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Role of Feed Substrates on the Reproductive Potential of Earthworm *Metaphire posthuma*

Rai Shruti and Singh Keshav*

Vermibiotechnology Laboratory, Department of Zoology, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India

**Corresponding Author*

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Abstract: Among several species, *Metaphire posthuma* has emerged as a crucial earthworm species for soil fertility due to its remarkable adaptability and efficient ability to manage organic waste. However, earthworm ability to reproduce is greatly influenced by the quality of their habitat, particularly the type of organic material available. The organic wastes that are plentiful and rich in nutrients include animal dung, leaf litter, and poultry litter. These substrates provide earthworms with the ideal conditions for reproduction and feeding. The kinds of organic feed ingredients employed affect growth, cocoon creation, hatching success, and overall reproductive efficiency. High-protein substrates that promote faster maturation and more cocoon growth include cow dung, poultry manure and composted kitchen trash.

Keywords: Organic feed substrate, Animal dung, Nutrients, Earthworm, *Metaphire posthuma,* Cocoon production

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Introduction

Earthworms are vital to soil processes because they act as aerators, crushers, grinders, chemical degraders, and biological stimulators (Edwards and Bohlen, 1996). *Metaphire posthuma* is well known for its efficacy in organic matter degradation and soil conditioning (Bhattacharjee and Chaudhuri, 2002). One of the key factors affecting their reproduction is the type of feed substrate available to them, which determines their growth, maturation, and cocoon formation. Organic wastes that are plentiful and rich in nutrients include animal dung, leaf litter, and poultry litter (Yadav and Singh, 2024). Similarly, the physiochemical properties of soil can have a significant influence on earthworm activity and reproduction. They have been demonstrated to be beneficial for managing organic waste, enhancing soil, and reclaiming land. These benefits include texture, pH, and moisture holding capacity of protein for animal feed. Only a small portion of the organic waste that earthworms consume is utilized for bodily production. Rather, the vast majority of this waste is excreted in a partially digested state. The intestines of earthworms are home to a wide variety of microorganisms, enzymes, hormones, etc. In a brief time frame, these partially digested solids swiftly decompose and turn into vermicompost (Edwards and Lofty, 1972).

The density of earthworms is one of the key elements influencing the physicochemical texture and characteristics of soil. Jansirani *et al.* (2012) reported that the earthworms can transform nutrients by significant factors such as temperature, food, moisture, pH, and the level of soil distribution. Earthworm castes have more accessible nitrogen, phosphorus, potassium, and calcium as well as a greater ability for cation exchange than the surrounding soil. Certain micronutrients, like zinc and boron, are more easily accessible in earthworm excrement due to chelation. The soil particles that enter an earthworm's digestive system generally has a neutral pH, which is primarily attributed to organic compounds produced in the gut that act as buffers. As a result, earthworm casts tend to maintain a near neutral pH. The material released by earthworms contains a high concentration of beneficial microorganisms that assist in the decomposition of crop residues. Within the digestive system of earthworms, millions of microorganisms play a crucial role in nitrogen fixation and the breakdown of organic matter (Garg *et al.*, 2005). Due to these diverse influences on the soil structure, nutrient cycling and biological acivity, earthworms are widely recognized as "ecosystem engineers" (Jones *et al.*, 1994).Consequently, there has been significant scientific focus on identifying the specific factors influencing the population density and structure of earthworm communities.

Biological wastes:

Biological systems generate biological wastes, which endanger the environment and have a number of detrimental effects on domesticated animals and human life in the absence of appropriate protocols for disposal and management. The massive generation of fly ash poses a critical ecological challenge. Fly ash, a particulate by-product, causes major waste disposal problems when coal is used in power plants. This substance significantly modifies the pH balance and moisture retention capabilities of sandy soils. Furthermore, the biological breakdown of this refuse generates a number of dangerous gases. India produces vast quantities of bovine manure alongside residential and agricultural waste annually. The surrounding neighbourhood experienced a variety of odor's and environmental issues as a result of these wastes. Industrial wastes from gaur gum released toxic gasses that caused major environmental issues. If horse, goat, and sheep manure is not correctly managed, it might cause toxic concerns (Bhattacharya and Chattopadhyay, 2004; Nath and Singh, 2016).

