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Potential Combinations of Biological Wastes for Growth and Reproduction of Earthworm *Lampito mauritii*

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Abstract: The generation of organic waste due to anthropogenic activities is a serious problem for society. The management of organic waste, including animal and vegetable waste, has become an important concern due to the global rapid urbanization. Improper storage, collection, and disposal of these biological waste is hazardous to both environmental and human health. However, these organic wastes can be converted into nutrient-rich biofertilizers by the vermic-activity of earthworms and associated microbes through the process of vermicomposting. The process of vermicomposting significantly decreases the level of pH, total organic carbon (TOC), electrical conductivity (EC), and the C:N ratio. Whereas there is a significant increase in total Kjeldahl nitrogen (TKN), total available phosphorus (TAP), and total calcium (TCa) through the vermic-activities. The significant growth and reproduction of earthworms were obtained in feed material of different biological waste as well as in buffalo dung with vegetable waste and banana peels. The present review article is based on the knowledge of using various species of earthworms as well as *Lampito mauritii* to stabilize organic waste.

Keywords: Banana peels, Buffalo dung, Earthworms, *Lampito mauritii*, Organic waste, Vegetable waste, Vermicomposting

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Introduction

The term "biological waste" or "bio-waste" refers to a variety of waste materials, such as ashes, plant and animal wastes, commercial wastes, medical wastes, radioactive substance wastes, household waste, construction wastes, and industrial solid and liquid wastes (Singh *et al*., 2024). The increasing amount of waste generation by population growth, changed consumption and lifestyle patterns, development, production of food grains, economic expansion and industrial development are the major problems for society. Biological waste management is gaining greater importance on a global scale (Kumar *et al.*, 2020a; Chattopadhyay and Singha, 2022). The generation of solid wastes is unreservedly a global concern. Solid wastes include organic and inorganic materials discarded by various activities, losing their utility (Mukherjee, 2016). Pollutants from improper disposal affect the air, land, and water resources, especially in the developing world, whereby India is inclusive (Misra and Pandey, 2005). Thus, poor soil fertility is one of the most complex issues affecting the growth of agriculture in India. Industrial, agricultural, municipal, and commercial waste are some of the categories of solid waste, which is unwanted solid or semi-solid material arising from human and/or animal activities (Singh *et al.*, 2022). Worldwide fruit and vegetable production stands out at approximately 675 million metric tons yearly and a mind-blowing 1.3 billion tons of wastage relates to the concern. In India alone, the annual production of fruits and vegetables is 86.602 million metric tons, and it is estimated that about 5.6 million tons of waste are dumped on the outskirts of cities due to failure to control food processing industries and agricultural activities (Omre *et al.*, 2018). Fruits and vegetables market production rises year by year because of growing demand among customers. Therefore, in the year 2020, the global output of fruits was 887 million tonnes and vegetables 1148 million while in 2010, the global fruit production was 732 million tonnes and vegetables 936 million tonnes (Mandavgane *et al.*, 2023). Fruits and vegetable waste (FVW) production is widely reported in processing industries across the global markets (Akanbi *et al.*, 2019). For instance, organized sectors of India, the Philippines, China, and the USA manufacture, process, pack, distribute, and consume about 55 million tonnes of fruit and vegetable waste annually (Akanbi *et al.*, 2019). India annually produces about 62 million tonnes of municipal solid waste from urban centers (Sharma and Jain, 2019). Population growth, particularly in urban areas, movement from rural to urban areas, and rising per capita waste disposal have dramatically influenced municipal solid waste (MSW) generation (Sarkar *et al.*, 2016). Fruit and vegetable wastes pose significant hazards to the environment because most of them are discarded in landfills or dumped directly into rivers or other sources of water (Wadhwa and Bakshi, 2013). In today's environment, developing a sustainable method for managing fruit and vegetable waste has become crucial (Kumar *et al.*, 2020b). Many metropolitan areas still need to address efficient waste management (Mohanty *et al.*, 2021). The types of waste management are composting, recycling, energy conversion,and landfilling (Laxmi and Nagarnaik, 2011). As a result, recycling waste has become one of the vital options to offer renewable supplementary nutrients for plants and crops. The readily available sources of organic matter in India include crop residues, tree, and animal wastes in rural areas, and city wastes and agro-industries by-products in the urban centers can be scientifically converted into bio-fertilizers (Jan *et al.*, 2023).

The vermibiotechnology is one of the most effective methods for removing biological waste from the soil through the vermic-activity of earthworms (Singh and Fatima, 2019). Vermitechnology, which uses earthworms to enhance production and decrease environmental impact while promoting long-term soil and ecosystem sustainability, is an environmentally friendly and sustainable method of agriculture (Hajam *et al.*, 2023). Vermicompost is produced from various types of organic residues, including sewage sludge, animal wastes, crop residues, kitchen waste, floral waste, and industrial residues (Kumar *et al.*, 2021). Waste from the kitchen includes food scraps such as grains, residual unused food, mashed fruit fiber, and vegetable and fruit peels. These are easily recyclable and rich in organic matter and nutrients (Mukherjee, 2016). Earthworms and microbes work together to break down the nutrient substrate in organic waste, making vermicomposting a potential approach for converting a range of biodegradable wastes into organic fertilizer (Sharma and Garga, 2020; Sindhu and Annapoorani, 2021). Vermicompost is a biofertilizer for end-users like farmers to replace chemical fertilizers and obtain better prices for organic produce using such composting material (Ramnarain *et al*., 2019). Vermicompost effectively improves soil quality and enhances microbial activity and nutrient recycling to produce high-quality crops (Nurhidayati *et al*., 2018). Thus, vermicomposting involving vegetable waste, banana peels, and buffalo dung eliminates waste disposal issues and enhances soil quality. The compost contains beneficial microorganisms and provides potassium, phosphate, and nitrogen, resulting in increased crop and food production, and making farming more sustainable (Edwards and Bohlen, 1996; Singh and Longkumer, 2018).

