem from the consistent application of pesticides, insecticides, and herbicides in the cultivation process. They primarily consist of solid wastes like pesticide containers and bottles. In developing countries, these chemical applications are often managed by rural, uneducated farmers. Consequently, the disposal of such solid wastes is typically overlooked by farmers or users. This neglect results in an imbalanced environmental state. Approximately 2% of pesticides tend to remain unused in the containers, leading to the disposal of these hazardous materials by discarding them into nearby ponds or open fields. This form of negligence can give rise to severe environmental issues such as food poisoning, water pollution, and air pollution (Buzby and Jeffrey, 2011).

4. **Industrial horticultural wastes**

   Numerous food processing industries utilize potentially hazardous materials in their operations, including coloring agents, dyes, and by-products like banana peels and coconut husks, along with various bioactive compounds such as phenols, flavonoids, flavanols, and anthocyanins that consistently emerge as by-products in these processes. Swift and efficient disposal methods are crucial for managing such waste. Failure to dispose of these by-products in a timely manner poses a significant threat to both human well-being and environmental equilibrium. The heightened emission of pollutants further exacerbates the vulnerability of the environment. Therefore, it is imperative to find practical applications for these compounds, as allowing them to go unused can contribute to environmental pollution (Hassan *et al*., 2022).

Horticultural wastes as environmental concern

The environment is increasingly at risk due to the unmanaged waste generated from diverse sources within the horticultural sector, encompassing both agricultural and industrial aspects. Pollutants originating from horticultural waste significantly impact the three key components of the environment: air, water and soil.

Impact of waste on air quality, water contamination and soil

At times, waste disposal methods involve burning, but this approach is not always effective. Burning crop stubbles releases hazardous emissions, including carbon monoxide, nitrogen oxide, nitrogen dioxide, sulfur dioxide, methane, and other toxic hydrocarbons. These harmful gases and particulate matter adversely affect air quality, posing risks to both human and animal health.Water contamination is not solely attributed to industrial solid wastes with heavy metals; horticultural wastes, especially those from cultivation systems and processing by-products, contribute to water quality deterioration. Fertilizers and pesticide chemicals are culprits for contaminating both ground and surface water. Toxic trace elements render essential nutrients unavailable, leading to the extinction of beneficial soil-borne microorganisms. The water pollution pyramid indicates that groundwater has become unsafe due to chemical toxicity. Continuous cultivation results in erosion, sedimentation, and salinity issues.The prolonged use of fertilizers and the presence of non-degradable plastic solid waste render the soil unsuitable for crop cultivation. Additionally, certain plant residues contain toxic chemicals, such as secondary metabolites, volatile terpenes and phenolic compounds, which can inhibit the growth and productivity of other crops. This phenomenon is known as crop-crop allelopathy, primarily associated with postharvest residues (Breś and Politycka, 2016).

Advantages of Waste Management

- Mitigation of environmental pollution.
- Valuable nutritional supplement for the human population.
- Creation of diverse value-added products.
- Contribution to addressing food scarcity challenges.
- Enhancement of soil fertility through nutrient-rich content.
- Effective supplementary resource for agricultural irrigation.
- Resolution of salinity hazards in soil.
- Potential for boosting economic returns in the industry.

Waste Management Strategies

The effective management of waste can be achieved through the application of suitable waste treatment or utilization technologies. Previous studies have highlighted that waste generated by fruit and vegetable processing industries contains valuable constituents, presenting significant potential for the creation of value-added products. Therefore, adopting the right approach and strategy is crucial for waste management. Several strategies applicable to the industry include:

1. Opting for techniques that generate little to no waste, such as employing enzyme technology for juice extraction.

2. Maximizing the recovery of useful materials (extracting oil from apricot stones, obtaining pectin/fiber from apple pomace, extracting lactose from whey).

3. Using waste as a substrate for producing valuable substances, such as utilizing spent mushroom substrate for crop production, employing solid-state fermentation (SSF) of waste for mushroom, vitamins, single-cell protein, and pigment production.