If biological wastes are not effectively managed, they pose a major threat to human and animal health as well as the environment (Kaviraj and Sharma, 2003; Bhattacharya and Chattopadhyay, 2004; Deka *et al.*, 2013). Large amounts of biological waste were produced in both industrialized and developing nations as a result of the world's population growth. Joshi and Chauhan (2006) reported that thousands of tons of municipal solid trash are produced every day due to the expansion of industries and the human population. Suthar and Singh (2008) noted that India generates immense quantities of cattle manure alongside agricultural and domestic refuse annually. Such organic residues contain a variety of dangerous bacteria that generate different odours and environmental issues. Suthar *et al.* (2005) estimated India's annual generation of farm waste to be approximately 320 million tons.

This enormous volume of garbage originates from residential activities as well as urban, industrial, and agricultural sources. In India and other poor nations, using animal manure to produce high-quality crops is a popular technique (Wijewardena, 1993, 2000; Wijewardena and Yapa, 1999; Garg *et al*., 2005). Heavy metal levels in specific agricultural fields rise when chemical fertilizers and animal manure are applied to boost crop output (Wijewardena and Gunaratne, 2004). Biological treatments provide a more efficient way to turn these residues into fertile, high-quality organic compost (Paraskeva and Diamadopoulos, 2006). Nair et al. (2006) indicated that the management of solid waste stands out as a critical global ecological challenge stemming from urbanization and population growth. Environment and human health are at risk due to the hazardous problem of municipal solid wastes that contain large amounts of metals like Fe, Cu, Zn, and Pb. Distillery effluents and sugar mill sludge are examples of industrial pollutants that exert detrimental effects upon ecological integrity and human well-being (Pandey and Carney, 1994).

Animal wastes:

Every year, India produces millions of tons of agricultural waste and cow manure (Gupta, 2005). Reinecke *et al*. (1992) reported that the microbial breakdown of these wastes results in unpleasant odours and contributes significantly to pollution, which can cause several diseases posing a major threat to both human and animal health. Improper discharge of animal wastes leads to the spread of animal diseases, contamination of groundwater, runoff into surface water bodies, degradation of soil biological structure and disastrous spills (Sakar *et al*., 2009).

Additionally, livestock excrement and industrial sludge constitute a severe risk to both human safety and the ecological system (Bhartiya and Singh, 2012). Heavy metals and hazardous metals are added to soil by animal faeces. It enter into the human body through food chain (Hernandez *et al*., 1991; CRI, 1994; Hu, 2002). livestock dung in India is produced at a rate of 12.20 kg per animal per day for buffalo, 11.6 kg per animal per day for cows, and 0.70 kg per animal per day for goats. High livestock density is always accompanied with creation of an excess of animal waste, signifying major pollution concern for the environment in these places. 60% of the manure produced worldwide comes from cattle. Poultry and pigs make up 10% and 9%, respectively. Farmers and animals may suffer as a result of anaerobic fermentation in open Hargon’s dole, which produces substantial methane emissions and dangerous gases during the biological breakdown of the manure (Poeschl *et al*., 2012).

Horse manure has been reported to reduce soil populations of eggplant parasites by enhancing nutrient retention, particularly phosphorus and nitrogen. However, major risks associated with its use include pathogen contamination and ammonia volatilization (Holm-Nielsen *et al*., 2009). Despite its high fertilizer value, animal waste is currently underutilized, resulting in the loss of valuable nutrients and increased environmental concerns, particularly due to odor emissions .

Traditional farming practices in India have historically emphasized the integration of crop and livestock production, with animal manure commonly used as a natural fertilizer. However, the expansion of the chemical fertilizer sector during the Green Revolution enabled the widespread availability of low-cost inorganic fertilizers, which rapidly replaced organic manures derived from animal waste .

Agro wastes:

The term 'agro-waste' denotes to residues generated from diverse agricultural activities. Such agricultural by-products comprise manures, animal bedding, stalks, husks, foliage, and vegetable matter. Farming activities are the standard source of agro-waste. Within agrarian environments, agricultural waste is frequently worthless and will be thrown away. Concerns about health, safety, the environment, and aesthetics may arise from the buildup of agricultural waste. Accordingly, this is an issue that needs to be disposed of safely. Rao (1993) reported that wastes contain both non-soluble materials such as cellulose and lignin, as well as soluble compounds including sugars, amino acids, and organic acids. Additional components include lipids, oil waxes, resins, pigments, proteins, and minerals. Agricultural waste, such as decomposing plant parts, is the principal origin of organic content within the soil. As a result, farmers can employ agro-wastes as the least expensive way to increase soil fertility. The construction of a traditional agricultural system that is chemical-free and safe for both humans and animals includes a variety of unconventional farming methods known as organic farming and organic vermicomposting which is the way to live in balance with the natural world (Gupta and Garg, 2007).