During the vermicomposting process, earthworms elevate levels of total Kjeldahl nitrogen, available phosphorus, potassium, and calcium while reducing the C: N ratio, total organic carbon, pH, and electrical conductivity (Suthar, 2009). Additionally, through earthworm movement, nutrients in the vermicompost are combined with micronutrients, plant hormones, enzymes, and other valuable nutrients (Umamaheswari *et al*., 2003; Pathak and Ram, 2004). Combining a variety of organic wastes, including water hyacinth, kitchen and agro-industrial wastes, paper mill sludge, and textile mill sludge, with animal dung helps in the growth and development of the earthworms, which allows for bioconversion of organic wastes effectively (Nath *et al*., 2009). This vermicomposting practice increases nutrient values and enriches the soil for sustainable production. This review focuses on utilizing vegetable waste, banana peels, and buffalo dung for the growth and reproduction of earthworms, which are generated in massive proportions and contribute to the generation of waste products.

Animal Waste:

Several millions of tons of animal waste, such as cow, buffalo, and goat dung, are produced yearly in India and seriously affect the environment and also cause a foul odor in the neighboring environment (Garg *et al*., 2005). It is challenging to completely utilize animal wastes, especially dung, due to India's large cattle population and dung productivity. Animal dung generally contains a significant amount of organic matter and nutrients, making it beneficial in improving the physiological and chemical properties of soil and increasing the production of crops (Cao *et al*., 2021). Animal dung has been utilized by studies as the sole material used for vermicomposting, or in combination with other organic solid wastes as a bulking agent to produce more stable, nutrient-rich vermicompost, or to observe the development and reproduction of earthworms (Bhat *et al*., 2016a, Rini *et al*., 2020; Yuvaraj *et al*., 2020).

The estimated yearly production of dung is 659 Mt, of which 344 Mt comes from cow dung and 315 Mt from buffalo dung (Sharma and Iqbal, 2022). The digestive waste produced by buffalo is known as "buffalo dung," and it can be harmful to human health and the environment. Nitrogen, phosphorus, calcium, and water are among the macronutrients found in buffalo dung waste that may act as a bioactivator during the composting process. N, P, and K contents in buffalo dung range from 1.03-2.12%, 2.23-5.54%, and 1.30%, respectively. Using a bioactivator made from buffalo dung during the composting process is an additional way to use the solid waste from buffalo dung. Buffalo dung has several beneficial microbes that help in the hydrolysis of organic materials, including cellulolytic, hemicellulolytic, and amylolytic ones (Anwar *et al*., 2021). The uncontrolled handling and storage of dung cause loss of organic matter, pollution, and odor problems (Reinecke *et al*., 1992). Since buffalo dung contains soil moisture and provides earthworms with nourishment and microbial nutrients for efficient decomposition, it is an excellent resource for vermicomposting (Suthar, 2009). Buffalo dung is widely available in Asian nations, especially India. Additionally, it was determined that buffalo dung could be used as a suitable bedding material compared to other types of cattle dung (Karwal and Kaushik, 2021).

Buffalo dung is a sustainable and renewable energy source that can help reduce environmental pollution, minimize agricultural waste, and produce primary energy (Sahito *et al*.,2013). Manure can enhance soil aeration, boost the soil's capacity to hold water, retain nutrients, improve soil buffering, and provide a source of nutrients and energy for soil microorganisms. Solid buffalo dung is one type of organic fertilizer that may be applied to enhance soil fertility and raise the concentration of chemical nutrients including potassium, phosphate, nitrogen, and water (Ningsih *et al*., 2018). Buffalo manure is a rich source of nutrients for crops and is utilized extensively throughout the world. An animal's waste can account for as much as 40% of its overall value. The 4-6 tons of dung that an adult buffalo may produce a year are utilized to keep the land fertile for crops (Nanda and Nakao, 2003). Abdel-Hadi and Abd El-Azeem (2008) reported that the C/N ratios of fresh cattle dung and buffalo dung are 38.1 and 29.0, respectively. Manure can be readily obtained, abundant in plant nutrients, and has the potential to lessen the need for mineral fertilizers.

Banana Peels:

Bananas (*Musa sapientum*) is classified under the Musaceae family; it is one of the most valuable crops cultivated by local growers and big cultivators around the globe (Sau *et al*., 2023). The global banana output is approximately 72.5 million metric tonnes annually. With a 21% share, India contributed hugely to 21.77 million metric tonnes (Morais *et al*., 2017). Approximately 36 million tonnes of banana peel are produced each year, and the peel makes up about 35% of the weight of the entire fruit (Vu *et al*., 2018). Today, bananas are the second most produced fruit type in the world after citrus fruits and account for about 16% of the total fruit production in the world. India emerges again as the largest producer of banana; this accounts for 27% of the produce in the global market (Achsah and Prabha, 2013).

