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11. Vermiconversion of Fruit and Vegetable Waste into Organic Manure: An Approach Towards Sustainable Solid Waste Management

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Abstract:

The present era is facing the big challenge of managing enormous amount of solid waste along with its impact on the environment. With increase in production and consumption of fruits and vegetables worldwide in yester years, huge biomass is generated as waste through various processes and disposed off in the surrounding which results in reduced aesthetics in short term and release of greenhouse gases after decomposition in long term. There is a need to find environment friendly and cost effective solution for utilization of fruit and vegetable wastes so that locked nutrients can be recovered and recycled. One of the promising and eco-centric approach for regaining nutrients are microbe aided decomposition-composting and earthworm mediated decomposition- vermicomposting. Vermicomposting is carried out by earthworms that are considered as ecosystem's engineer and convert organic waste into valuable resource-vermicompost. Earthworms enhance the microbial activity and modify the degradation process without producing odours and greenhouse gases. Present chapter is an attempt to review various studies done on vermicomposting of fruit and vegetable wastes and to recognize its potential in managing vast amount of wastes. This chapter also signifies the enhanced levels of major nutrients (Nitrogen, Phosphorus and Potassium) in the vermicompost along with the physico-chemical characteristics of raw and vermicomposted fruit and vegetable waste biomass. Further studies for managing variety of fruit and vegetable wastes solely and in combinations can be carried out. Thus vermicomposting can prove to be an ecologically sound alternative for diverting fruit and vegetable wastes from unscientific landfills to resource recovery, used as an organic amendment in horticulture and crop lands paving the way towards sustainable solid waste management.

Index Terms: Earthworm-mediated decomposition, Fruit and vegetable waste, organic amendment, vermicomposting, sustainable solid waste management.

11.1 Introduction:

Advancement in industrialization, increase in population, and sprawling urbanization has resulted in endless heaps of solid waste making it difficult to manage for formal and informal sector. Solid waste has been an outcome of excessive use of natural resources and use-throw consumeristic attitude without giving a thought to ecosystem's assimilation capacity. With the increase in production and consumption of fruit and vegetables worldwide yesteryears, fruit and vegetable waste (FVW) is generated in vast quantity and forms a significant part of solid waste streams. Its improper disposal poses a significant threat to environment in one or the other way. Fruits and vegetables are of utmost importance to humans as they are loaded with nutrients, vitamins, minerals, fibres and important dietary elements. In India, out of total fruit and vegetable stock of 221.4 million metric tonnes, 5.8 to 18 percent forms a part of waste stream [1]. In fruit and vegetable markets, tonnes of fruits and vegetable get wasted on daily basis and become market waste. Households also generate fruit and vegetable waste as a part of domestic waste that later on becomes a part of municipal waste. About 25 – 30% of fruit and vegetable waste comprises of skins, peels, shells, pomace and seeds [2]. While producing, processing, distributing and consuming, more than 50% of fruits and vegetables get wasted [3].

Large portions of fruit and vegetable waste are dumped in open areas or in landfills, burnt or degraded anaerobically due to deficient infrastructure (Fig 11.1). These unscientific methods lead to loss of nutrients on one hand and on the other, burning and open dumping results in release of carbon dioxide or methane, potent greenhouse gases [4, 5]. Further, fruits and vegetables have high water content and high organic matter content, leading to fast decomposition and produce offensive odours, if left unattended. This practice also leads to depletion of biomass and nutrients, which would otherwise be put to good use. Thus, potentiality of FVW can be explored for reduction, reuse, recycling and recovery of nutrients in an efficient way [6]. There is a need to find eco-friendly strategies which are not only cost efficient, but also process the wastes in a manner to convert them into value added product [7, 8].

Fig. 11.1: Fruit and vegetable waste dumped in open areas (Source: Clean India Journal)

Composting and vermicomposting are among the viable methods for organic waste management that not only replenish the valuable nutrients but benefit our environment too. Vermicomposting is a process of waste decomposition by interaction of earthworms and microorganisms producing bio-manure rich in nutrients, humic substances and enzymes [9, 10].

Wastes organic in nature and non-toxic to earthworms can be bio-transformed into vermicompost. Earthworms modify the physical, chemical and biological properties of feed substrates and convert them into a stable product. Vermicompost is odorless, peat like material rich in nutrients and is non-toxic[11].Vermicomposting has been widely used for decomposition of animal excreta [12] and in fact, cow dung, buffalo dung, horse manure, goat manure, rabbit manure, etc. are used as an amendment to different types of organic waste favourable for the growth of earthworms.