Kitchen Wastes:

Vegetable trash makes up the majority of the 320 million tonnes of agricultural waste produced in India each year. Due to their high biodegradability, vegetable scraps that are gathered from the vegetable market and disposed of in municipal landfills cause environmental problems (Bouallagui *et al*., 2004). Compared to other wastes, vegetable waste decomposes more readily since it is a pure organic material, making it an excellent material for vermicomposting. Chinese mustards, cabbages, spinach, and leaf mustards, and other vegetables make up the most prevalent vegetable waste composition. Bananas make up almost 16% of all fruits produced worldwide, making them the second most popular fruit after citrus fruits. India is the world's biggest producer of banana fruit, accounting for 27% of global production. The banana is a very nutritious fruit that is high in calcium and potassium. Banana plant components are valuable in a variety of industrial uses, including food, feed, pharmaceuticals, and packaging. Vitamins, carbohydrate, crude protein, crude fat, total dietary fibre, polyunsaturated fatty acids, and micronutrients (K, P, Ca, and Mg) are all abundant in banana peels (Debabandya *et al*., 2010).

Vermicomposting of vegetable waste is considered as one of the greatest conditions for the development and growth of beneficial and symbiotic microorganisms. This method can be used to regulate soil fertility in the longer term to ensure agricultural sustainability (Vuković *et al*., 2021). Using vermibiotechnology, earthworms may convert kitchen waste into rich nutrient biofertiliser, and this process is the most effective technique to reduce kitchen waste properly.

Effect of feed combination and earthworm reproduction:

Suthar (2007) reported that trash and earthworm output were closely linked to substrate quality, primarily in terms of their chemical and biological makeup. Cattle excrement is one of the best food sources for earthworm (Siddique *et al*., 2005). These workers observed that when earthworms were added to organic wastes, their growth rate and reproduction activity increased. When earthworms were fed a diet high in nitrogen, they grow more quickly. and generate more cocoons than when nitrogen is scarce. Earthworms that are fed animal dung, protein-rich leaf litter, and soluble sugar grow more quickly. The growth and reproductive performance of *Perionyx excavatus* was investigated after feeding with cattle and goat manure vermicompost. Loh *et al.* (2005) found that *Eisenia fetida* produced more cocoons and gained more weight in cattle faeces than in goat dung. Kale *et al*. (1982), observed *Perionyx excatuvus* capacity to decompose organic waste. Chaudhuri *et al.* (2000) reported that the feed mixture of cow dung and straw had the highest rate of reproduction in *Perionyx excavatus*. The earthworm *Perionyx excavatus* grows and reproduces most when fed a mixture of cow dung and banana trunk or cow dung and vegetable scraps (Sadia *et al*., 2020).

The makeup of the meal is one of the key elements for improved clitellum growth in earthworms. *Perionyx excavatus* generated more cocoons (1.4/worm/day, or 2.8/worm/week) beginning on day 70 and continuing until the trial was finished. Reineck and Hallatt (1989) and Elvira *et al*. (1998) observed that adding cattle faeces to paper mill effluent increased overall biomass by 2.2 to 3.9 times and the number of earthworms by 22 to 36 times. Earthworm survival, development rate, and reproductive potential are influenced by food type, palatability, and quality (Tripathi and Bhardwaj, 2004). Bhat *et al*. (2014) discovered that the earthworm population decreased when the meal mixture's press mud content increased. Since this was shown to be suitable for *Lampito mauritii* growth and population development as well as the vermicompost's final granulating on its surface at its earliest stage, the ideal ratio of bagasse to buffalo dung was 1:1.