4. Converting waste materials into useful products (producing ethanol from fruit waste, extracting citric acid from pomace, deriving enzymes from wheat bran, and creating animal feed from waste).

5. Giving priority to waste materials of fruit and vegetable origin for the production of food/feed-related substances, followed by biogas.

6. Ensuring that wastewater treatment aligns with the requirements of pollution control agencies.

Waste treatment

The Effluent Treatment Plant (ETP) within the food processing sector holds significant importance in addressing polluted water, prompting environmental protection agencies to intervene if not managed properly. State pollution control boards play a crucial role in implementing ETPs in these industries. Effluent, a liquid waste from industrial processes, particularly in distilleries, generates substantial daily effluents. While rich in organic carbon and plant nutrients, its agricultural use is limited due to high Biochemical Oxygen Demand (BOD). Many distilleries now employ biogas plants to produce methane, reducing BOD and benefiting crops through pre-sowing irrigations. The effluent, after appropriate dilution, can also be used for crop irrigation. To meet pollution control board standards, wastewater undergoes treatment before discharge, accomplished through specific processes in the Effluent Treatment Plant. The ETP, equipped with components like lime doser and settling tanks, neutralizes toxicity, making the waste/polluted water suitable for river disposal (Raj *et al*., 2016).

Waste utilization

The waste materials generated by the food processing industry contain valuable components, emphasizing the crucial need to identify effective methods for their utilization. It is essential to employ these waste materials in a manner that maximizes benefits without incurring financial losses or posing environmental risks. Options for utilization include composting and landfill through aerobic or anaerobic treatment, biogas production, and the creation of value-added products. By recycling waste materials into useful products, the challenges of waste disposal and pollution hazards within the food industry and its surroundings can be effectively addressed. Various approaches for transforming waste materials into valuable end products are explored in the following discussion.

1. **Composting and landfill:** The substantial rise in processed product production over the past few decades has led to a corresponding increase in post-processing waste. Proper disposal of this waste poses a challenge for industrialists, particularly those in urban areas where land costs are high. Environmental protection agencies have raised concerns about unregulated waste disposal, prompting a need for environmentally friendly solutions. In recent years, waste disposal has become a challenge for processors under pressure from various agencies to adopt eco-friendly waste treatment methods. Composting emerges as a promising solution, achievable through natural weathering, aerobic, and anaerobic processes in pits lasting 12-18 months. The resulting compost can be utilized as ready-to-use manure for crop cultivation. Spent mushroom substrate (SMS) serves as organic manure, addressing nutrient-poor and acidic soils, as well as improving polluted sites. Vermicomposting provides another effective avenue for waste material utilization. Fruits, vegetable, and floricultural crop leaves can also be composted or vermicomposted. This process not only prevents the spread of insects and diseases but also produces material suitable for landfilling on barren land. The 12-18 months composting cycle enhances NPK content, water retention, and organic carbon, thereby improving soil fertility.

Composted apple pomace can even be used for mushroom cultivation in solid-state fermentation (SSF), contributing to the cultivation of polluted land and expanding agricultural and horticultural areas, consequently boosting food production (Ayilara *et al*., 2020).

2. **Biogas production:**Waste from fruit and vegetable processing industries, abundant in biodegradable components, can be utilized for biogas production through anaerobic digestion. Biogas is generated by the breakdown of fruit and vegetable waste, such as apple pomace or orange peel. In this procedure, acid-forming bacteria first hydrolyze complex polymers into simpler substances, followed by anaerobic digestion by methanotropic bacteria, leading to the release of methane gas (Sagagi *et al*., 2009).

Prospects of horticultural waste management

Disposing of waste is a complex task, requiring significant resources and proper methods to minimize adverse effects. Not all waste disposal techniques are consistently efficient. The US EPA's Food Recovery Hierarchy emphasizes that various methods are proficient at different levels. Landfilling and incineration, the last resort for waste disposal, can be harmful to the environment, causing soil pollution and releasing toxic gases. Composting, creating nutrient-rich soil amendments, demands specialized areas and more time for disposal. Industrial use of waste ranks just above composting, providing waste oils for rendering, dual conversion, and food scraps for energy recovery. Source reduction is a key strategy, emphasizing the need to donate excess food to reduce waste. Public awareness plays a significant role in effective food waste management, particularly in the horticultural sector.