Banana peels are significantly enriched with vitamins, starch, crude protein, crude fat, total dietary fiber, polyunsaturated fatty acids, and the micronutrient potassium, phosphorus, calcium, and magnesium (Mohapatra *et al*., 2010).Traditionally, breaking down banana peels to enhance soil nutrients has been used as a fertilizer. In compost supplemented with banana peel, Kalemelawa *et al*. (2012) reported higher levels of N and K, suggesting that banana peel has a good potential as a source of N and K. These nutritional components add value to banana peels to improve soil quality for composting and promote earthworm growth and reproduction (Zou *et al*., 2022). Banana peels are used in vermicomposting, whereby bananas are used as food for earthworms (Komesu *et al*., 2022). This coupled advantage points towards their use in more positive waste management practices and production of other valuable products concerning their use in agriculture and environmental conservation.

Banana peels, a waste product of banana production, are thrown away without being utilized and are typically categorized as solid waste, which includes significant costs (Padam *et al*., 2014). When treated with other organic wastes, banana peels, when fed to earthworms, can generate vermicompost that enhances the soil's fertility and plants' growth by a significant margin (Achsah and Prabha, 2013). Banana peels can, therefore, be added to vermicomposting to add value to waste minimization through the return of nutrients into the soil, banana peels are an important bio-waste that can contaminate the ecosystem if improperly managed (Budhalakoti, 2019). Banana peels contain the highest concentration of potassium, which is followed by magnesium, calcium, sodium, and other minerals (Aboul-Enein *et al*., 2016). Earthworms especially prefer high potassium content, stimulating the growth of that organism, and the process of vermicomposting and banana peels are good sources of potassium (Vu *et al*., 2018). Banana peels were broken down and applied as fertilizer to restore soil nutrients. When banana peel is mixed with cow dung, both aerobic and anaerobic conditions are met with it. Earthworms then use the combined ingredients to create organic fertilizer. The high potassium (>100 g/kg) and high nitrogen (>2%) content of the organic fertilizer works well for a wide range of plants (Kalemelawa *et al.*, 2012). A study involving banana peel and cow dung mixtures showed that vermicomposting for three months was effective for plant growth and yield (Mohanapriya *et al.*, 2021).

Vegetable Waste:

India is the world's second-largest producer of vegetables, with 90 million metric tons produced per year; however, only 2% of these are processed and over 33% are lost in the harvesting, selling, and processing stages (Wadhwa *et al.*, 2006). Fruit and vegetable-based organizations, as well as domestic kitchens, produce a significant quantity of peel waste, which has resulted in significant nutritional and financial losses as well as environmental issues. Even the processing of fruits and vegetables results in a large amount of waste between 25-30% of the finished product. Fruits and vegetables are the main source of this waste. India loses almost one-third of its crop production of fruits and vegetables (Negi and Anand, 2016). Vegetable wastes are abundant in nutrients and vitamins. Vegetable waste is suitable for recycling due to its high breakdown and low toxic effects (Yadav *et al.*, 2023). Vegetable waste comprises a significant amount of municipal solid waste, and its rapid breakdown and high organic matter present serious hazards to the environment (Malenica and Bhat, 2020). A large amount of food waste is vegetable waste, which is frequently challenging to handle because of its high moisture content and storage issues. In developing nations, vegetable and fruit waste is the most significant component of household waste (Esparza *et al.*, 2020). Hence, the conversion of these wastes into a valuable resource through eco-friendly valorization techniques is the need of time. Among different valorization techniques, composting and vermicomposting are highly suitable for nutrient recovery from recalcitrant biowastes owing to their simplicity and eco-friendly nature (Bhat *et al.*, 2016b). Vermicomposting has been reported to be more advantageous than composting due to its rapidity, efficient nutrient recovery potential, and pollutant remedial role (Paul *et al.*, 2011).

Vermicomposting:

Vermicomposting is an ecologically conscious and environmentally friendly approach to managing organic waste. It also reduces waste going to landfills and creates beneficial fertilizers for the soil that may be used in horticulture and agriculture (Kumari *et al.*, 2024). It is a globally accepted technology in almost all fields of human activity due to its economic value, social acceptability, and impact on the environment. Vermicomposting is a process of using earthworms to manage all types of organic waste to produce a valuable product of high economic value which is the organic fertilizer (Singh *et al.*, 2020; Yuvaraj *et al.*, 2020; Yatoo *et al.*, 2020). Vermicomposting is a technique in which vegetable waste is fed to earthworms, converting it into vermicast, which is good manure. It is worth appreciating the augmentation of vegetable waste in the vermicomposting systems because it immensely enhances the nutrients present in the vermicast, making it a rich source of all the macro and micronutrients a plant requires for growth (Lim *et al.*, 2015).

Earthworms are involved in the vermicomposting process by aerating the substrate, mixing it, grinding it, breaking it up, consuming it with enzymes, and allowing microorganisms to break down the substrate in their intestines (Hand *et al.*, 1988; Sharma *et al.*, 2005). It, however, has high moisture content and easily degradable organic matter, mainly in the form of vegetables, which are suitable for earthworm movement and microbial growth. The best climatic condition favors the speed with which this decomposition dawns hence, the efficiency of nutrient release and the quality of the vermicompost produced (Naidoo *et al.*, 2017). Thus, vermicomposting with vegetable waste reduces waste disposal and positively affects soil health and agriculture output. Vermicomposting influences the soil's physical, chemical, and biological characteristics and enriches organic matter (Przemieniecki *et al.*, 2020).