The production of cocoons is significantly influenced by the nitrogen content of the substrates. Food supplies are also crucial for cocoon production. Ramalingam (1997) used press mud to study the life cycle, growth, and reproduction of *Eudrilus eugeniae* and *Lampito mauriti*. Higher concentrations considerably slowed down the rate of degradation and had a delayed and diminished effect on earthworm cocoon production using various binary combinations of buffalo dung and agro-wastes significantly increased *Eisenia fetida* growth and cocoon formation.

It has been reported that the worm biomass increased in all bagasse feed combinations except for buffalo dung combined in 1:3 ratios with sugarcane bagasse. When *Eudrilus eugenia* feed on different organic substrates, their body weight increased (Ratnabala *et al*., 2008). The worms gain weight as a result of having more food due to the presence of fungi during the vermicomposting process (Pramanik and Chung, 2011). Sogbesan *et al.* (2007) reported that cellulose substrate had the highest specific growth rate at 0.76%, whereas soil substrate had the lowest at 0.62%. Manna *et al*. (2003) and Pramanik *et al*. (2007) reported that sugarcane processing by-products are excellent substrates for earthworm rearing. They also produce a product that is rich in chelating and phyto-hormonal components, high microbiological content, and stabilized humic compounds.

Effect of feed combination on Metaphire posthuma:

More than 80 years ago, Gates (1939) classified 24 species of the Megasocieties family in Thailand. The majority of these species are from the genera *Amynthas* Kinberg, 1867, and *Metaphire* Sims and Easton, 1972. In Southeast Asia, the two genera are widespread and cohabit practically everywhere (Gates, 1972). Because the two genera are so similar, it is difficult to distinguish between them. In *Metaphire*, ovulatory pouches with male pores are present, whereas in *Amynthas,* male pores are superficial. With 112 nominal species spread across 13 species groups, the genus *Metaphire* is the second biggest group after *Amynthas.* The diversity of *Metaphir*e was expanded to about 200 species by later descriptions from different parts of the world (Blakemore *et al*., 2006). One of the most common terrestrial earthworm genera in Thailand and the surrounding nations is the genus *Metaphire*. Six *Metaphire* species-- *Metaphire anomala*, *Metaphire bipora*, *Metaphire peguana*, *Metaphire planata*, *Metaphire posthuma*, and *Metaphire virgo* have been reported from Thailand .

The Tarai region is home to the endogenic *Metaphire posthuma*, a geophagias burrowing worm that clearly prefers organic substrate. In adverse condition it can reach up to 10 cm to 20 cm in depth. It can be found in lawns, gardens, grasslands, cultivated land, deep forests, and riverbanks. The reproductive capacity of the earthworm *Metaphire posthuma* varies significantly emergent upon the specific feed substrate provided. *Metaphire posthuma* exhibits a dietary preference for cow dung and poultry droppings rather than field soil, as demonstrated by the fact that earthworms raised on cow manure (raised alone) grew more quickly than those raised in field soil (raised alone). *Metaphire posthuma*'s growth and reproduction rates depend on the parameters that determine its potential utility as a waste decomposer and for plant development.

Metaphire posthuma may be more advantageous in some circumstances because it possesses a significantly abbreviated life cycle and holds the capability to reproduce without mating; however, this is balanced by a reduced growth velocity and a lower yield of cocoons and hatchlings per cocoon compared to other vermicomposting species. These findings also suggest that the formation of a viable population of *Metaphire posthuma* in agricultural fields may depend critically on the application of organic manure to affect crop productivity and soil fertility. The growth and reproduction of *Metaphire posthuma* in three distinct substrates field soil, cow manure, and poultry droppings were assessed in a study by Bisht *et al*. (2007). The results showed that earthworms raised in cow manure had the fastest development rates; they reached sexual maturity on day 51 and when kept alone, produced about 0.16 cocoons per worm per week. On the other hand, worms raised in poultry droppings matured by day 64 and produced about 0.15 cocoons per worm week, whereas worms raised in field soil reached maturity by day 50 and produced about 0.24 cocoons per worm per week. In contrast, singly raised worms produced more cocoons across all substrates than those reared in batches. Cocoons had an average incubation duration of 23 days, an 84% hatching success rate, and roughly 1.3 hatchlings per cocoon. The cow manure is the best substrate for increasing *Metaphire posthuma* capacity for reproduction, followed by field soil and poultry droppings due to its high nutrient content, favorable C:N ratio and enhanced microbial activity.