While the food processing sector in agriculture has expanded, preventing perishable commodity wastage, it simultaneously generates a substantial quantity and variety of waste, posing environmental and health hazards. The waste includes materials from harvesting, food preparation, processing operations, and unused materials. Inefficient agri-economy practices contribute to significant food material wastage. Waste disposal becomes a challenge for processors as environmental agencies push for eco-friendly treatment methods. Utilizing waste for producing value-added products becomes crucial in managing food processing waste.

Various categories of waste generated by food industries include:

1. Waste from the fermentation industry
2. Residue from the fruit and vegetable industry
3. Discards from the sugar and starch industry
4. Byproducts of the dairy industry
5. Leftovers from meat processing
6. Residuals from the coffee industry
7. Waste produced by the palm oil industry
8. Discarded materials from fish processing

Types of Processing Waste

In India, food processing industries generate a substantial amount of solid waste, and in addition to this, the food industry also produces a significantly larger quantity of wastewater compared to solid waste. Various microorganisms present in the solid wastes of food industries contribute to the production of metabolic end products, leading to both chemical and biological environmental pollution (Narasimmalu and Ramasamy, 2020).

Value Added Products from Processing Waste

- **Citrus:** Citrus waste proves to be a valuable reservoir of essential oils, with the concentration of citrus essential oil ranging from 1:5 to 1:20. This oil finds applications in cosmetics, pharmaceuticals, perfumes, and soap scenting. A significant by-product of the citrus industry is D-limonene. Essential oil in citrus develops within receptacles on the flavedo of the peel, protected by a wax layer. Before juice extraction, the fruit undergoes washing, and an oil extraction machine, making numerous small cuts on the skin, removes the skin oil. The quality and quantity of the oil are influenced by the ripeness of the fruit (Dosoky and Setzer, 2018).

- **Stone fruits:** The kernels of stone fruits present a valuable oil source. The leftover stones post-pulping can be employed for oil extraction, yielding oil comparable in quality to almond oil. This extracted oil finds applications in the production of facial cream, lip balm, soap, and other products.
- **Apple:** Apple pomace, the byproduct of apple juice production, constitutes approximately 30% of the initial fruit. Both fresh and dried apple pomace can serve as animal feed. However, due to its limited nitrogen content, it is not a comprehensive animal feed on its own. Through fermentation with various yeasts and subsequent drying, apple pomace becomes enriched with proteins, vitamins, minerals, and fats, making it suitable for animal nutrition.
- **Banana:** It is extensively employed in the diet of dairy and beef cattle. Cultivating yeast on it and incorporating it into animal feed provides additional benefits. Sun-drying ripe banana peels, comprising approximately 22-30%, serves as poultry feed. The banana pseudo stem yields around 5% edible starch.
- **Mango:** The industrial processing of mangoes results in a significant quantity of discarded stones and peels, contributing to waste. Mangoes typically have a stone content ranging from 9-23%, averaging at 15%. Notably, the major waste, mango seed kernel, serves as a valuable carbohydrate source and can substitute approximately 20% of corn in chicken diets for growth and egg production. Drying mango kernels and peels can yield high-quality energy-rich feed for animals. Abundant sources like mango peels and apple pomace from processing plants are also found to be rich in pectin. Additionally, mango seed kernels may offer a potential source of starch (Lebaka *et al*., 2021).
- **Grapes:** Waste produced post-fermentation in wineries, breweries, and distilleries can be repurposed as livestock feed. Grape pomace and wine lees can be utilized to produce animal feed by cultivating microbes on them. The waste generated by breweries and distilleries also contributes to the production of Single-Cell Protein (SCP). Additionally, natural colors can be extracted from the skin of blue grapes.
- **Pineapple:** In Hawaii Island, there is high demand for using pineapple bran as cattle feed. Additionally, cannery wastes are utilized as feed for dairy cattle in Hawaii, especially after the ensiling process. The waste derived from fruit and vegetable processing is fiber-

rich, containing cellulose, hemicellulose, lignin, and silica, with a relatively low protein content.