Earthworms:

Earthworms belong to the class Oligochaeta of phylum Annelida. Annelids are the first true coelomates that appeared during evolution (Singh and Fatima, 2022; Singh and Singh, 2023a). Earthworms are one of the main soil macro-fauna groups and influence soil properties (Coleman *et al.*, 2024). As "ecosystem engineers," they drastically enhance the physical characteristics of the soil, the nutrient turnover, and the decomposition of organic matter (Devi and Khwairakpam, 2022; Fatima *et al.*, 2023). The earthworm’s diversity is important for research because they manage organic wastes, alter the biological, chemical, and physical properties of soil, and promote soil fertility and structure (Singh and Singh, 2023b; Singh *et al.*, 2024). Earthworms are essential in improving agricultural productivity by enhancing roots' aeration, drainage, and penetration into the soil. They feed on organic matter that is either mechanically chopped or chemically decomposed in the earthworms' gut to produce vermicast. It has microelements like nitrogen, phosphorus, potassium, and microorganisms, which makes vermicast a good soil conditioner (Lavelle *et al.*, 2016). Earthworms constitute the majority of animal biomass in numerous temperate environments and modify the soil's physical, chemical, and biological characteristics (Akhila and Entoori, 2022). Different earthworm species have unique ecological niches and life cycles. Bouché (1977) classified them into three main types according to their feeding and burrowing strategies: epigeic, anecic, and endogeic, which are the three great groups of edaphic organisms (Pham, 2023).

Earthworms are found in about 4400 different species worldwide. However, only a few species are used in the vermicomposting process (Thakur *et al.*, 2021; Naik *et al.*, 2024). Earthworms feed mainly on dead plant roots, litter, and animal waste products such as excretions (Curry and Schmidt, 2007). Epigeic earthworms inhabit the organic mineral top layer and the surface debris, with a dietary preference for large organic particles. Anecic are characteristic of deep vertical casts and feed on the soil and organic components; their feces are organo-mineral. Endogeic species are found within the soil horizons; they feed on soil combined with organic matter (Kumar *et al.*, 2020b). In nutrient cycling, earthworms provide their best effort, a crucial aspect of soils. They break up dead plant and animal particles or reduce nutrients that enhance plant uptake to a usable form (Edwards and Arancon, 2022). By enhancing and maintaining the soil's capacity for provisioning nutrients, earthworm activities make decomposition a continual process and the cycling of nutrients in the soil a continuous cycle (Ahmed and Al-Mutairi, 2022). The capacity of earthworms to convert a wide range of waste materials into plant-nutrient-rich, marketable products can increase farmers' profitability and reduce their waste load (Saharia *et al.*, 2024). Earthworms are seen as agricultural supporters and an effective means to measure the quality of the soil since they fertilize areas of crops (Fatima *et al.*, 2024).

According to recent research, epigeic species found in India, including *Perionyx excavatus*, *Perionyx ceylanensis*, *Eudrilus eugeniae*, *Eisenia fetida*, and *Eisenia andrei*, can complete their life cycle in organic waste and create vermicompost. The following earthworm species can break down organic matter in municipal sewage sludge that contains significant numbers of sand particles: *Lampito mauritii*, *Polypheretima elongata*, *Drawida nepalensis*, *Drawida willsi*, *Metaphire posthuma*, and *Metaphire houlleti* (Chaudhuri and Debnath, 2020). However, *Lampito mauritii* may be a better choice as a substitute species for vermiculture and vermicomposting because of its greater rate of hatching success, a high number of hatchling production, and tolerance to a wide variety of environmental conditions (Parthasarathi, 2007).

Effect of Vegetable Waste as Feed Material for Earthworms:

Vegetable wastes are highly moist and easily degradable, thus proving to be perfect meals for earthworms, improving their health and productivity (Edwards and Bohlen, 1996; Dominguezand Edwards, 2010). The earthworm biomass production is increased when using these different substrates because it results in a feed mix with a varied nutritional composition. Vegetable waste provides various benefits that influence the growth, reproduction rate, and activity of worms in a vermiculture system (Edwards and Bohlen, 1996). Different vegetables generate varying amounts of waste, but since they are composed mainly of organic matter and the necessary nutrients required for the enhancement of the earthworms, then it results in better vermicomposting and higher quality vermicast yield (Gajalakshmi and Abbasi, 2008). Using suitable food sources is crucial for enhancing the growth and reproduction of earthworms in culture. The banana plant trunk has potential as a food source by producing increased reproductive efficiency and improved vermicompost quality. The combination of cow dung mixed with vegetable scraps and cow dung mixed with banana trunks increases *Perionyx excavates* maximum development and reproduction (Sadia *et al*., 2020).

Merta and Raskun (2022) observed that different doses of banana peel significantly affected the increase in the number of earthworms and the weight of the earthworm population. Tripathi and Bhardwaj (2004) reported that supplementing vegetable waste and banana peels with buffalo dung will enhance the growth rate of earthworms. The earthworm's body weight and length may increase as well when it consumes vegetable and papaya waste (Liberty and Endrawati, 2022). In a recent study, it was reported that adding vegetable waste to feed can increase the total number of earthworms, increase their total weight, and provide better growth to the earthworm (Merta and Raksun, 2024). The findings proved that earthworms have the potential to produce high-quality vermicompost from vegetable wastes and that the cast content may be improved by intentional selection and thorough combining of various vegetable wastes.

Reproductive Potential of Earthworms in Different Feed Material:

Organic waste such as weeds, leaf litter from forests, agricultural industrial waste, etc. are the main source of food for earthworms. They also produce vermicompost, which are particles of waste. This is rich in beneficial microflora, macro and primary elements, and plant growth regulators, among other plant nutrients. Temperature, humidity level, moisture, and bed wetness are some of the environmental factors that impact earthworm growth and reproduction. In the field, these factors also have a direct effect on the earthworm population (Manikanta *et al*., 2023). Under favorable conditions, earthworms consume a variety of organic wastes, mainly cow dung. These wastes include vegetable and agricultural wastes like banana waste (Khan and Tripathi, 2020) (Table 1).