Effect of factors on feed substrates and earthworm reproduction:

Temperature, aeration, moisture content, pH level, C/N ratio, soil type, and organic matter are the most important biotic and abiotic factors that influencing earthworm reproduction.

(i) *Moisture*:

There is a strong correlation between the moisture saturation of organic refuse and the rate of earthworm development. A comparison of earthworm maturation and the vermicomposting mechanism across diverse thermal conditions and humidity levels suggests that the ideal moisture spectrum for vermicomposting is 65–75% across all temperature ranges (Zuberi *et al*., 2015). Vermicomposting bedding needs to be able to retain enough moisture while the earthworms breathe through their skins. If the bedding has less than 45% moisture, the earthworm survival may be severely affected. Although earthworms can tolerate moisture levels ranging from 50% to 90%, the epigeic species *Eisenia fetida* and *Eisenia andrei* exhibit faster growth and development at moisture levels between 80% and 90%. The microorganisms are also necessary for vermicomposting. Tchobanoglous *et al*. (1993) reported that vermicomposting becomes less effective at moisture concentrations below 40% and almost ceases at level below 10%. Moisture is one of the most important features of soil. Earthworm diversity is influenced by both temperature and moisture (Bhaduria and Ramakrishna, 1989).Total earthworm density was positively correlated with soil moisture and showed a significant correlation with biomass.

(ii) *Temperature*:

Earthworm activity, metabolism, growth, respiration, and reproduction are all significantly impacted by temperature. Sinha *et al.* (2008) stated that an earthworm population cannot continuously grow at temperatures higher than 25°C. *Eisenia fetida* cocoons can withstand extended deep freezing and still be alive (Georg, 2004) but when the temperature falls to single digits, they are unable to procreate and eat enough food. For the best vermicomposting efficiency, temperatures should be kept at 15°C, and for successful reproductive vermiculture operations, they should be kept at 20°C. Earthworms either migrate away from unfavourable conditions or, if unable to do so, rapidly perish at temperature exceeding 35°C. Because bacteria reproduce twice for every degree celsius that the temperature rises and most active between 15 and 30°C, temperature also has a big effect on bacterial activity. Earthworms' activity, metabolism, growth, respiration, and reproduction are all strongly impacted by temperature, just like those of other poikilothermic species. Humidity and temperature frequently have a negative relationship, and high surface temperatures and dry soil greatly restrict earthworms more than low temperatures and wet soil. With dwindling populations, earthworms can mitigate the consequences of climate change, which can then interact with soil biota. They also came to the conclusion that earthworm buildings are especially crucial for species to find cover and avoid unfavourable soil conditions like water scarcity as temperatures rise.

(iii) *Aeration*:

Earthworms cannot live in an anaerobic environment because they need oxygen to breathe. The compost material works best when it is porous and well-aerated. Earthworms also benefit from moving about their bedding, which helps to aerate it. Large-scale migration of *Eisenia fetida* from oxygen-starved, water-saturated substrates or from regions where carbon dioxide or hydrogen sulfide has been accumulated (Edwards and Arancon, 2004; Dominguez and Edwards, 2011). For better aeration conditions, vermibed should be properly aerated either mechanically or manually which cause better growth of earthworm's (Ismail, 1997). In around 36 hours, the large species *Lumbricus terrestris*, which emerges at night to feed at the soil surface, died when oxygen levels reached 0.82mg oxygen.

(iv) *pH value*:

The vermicomposting process is significantly impacted by the pH level. Edwards (1998) reported that epigeic worms can live in a pH range of 5 to 9. Worm bedding often has a lower pH over time. The pH of the bed falls to neutral or slightly alkaline if the food source or bedding is alkaline; it may fall considerably below 7 if the food source or bedding is acidic. Most majorities of species prefers slightly soils with pH ranging between 7.4 and 7.8. *Eisenia fetida* and *Perionyx excavatus* prefer a pH range of 8.1 in the dung heap for a better growth rate . While urbanization reduces earthworm biomass and abundance, with soil moisture and pH being the two most significant edaphic variable (Xie *et al.*, 2018). Compost can thrive at pH levels as low as 4, but 6.5 to 7.5 is the ideal range.