Conclusion

Waste utilization in horticulture offers numerous benefits ranging from environmental sustainability to economic viability. By effectively managing and repurposing waste materials generated in horticultural processes, such as fruit and vegetable processing, wineries, and breweries, significant strides can be made towards reducing environmental pollution and promoting resource efficiency. Various methods such as composting, anaerobic digestion, and fermentation offer avenues for transforming waste into valuable resources such as organic fertilizers, animal feed, and energy sources like biogas. Moreover, advancements in technology, including precision agriculture and smart waste management systems, facilitate the efficient utilization of waste in horticulture. These innovations enable data-driven decision-making and optimized resource allocation, leading to enhanced productivity and sustainability in agricultural practices. Additionally, waste utilization contributes to circular economy principles by closing the loop on waste streams and promoting a more holistic approach to resource management. Overall, embracing waste utilization in horticulture not only mitigates environmental impacts but also fosters resilience and innovation within the agricultural sector, paving the way towards a more sustainable future.

References:

Adejumo I.O., Adebiyi O.A. (2020). Agricultural solid wastes: Causes, effects, and effective management. In: Strategies of Sustainable Solid Waste Management. Rijeka: IntechOpen; 2020.

Ahuja V, Macho M, Ewe D, *et al* (2020). Biological and Pharmacological Potential of Xylitol: A Molecular Insight of Unique Metabolism. *Foods*. **9**(11):1592.

Ayilara, M.S., Olanrewaju, O.S., Babalola, O.O., & Odeyemi, O. (2020). Waste management through composting: Challenges and potentials. *Sustainability*, **12**(11), 4456.

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

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

Buzby J.C., Jeffrey H. (2011). Total and per capita value of food loss in the United States. *Food Policy*. **37**:561-570.

Dosoky, N.S., & Setzer, W.N. (2018). Biological activities and safety of Citrus spp. essential oils. *International journal of molecular sciences*, **19**(7), 1966.

Hassan, J., Khan, M. N. E. A., Rajib, M. M. R., Suborna, M. N., Akter, J., & Hasan, M. F. A. (2022). Sustainable Horticultural Waste Management: Industrial and Environmental Perspective. *Pectins: The New-Old Polysaccharides*, 19.

Kumar, H., Bhardwaj, K., Sharma, R., Nepovimova, E., Kuča, K., Dhanjal, D. S., ... & Kumar, D. (2020). Fruit and vegetable peels: Utilization of high value horticultural waste in novel industrial applications. *Molecules*, **25**(12), 2812.

Lebaka, V.R., Wee, Y.J., Ye, W., & Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit. *International Journal of Environmental Research and Public Health*, **18**(2), 741.

Narasimmalu, A., & Ramasamy, R. (2020, November). Food Processing Industry Waste and Circular Economy. In *IOP Conference Series: Materials Science and Engineering* (Vol. 955, No. 1, p. 012089). IOP Publishing.

Raj, D., Senapati, A., & Patel, N.L. (2016). Waste Management in Horticulture Processing Industry. *Commercial Horticulture; Patel, NL, Chawla, SL, Ahlawat, TR, Eds*, 391-401.

Sagagi, B., Garba, B., & Usman, N. (2009). Studies on biogas production from fruits and vegetable waste. *Bayero Journal of Pure and Applied Sciences*, **2**(1), 115-118.

Sánchez-Bayo F. (2011). Impacts of agricultural pesticides on terrestrial ecosystems. Ecological Impacts of Toxic Chemicals:63-87.

Shehrawat, P.S., Nitu, S., & Parmila, D. (2015). Agricultural waste awareness and utilization for healthy environment and sustainable livelihood. *Scientific Papers Series-Management, Economic Engineering in Agriculture and Rural Development*, **15**(2), 371-376.