Various initial food combinations cause earthworms to produce cocoons in different ways. Earthworm reproduction patterns are directly influenced by the feed that is provided to it. The food sources for earthworms are organic waste, live microorganisms, and decomposing remains of animals. The beginning and rate of reproduction are primarily affected by the quality of organic wastes (Domínguez *et al*., 2000). Earthworm reproduction in a vermicomposting system is an effective indicator of the potential of the food source for earthworm growth rate during vermicomposting which depends on the quality of the feed, absorption rate, microbial growth in waste, and the suitability of feeding medium for inoculation worms (Suthar *et al*., 2016; Biruntha *et al*., 2020). Due to the presence of a large amount of organic matter, water hyacinth can be utilized as a substitute feed to increase earthworm growth and development (Rohani *et al*., 2022).

Additionally to environmental factors, the quality of food has a major effect on earthworm reproductive potential (Manna *et al*., 1997). Studies have reported significant growth and

Table 1: Vermicompost of organic waste and its substrate

Substrate	Organic waste	Earthworms	References
Cow manure	Oat straw	*Eisenia fetida*	Contreras-Ramos *et al*. (2005)
Cow dung and Agriculture residues	Leather processing sludge	*Eisenia fetida*	Nogales *et al*. (2005)
Sawdust and cow dung	Guar gum	*Perionyx sansibaricus*	Suthar (2007a)
Cattle dung	Beverage industry sludge, sugar industry waste, tannery sludge	*Eisenia fetida, Perionyx excavatus,* and *Eudrilus eugeniae*	Vig *et al*. (2011)
Agricultural residues	Solid textile mill sludge	*Eisenia fetida*	Arumugam *et al*. (2015)

development of *Eisenia fetida* when fed with combinations of different animal dungs and agro-wastes (Chauhan and Singh, 2012). Dar and Senthilmurugan (2022) found that the biomass and populations of earthworms increased when they were fed different combinations of cow dung (CD), mango litter (ML), and municipal solid waste. The type of feed material appears to be the most crucial factor among the other variables for earthworm generation (Fayolle *et al*., 1997). Based on the study, *Eisenia fetida* displayed a change in its reproductive pattern depending on the type of food it consumed (Suthar *et al*., 2005). Yadav and Garg (2011) have confirmed the effect of vermibed substrate on earthworm reproductive potential. For each gram of body weight, worms consume between 100 and 300 mg of food each day. Buffalo dung combined with gram bran showed a significant rise in the number of earthworms compared to the dung alone. For the growth and development of *Eutyphoeus waltoni*, it has been observed that buffalo dung is highly effective (Singh, 2020). Singh and Singh (2023c) reported that different combinations of industrial waste can be utilized as a preferable feed mixture for the maximum growth and reproduction of earthworms. Various earthworm species, including *Megascolex mauritii*, *Eisenia fetida*, *Eudrilus eugeniae*, *Perionyx excavatus*, *Lampito mauritii*, *Eisenia andrei*, and *Drawida willsi*, have been utilized in vermicomposting and have shown increases in both number and size during the process (Manyuchi and Phiri, 2013). *Eisenia fetida* exhibited the highest growth rate when fed with 100% cow dung (Sangwan *et al*., 2010). Optimal growth of *Eisenia fetida* was observed during vermicomposting of press mud sludge mixed with cattle dung in a 1:3 ratio (Bhat *et al*., 2016b). Cocoon production and biomass gain were noted in cattle waste compared to goat waste (Loh *et al*., 2005). Additionally, *Eudrilus eugeniae* showed superior life cycle performance in a substrate of paper waste (Jesikha, 2014).

Lampito mauritii Kinberg:

Lampito mauritii Kinberg has been found in every type of habitat, including gardens, grasslands, cultivated fields, paddy fields, groundnut fields, millet fields, and vegetable fields (Singh and Fatima, 2019). The various agro-systems of Punjab, Rajasthan, Tamil Nadu, Pondicherry, and Uttar Pradesh are where this species is most commonly spread in India (Tripathi and Bhardwaj, 2004; Karmegam and Daniel, 2007). In the fields of different blocks of Gorakhpur district, earthworm *Lampito mauritii* is widely distributed (Singh and Singh, 2023d). This species has spread widely across the whole country. The color of *Lampito mauritii* is a deep yellow. diameter: 5.0-5.3 mm, length: 92-168 mm, total segments: 126-170. Dorsally, the color is grey, brown, or yellow with a hint of purplish at the front end. The prostomium has a half-closed tongue and is epilobic. On 10/11 or 11/12, the first dorsal pore. Preclitellar region setals are arranged perichaetinically, with 40–50 setae per segment. There are no genital marks. Their casts are like granules (Singh and Fatima, 2019). The vermicomposting capability of *Lampito mauritii* Kinberg, a well-known and widely used class of earthworms for vermicomposting, is due to their flexibility in terms of growth requirements as well as adaptability to local environments. These earthworms can transform a wide array of organic materials into valuable vermicompost. The earthworm species such as *Amynthas morrisi*, *Perionyx excavatus*, *Lampito mauritii*, *Drawida willsi*, *Dichogaster bolaui*, and *Perionyx sansibaricus* are abundantly distributed in India and their role in composting biosolids is well recognized (Kale *et al*., 1982; Chaudhuri and Debnath, 2020).