The most important characteristic of soil is its pH level, which influences all other soil properties as well as the availability of nutrients. It limits the variety, range, and species of earthworms. Goswami and Mondal (2015) reported that the high earthworm population may be caused by high nitrogen, organic carbon, steady moisture, and soils with a pH range that is rather neutral. As a buffer, vermicompost keeps the soil's pH stable (Singh and Kaur, 2014). Earthworms are extremely sensitive to the pH (hydrogen ion concentration) of aqueous solutions. The majority of earthworm species prefer soils with a neutral pH (pH = 7.0) (Kumar and Singh, 2013).

(v) *C/ NRatio*:

Since carbon and nitrogen constitute the essential building blocks for cellular development, a good vermicomposting process requires an ideal carbon to nitrogen ratio. Vermicomposting does not have a set C/N ratio. Factors such as the nature of the feedstock, the specific earthworm species utilized, and the targeted objective (substrate stabilization versus earthworm proliferation) all influence the ideal C/N ratio. Ndegwa and Thomson (2000) discovered that while an elevated C/N ratio yielded a more stabilized end-product, a reduced C/N ratio enhanced the accumulation of earthworm biomass. They suggested that C/N ratio of 10 is optimal for maximizing earthworm reproduction when utilizing bio solids as a substrate, whereas a ratio of 25 is preferable for generating stable vermicompost.

(vi) *Soil type*:

Soil biota is influenced by soil types. In addition to management approaches, biotic and abiotic factors also have an impact on earthworm variety and abundance. High earthworm density and biomass have been found in a variety of soil types, including sandy clay and loamy. Different soil types, such as loamy sandy and clay, have proven important because of their high biomass and earthworm density. Cast characteristics are more influenced by the type of soil than by earthworms. Earthworms are found in nearly every kind of soil ecosystem. Healthier soil will have a higher concentration of earthworms.

(vii) *Organic matter*:

The quantity of organic material present in the soil significantly impacts earthworm diversity. A region's diversity is determined by its climate and the amount of organic matter present (Hackenberger and Hackenberger, 2014). Because they carry out a variety of tasks, including decomposing organic debris and releasing plant nutrients into the nearby soil, earthworms are crucial to the ecosystem as a whole. Earthworms proliferate and spread more readily when there is organic carbon in the soil. Soil fertility and productivity are indicated by the volume of organic matter contained within. More than 3% organic matter makes good soil. The most significant soil creatures influencing the breakdown of organic materials are earthworms. Soil nitrogen cycling and structural evolution, especially in productive environments. It demonstrates that earthworms like the soil ecosystem's abundant organic matter and nitrogen. The spatial arrangement of organic material within the soil plays a major role in determining earthworm distribution. High-grade organic substances provide positive support for earthworm populations (Cesarz *et al*., 2013). Earthworms population are generally low in soils with low levels of organic matter. Numerous studies have documented robust positive correlations linking soil organic matter content with earthworm abundance and biomass.

Conclusion

Vermicomposting is a technique employing earthworms to convert organic refuse into superior-grade compost. Increased earthworm populations will improve waste conversion. Vermicomposting is a less expensive, non-hazardous, and environmentally friendly method of managing organic waste. It also produces biofertilizers that increase soil fertility. By recycling trash, the earthworm, a major member of the soil fauna, helps to maintain the physical and chemical structure of the soil. *Metaphire posthuma* is an ecologically and economically important earthworm species with significant potential in soil fertility improvement, organic waste recycling and sustainable vermiculture practices. Its reproductive success is highly influenced by environmental conditions, particularly the quality of soil and availability of organic matter. Favorable substrate rich in nutrient and microbial activity enhanced cocoon production, hatching success and juvenile survival, while poor or contaminated substrate adversely affect its reproductive performance. The species exhibits considerable adaptability to different soil types and organic feed resources, indicating high reproductive plasticity under suitable conditions. This adaptibilty makes *Metaphire posthuma* a valuable species for organic waste management and soil restoration programs. Therefore, it has been determined that the various organic wastes can be used as an ideal feed mixture for earthworm development and reproduction. Its main objective is the recycling of different wastes to produce new, profitable, and agriculturally significant goods.

Ethical Statement

This is a review article hence no Ethical Approval needed.

Author Contributions

Each author has contributed equally in designing the research, conducting thorough analysis, drafting the manuscript, and refining its content. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

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