Cow dung is the most frequently used spike for vermicomposting process as it highly supports the growth of earthworms. Epigeic species of earthworms are mainly used for vermicomposting of biodegradable wastes [13] Commonly used earthworm species are Eisenia fetida, Eudrilus euginae, Perionyx excavatus, Lampito mauritii, Metaphire posthuma, Drawida willsi, etc. Eisenia fetida is the most extensively used earthworm species for vermicomposting as it can accept variety of feed materials, has high assimilative capacity, high tolerance to temperature and moisture conditions and efficient waste conversion ability [14, 15]. Table 11.1 represents various earthworm species and bulking materials used in vermicomposting process by various researchers in their experimental trials.

Present chapter reviews the efficacy of FVW as raw material for vermicompost production in terms of various physico-chemical characteristics as pH, electrical conductivity, Total organic carbon, nutrients (NPK), and stability parameters as ash content, C/N ratio, C/P ratio etc. This will also focus on how reuse, recovery and recycling can be a feasible option for managing heaps of waste reducing the load on landfills, helps to mitigate climate change and make solid waste management system a sustainable one.

Fig 11.2: Vermicomposting process (Source: Agri-farming)

Table 11.1: Different types of wastes, bulking materials and earthworm species involved in vermicomposting process

Sr. No	Type of waste	Bulking material	Earthworm species	Reference
1.	Municipal Solid waste	Cow dung	*Metaphire posthuma, Eisenia fetida*	[16]
2.	Pre-consumer vegetable processing waste	Cow dung	*Eisenia fetida*	[17]
3.	Fresh fruit and vegetable waste	Soil, cow dung vermicompost and fruit and vegetable waste	*Eisenia fetida and Eudrilus euginae*	[18]
4.	Fruit and vegetable waste	Cowdung and fruit and vegetable waste vermicompost	*Eisenia Andrei*	[19]
5.	Green waste	Cow dung	*Lumbricus rubellus*	[30]
6.	Apple pomace waste	Beef manure	*Eisenia fetida*	[31]
7.	Food and vegetable processing waste	Buffalo waste	*Eisenia fetida*	[32]
8.	Grape marc	Cow dung	*Eudrilus andrei*	[26]
9.	Vegetable market solid waste	Cow dung	*Eisenia fetida*	[22]
10.	Rice husk and market refused fruit	Cow dung	*Eudrilus euginae*	[28]
11.	Bakery industry sludge	Cow dung	*Eisenia fetida*	[27]
12.	Tomato fruit waste	Sheep manure	*Eisenia fetida*	[25]
13.	Fruit and vegetable waste	Soil, Excess activated sludge	*Eisenia fetida*	[33]
14.	Fruit and vegetable waste, pruning waste	Cow dung	*Eisenia andrei* *Eisenia fetida*	[20]

11.2 Fruit and Vegetable Waste Vermicomposting Studies:

Many researchers have studied vermicomposting process for organic residues, some include Municipal Solid waste [16], fruit and vegetable processing waste [17, 18, 19, 20, 21, 22, 23, and 24], tomato waste [25], grape marc [26], bakery industry sludge [27], rice husk [28]. Major issues in vermicompost production of waste is the level of nutrients present in raw materials and for this, wastes in combinations can be used as feed stock for earthworms [29]. Here, a brief review of the studies by different researchers is presented.

Huang et al [19] studied the vermicomposting of fresh fruit and vegetable wastes for five weeks and found the changes in various physico - chemical paramaters. Earthworms also promoted the microbial growth and modified the decomposition of FVW. A comparison was made for two systems, composting and vermicomposting and it was reported that vermicomposting resulted better rate of humification and nitrification at the end of process. While, Sethuraman and Kavitha [30] performed vermicomposting of fruit and vegetable waste with bedding material (cow dung, mango leaves and sawdust) in ratio of 1/1 in plastic tubs for 60 days and studied the changes in various parameters. At the end of experiment, the C: N ratio was found to be reduced in comparison to previous levels.

Garg and Gupta [17] experimented on pre-consumer processing vegetable wastes and reported reduction of 30.6% in organic matter and carbon to nitrogen ratio was found to be decreased in range of 15.1 -9.7 signifying high rate of stabilization. Total Kjeldahl Nitogen (TKN), Total available Phosphorus (TAP) and Total Potassium (TK) were also increased from initial levels. Gomez Brandon et al [26] studied vermicomposting of grape marc with Eudrilus andrei and reported that grape marc got stabilized in short time with good organic matter degradation and high rate of mineralization and nitrification depicting the stability of vermicompost produced. Hanc and Chadimova [31] carried out the vermicomposting of apple pomace from food processing industry to recover the nutrients. They observed that weight and volume of waste reduced by 84-89% which depended upon the amount of straw as mixing material to enhance the nutrient levels. About 33% deduction in C:N ratio was observed indicative of mineralization of organic compounds and significant increase was found in NPK values in the apple pomace waste amended with straw.