Earthworms include a high degree of decomposition, nutrient recycling, humus production, soil physical and structural development, and biological organic residues and improvements in the soil through their feeding and investigation activity (Mackay and Kladivko, 1985). By reducing the toxic qualities of organic wastes, lowering pathogens and harmful microorganisms, and converting agro-industrial wastelands into nutrient-rich biological fertilizers, vitamins, humic acid, enzymes, growth hormones, and antibiotics, earthworms also improve the soil environment through vermicomposting. Earthworms not only improve nutrient recycling through soil and humus absorption and cast formation, but they also change the physical, chemical, and natural characteristics of soil. Vermicompost is recycled as an organic fertilizer, assessment of the properties of vermicomposts found from different organic wastes on plant growth and produce is the significant preliminary prerequisites to commend these vermicomposts as an actual organic fertilizer. The anecics however are capable of both organic waste consumption as well as in modifying the structure of the soil. Such burrowing species that are widely used in soil management like the earthworms, and *Lampito mauritii* also effectively create a drilosphere apart from helping in compost production (Ismail, 1993). The anecic earthworm *Lampito mauritii* is geophytophagous, which has assisted with hosting in the topsoil layers and being prevalent in every agrosystem of India (Nair *et al*., 2017). It tolerates variations in environmental conditions and abnormality in its temperature and moisture content (Prakash, 2017). This effectively conditions organic wastes from canteens, households, municipalities, and farms (Gergs *et al*., 2022). Experimental studies have also revealed that *Lampito mauritii* could turn various organic wastes into valuable compost. Vermicomposting an eco-technologically acceptable method of bio-waste treatment with *Lampito mauritii* is gaining more acceptances (Fatima and Singh, 2023a).

Reproductive Potential of Earthworm Lampito mauritii in Different Feed Material:

Earthworm species and type of feed material affected the worms' biomass and rate of cocoon development. It was observed that the number of hatchlings increased proportionately with the quality of the substrate (Hijam *et al*., 2022). The addition of bedding material is crucial to the vermicomposting process because it supports earthworm growth and this in turn increases the microbial population, provides nutrients, and reduces the amount of organic carbon in the compost, which contributes to the compost's increased efficiency (Eriksen-Hamel and Whalen, 2007). Higher levels of enzymes in the vermicompost of *Lampito mauritii* as compared to the initial feedstock show that it has potential for organic and sustainable farming. An excellent source of organic manure, the worm-worked vermicompost has greater microbial, NPK, and enzymatic activity. The enormously available yet unutilized MSW can be vermicomposted along with any other organic wastes that may include industrial Sludge, CD, sheep dung, pig manure, kitchen wastes (vegetable wastes), flower waste, and agricultural wastes which can be converted into this valuable organic manure (Ananthakrishnasamy, 2019). Parthasarathi (2010) concluded that the earthworms' ability to grow and reproduce was directly associated with the feed stock's quality, which has been reported to have an impact on the development of the cocoon and hatchling (Prashija and Parthasarathi, 2016).

The mixing of food materials significantly affects the growth and reproduction rate of earthworm *Lampito mauritii* due to the enhanced food supply, excellent nutritional value, and perfect moisture content, it was found that the bone meal and cow dung feeding material was the most suitable for the *Lampito mauritii* earthworm (Chitrapriya *et al*., 2017). The crop residues and leaf litter wastes can be vermicomposted using the native endogiec earthworm species *Lampito mauritii* (Sumathi and Isaiarasu, 2009). Sago solid waste and cow dung manure was mixed in a 1:1 ratio and vermicomposted for 60 days using *Lampito mauritii* earthworms, showing potential for converting industrial waste into nutrient-rich biofertilizers (Thirunavukkarasu and Senthil, 2022). Fatima and Singh (2023b) observed that the earthworm *Lampito maritii* shows high density and biomass potential in the combination of animal dung with MSW. The *Lampito mauritii* turned manures into castings that had greater nutritional content and increased the mineralization process. These composts have a low carbon-to-nitrogen ratio and an excellent nutritional value, making them ideal for usage in farms where they will increase the production of crops (Singh and Singh, 2023d). The feed material for *Lampito mauritii* mixed with buffalo dung and sugarcane bagasse diet has enhanced cocoon yield greatly. It reveals that more cocoon production with higher hatchlings per worm is possible with the 1:1 ratio of buffalo dung and sugarcane bagasse feed which is effective for industrial waste management (Singh and Singh, 2024). Earthworm growth and reproduction have been observed using the vermicomposting of Poultry waste (PW) supplemented with press mud (PM) and cow dung (CD). PW is a good feed material for earthworms for vermicomposting. Meharaj and Manivannan (2015) observed that the ideal waste mixture was a 1:1:1 vermicompost mixture of poultry waste, cow dung, and pressmud that supported the growth and reproduction of *Lampito mauritii* and *Perionyx excavatus*.

The earthworms *Lampito mauritii* are efficient in managing paper mill effluent, exhibiting a high rate of reproduction during the vermicomposting process (Banu *et al*., 2001). It was observed that fly ash is converted into quality manure by the local earthworm species *Lampito mauritii*. Gates (1972) reported that the formation of cocoons is possible throughout the year, in the case of *Lampito mauritii* using vegetable market waste as a feeding medium. The production of cocoons from the earthworm *Lampito mauritii* has been obtained in feed material of cow dung at different per cent substrate ratios. Meinhardt (1974) reported high rates of cocoon production with 4-6 cocoons/worm/month and suggested that *Lampito mauritii* could be induced to produce cocoons throughout the year. Since cocoon is the product of clitellum, clitellate individuals have been observed throughout the year under field conditions. The earthworm *Lampito mauritii* can also reproduce throughout the year as suggested by Butt (1993). Manimegala *et al*. (2009) reported that a flyash mixture containing cashew leaf litter and cow dung had the highest rates of *Lampito mauritii* growth and reproduction. This can be caused by including more bedding materials along with more nutrients. Banu *et al*. (2008) observed that during vermicomposting, 50% of earthworms, *Lampito mauritii*, have been found to have a high reproductive rate. The microbial population in 50% of the sago waste utilizing traditional bedding materials was higher than in 75% and 100% of the sago waste. Utilizing earthworm *Lampito mauritii* in sago solid waste converted waste into high-quality vermicompost. This innovative approach could transform industrial waste into valuable biofertilizers, offering a sustainable solution for both the environment and the agricultural industry. Utilizing native earthworms *Perionyx excavatus* and *Lampito mauritii*, the suggested ratio of 2:2 of animal dung and wastes, particularly cow dung and cashew leaf litter, is suitable for better growth and maximum reproduction (Prashija and Parthasarathi, 2019).

Physico-Chemical Changes in Feed Material by Utilization of Different Species of Earthworms:

Various physico-chemical factors, feed availability, and quality, as well as other factors all, have a significant impact on earthworm development and reproduction (Reinecke and Hallatt, 1989). According to Edwards and Fletcher (1988) and Ananthakrishnasamy *et al*. (2007) earthworm development and reproduction are made easier by feed that contains a sufficient amount of highly metabolizable organic matter and non-assimilated carbohydrates. Kaviraj and Sharma (2003) found that whereas *Lampito mauritii* improved total potassium by 5%, *Eisenia fetida* increased it by 10% during the vermicomposting of MSW. They suggested that the actions of microorganisms were the reason for the increase. Garg *et al*. (2005) and Siddique *et al*. (2005) have found that organic waste (press mud) has a higher C/N ratio and phosphorus (2.5%) content than worms fed with cow dung or clay loam soil alone, which supports better growth (length and biomass) and results in earlier development, clitellum differentiation, and cocoon release in *Lampito mauritii* and *Eudrilus eugeniae*. *Eudrilus eugeniae* showed the maximum hatching viability, the greatest cocoon, and biomass. After processing earthworm *Eutyphoeus waltoni*, all combinations of animal dung and kitchen waste showed a substantial decrease in pH, Electrical Conductivity (EC), Total Organic Carbon (TOC), and carbon-to-nitrogen ratio as compared to the original feed mixture. Humic acid generation and the mineralization of nitrogen and phosphorus compounds during vermicomposting are responsible for pH reduction (Siddiqui and Singh, 2023a). Due to the activities of the earthworms, the microorganisms in their guts produce organic acids, which can lower the pH in feed combinations. After consuming the earthworms, the original feed mixture's electrical conductivity significantly declined. This could be due to the loss of nutrients and the subsequent release of various mineral salts. EC was significantly reduced (28.69%) in the final vermicompost during the sludge from textile industries (Badhwar and Singh, 2021). Bhat *et al*. (2015) reported that the vermicomposting with *Eisenia fetida* reduced the C/N ratio and increased TKN in textile mill sludge mixed with cow dung. Total K and Ca were lower in the final cast, while total P was higher. The study examines vermicomposting, a process that uses earthworms like *Lampito mauritii* to convert organic waste into nutrient-rich fertilizer. This process poses environmental risks as it transforms waste into biofertilizers. The procedure increases the waste's nitrogen concentration, exchangeable potassium, and accessible phosphorus while decreasing its pH, organic carbon, organic matter, and C/N ratio. This eco-friendly technique offers a solution to biological waste disposal issues (Fig. 1). Additionally, after using *Lampito mauritii* and *Eudrilus eugeniae* separately, Vasanthi *et al*. (2018) observed increased levels of macronutrients like N, P, K, and Mg in the vermicomposts made from single and combined uses of various organic wastes like coir, pressmud, farm wastes, farm yard manure, and cattle dung. It could occur as a result of the earthworms simultaneously absorbing nitrogen in the form of mucus and nitrogenous excretory material, and losing carbon through microbial respiration and mineralization (Suthar, 2007b).

Total phosphorus content significantly increased after earthworm *Eutyphoeus waltoni* processing, consistent with reports of increased phosphorus content during vermicomposting due to phosphorus mineralization (Suthar, 2007c). Phosphorus has mineralized, increasing phosphorus content in the final feed combination. Earthworms used P-solubilizing organisms in