Sharma and Garg [32] have experimented on vermicomposting of food and vegetable processing waste using buffalo dung as bulking material. Significant decrease in organic matter and carbon to nitrogen ratio was noted in all the vermi-set ups to different extents. Food and vegetable waste in suitable proportions lead to decrease in C: N and C: P values and nutrients like Nitrogen, Phosphorus and Potassium were found to be enhanced. The C: N and C: P ratios are considered as the index of vermicompost maturity and C: N ratio < 20 reflects the stability of vermicomposts to be used in agricultural lands. Li etal [33] has studied the effect of activated sludge on wet fruit and vegetable wastes by a bioreactor with separate bed and substrate compartments for banana peels, cabbage, carrot, lettuce and potato peels. Their results reflect the change in physico- chemical properties of substrate mixtures after addition of activated sludge. The C: N values decrease from their initial values except for banana and potato peels. Increase in N, P, K values was indicated at the end of vermicomposting process in various treatments up to varying extents which depend upon the nature of initial substrates. Table 11.2 presents some different vermicomposting studies based on different vermicomposting trial periods.

Table 11.2: Fruit and vegetable waste vermicomposting studies

Sr. No.	Type of Waste vermicomposted	Vermicomposting study	Vermicomposting trial period	Reference
1.	Fruit waste + vegetable waste + leaves	Waste was mixed with bedding material (cow dung, mango leaves and sawdust) in ratio of 1/1 in plastic tubs. Physico-chemical parameters change was studied. C: N ratio found to be reduced.	60 days	[30]
2.	Pre-consumer vegetable processing waste	Feed mixtures taken in 10 litre capacity tubs in different ratios, C: N decreased and TKN, TAP, TK increased.	105 days	[17]
3.	Food and vegetable processing waste	FYW amended with buffalo dung in varied proportions in plastic vermi-bins. Decrease in organic matter, Carbon to nitrogen ratio and Carbon to phosphorus ratio depicting high rate of stabilization. Nutrients like N, P, K get escalated.	90 days	[32]
4.	Apple pomace waste	Pre-composted apple pomace mixed with straw and beef manure in 4/1 ratio in plastic reactors. Nutrient levels enhanced, reduction in C: N ratio by 33% indicative of organic compound mineralization. Reduction in weight and volume.	30 days	[31]
5.	Grape marc	Grape marc mixed with mature vermicompost in plastic containers. Short time organic matter degradation achieved due to rich carbon pool. High nitification rate and complete processing in very short period of 15 days was noted.	15 days	[26]

Sr. No.	Type of Waste vermicomposted	Vermicomposting study	Vermicomposting trial period	Reference
6.	Fresh fruit and vegetable waste	FVW composting (without earthworms) and vermicomposting systems were studied separately and compared. Vermicomposting has shown better rate of humification and nitrification	35 days	[19]
7.	Wet fruit and vegetable waste	Excess activated sludge was mixed with wet fruit and vegetable waste and effect on decomposition was studied. Eleven plastic containers were used with two compartments: substrate and bedding material (soil+ vermicomposted FVW). Change in physico-chemical properties was observed along with the reduction in mass.	30 days	[33]
8.	Tomato fruit waste	Waste mixed with sheep manure in metal containers. Decline in C: N values indicated maturity of end product.	150 days	[25]
9.	Fresh fruits and vegetable wastes	FVW was mixed with the bedding materials (soil+ vermicomposted fruits and vegetables) in perforated plastic containers with three layers: substrate, bedding and leachate collecting layer. Drastic drop in organic carbon was observed. Increase in bacterial and fungal communities were reported in both composting and vermicomposting systems.	35 days	[18]
10.	Fresh fruits and vegetables	Five different types of fruits and vegetables chosen for experimental trial. Bedding material prepared by mixing cow dung and prepared	60 days	[23]

Sr. No.	Type of Waste vermicomposted	Vermicomposting study	Vermicomposting trial period	Reference
		vermicompost. More decrease in carbon content as compared to control system. Enhanced nitrogen content due to earthworm activity.		

11.3 Applications of Fruit and Vegetable Waste Management through On-Site Vermicomposting

- Collection and transportation costs can be reduced.
- Diversion of FVW from landfills reducing the stress of voluminous waste.
- Reduce greenhouse gas emissions (carbon dioxide and methane).
- Improves urban sanitation and public health.
- Recycling of FVW into valuable nutrients closing the nutrient loop.
- Reduces demand and use of inorganic fertilizers.
- Maintains sustainable approach towards FVW management.

11.4 Conclusion:

Managing food and vegetable wastes by vermicomposting is a promising method that not only reduces the overall load on our ecosystem but also provides us with bio-manure that has improved nutrient quality.

Vermicomposting technology has been emerged as a sustainable alternative for managing organic wastes in an eco-efficient and cost-effective manner rather than to leave them to decay unscientifically.

This will pave the way towards the concept of zero waste where wasteful wastage of waste is avoided leading to recovery and recycling of nutrients into the ecosystem.

Further explorations and advancements should be made in this field to manage the organic waste at the source level in a decentralized manner.

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