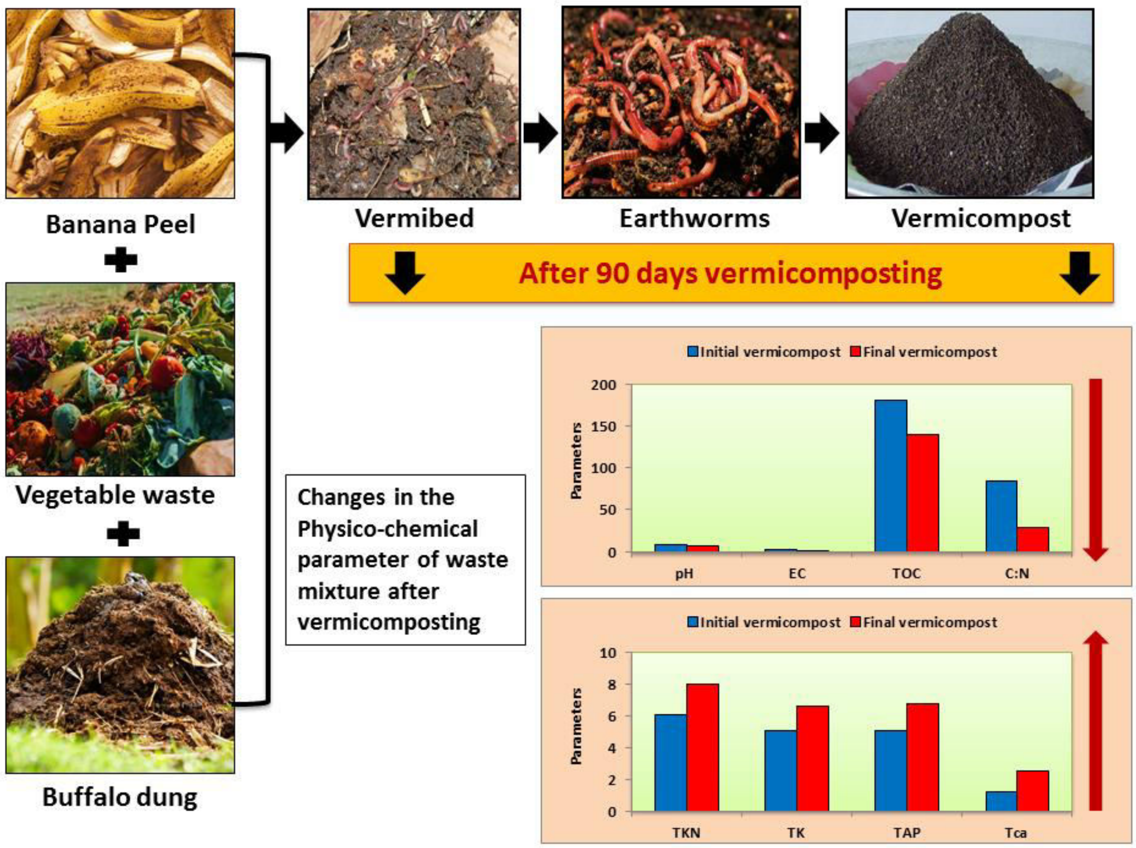

Fig 1: Potential utilization of biological waste as feed material for earthworms.

their guts that helped them turn insoluble P into soluble forms throughout the vermicomposting process (Gebrehana, 2023). Siddiqui and Singh (2023b) reported that the physico-chemical changes after cow dung mixed with vegetable waste and banana peels in different ratios after earthworm *Eutyphoeus waltoni* processing showed a significant decrease in the level of pH, EC, TOC, and C/N ratio whereas a significant increase in TKN, TK, TAP, and TCa. Chauhan and Singh (2012) reported that the utilization of earthworm *Eisenia fetida* improves the biofertilizer by enhancing the quantity of N, P, and K and also subsequently reducing the level of pH and EC as well as C/N ratio, a characteristic feature of the ideal fertilizer. After vermicomposting, *Eudrilus eugeniae* reduces the C/N ratio in the final mixture, indicating that this species improved the mineralization of organic matter more effectively (Pattnaik and Reddy, 2010). Bhadauria and Saxena (2010) observed that vermicompost made by earthworm species exhibited an important rise in total N, P, and K in the organic components. The microbial and enzyme activity in the earthworms' guts encouraged the mineralization of these elements during the vermicomposting process. Nath *et al*. (2009) reported that there were significant increases in total nitrogen, total phosphorus, total potassium, and total calcium in the final vermicompost using feedstock of different animal, agro, and kitchen wastes by *Eisenia fetida*. Bharadwaj (2010) reported that kitchen waste material had high pH values and trace amounts of nutrients such as potassium, phosphorus, and total nitrogen. The physical and chemical properties of the waste material were significantly altered by the vermicomposting activity, making it a valuable tool for organic farming. With the increase in the vermicomposting time, the pH starts to drop after 75 days. There could be a high level of potassium, phosphorus, and nitrogen mineralization. Revathi *et al*. (2014) observed increased N, P, and K due to higher mineralization during vermicomposting of jackfruit leaf litter and bedding material mixture. *Lampito mauritii* was found suitable for the vermicomposting of bedding materials (pressmud and cowdung) and municipal solid waste mixed with different ratios. The vermicomposts of *Lampito mauritii* contain the highest levels of N, P, and K mineralization among earthworms. The vermicompost of *Lampito mauritii* showed the maximum reduction pH, higher EC, and a lower percentage of C. It proves the high quality of the vermicompost produced by *Lampito mauritii*. The reduced C/N ratio improves this also (Ananthakrishnasamy and Gunasekaran, 2014). The recent findings observed that *Lampito mauritii* turned manures into castings that had greater nutritional content and increased the mineralization process. These composts have a low carbon-to-nitrogen ratio and an excellent nutritional value, making them ideal for usage in farms where they will increase the production of crops (Fatima and Singh, 2023a).

Conclusion

Different waste generated from household waste in the form of vegetable waste, fruit waste, and banana peels cause negative effects on the environment and also affect the physico-chemical properties of soil. The management of organic waste through vermicomposting is less expensive, non-hazardous, and eco-friendly as well as the production of biofertilizers which improve soil fertility. The earthworm is a major soil fauna, which is more beneficial for the maintenance of the soil's physico-chemical texture through the recycling of wastes. The earthworm *Lampito mauritii* is the most suitable species for the proper management of biological waste. A larger population of earthworms will be better for more conversion of wastes. Hence, it has been concluded that the different biological wastes can be utilized as a preferable feed mixture for the growth and reproduction of earthworms. Its primary goal is the recycling of various biological wastes to create new, economically viable, and agriculturally valuable products.

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