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Optimizing Agricultural Residue: A Comprehensive Review on Waste Utilization and Management, with Special Emphasis on Vermicomposting

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ABSTRACT

Agriculture wastes are the product,that are theremainsof agriculture products. These remains can be useful in many other ways. Globally, agriculture usage is increasing day by day which also leads to agriculture waste production. Agricultural waste, by-products, and co-products typically refer to residual materials from plants or animals that are not utilized as food or feed, and may contribute to extra environmental and economic challenges within the farming and initial processing stages. Therefore, management of agriculture waste is crucial. After management the waste should be utilize in adequate manner, so that waste problem can be puzzle out. Vermicomposting is the one of greatest method for agriculture waste management. Through vermicomposting people can produce organic fertilizer which is eco-friendly. It also providesjob opportunity and income for people. This review paper discussing about the management of agriculture waste and its utilization.

Keywords: Agriculture waste;management; utilization; earthworm; vermicomposting

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1. INTRODUCTION

The amount of organic waste being disposed of, such as agricultural waste, has increased, posing an increasing number of environmental and economic problems(Edwards et al., 2004).Agriculture waste is one of the world's most pressing issues today. Most of the rural population are depending upon agriculture, which increase the agriculture waste because of the large usage (Vyas et al.,2022). Compare to the local and traditional agriculture method, modern agriculture method produces large amount of waste (Lopez et al., 2020). The main reason for agriculture waste is due to the high demand of agriculture products (Hassan et al.,2020). The agriculture waste is also result in environmental pollution because the proper cleaning is not done before bringing the agriculture product into market (Gupta et al., 2019), so the waste is either burned or land filled (Mane et al., 2012). Because agriculture waste isorganic waste, they can convertinto products that are useful (Gupta at el., 2019).The main agriculture wastesare crops straw, livestock manure(Mengqiet al., 2021),aquaculture waste, agro-industrial waste, slaughter waste, and poultry waste(Koul et al., 2022).

Studies are found that, one of the best ways to prevent agricultural waste from building up is vermicomposting, which turns it into manure. Earthworms, which are beneficial to the environment and eco-friendly, are used in vermicomposting. This process turns organic waste into high-quality biofertilizer that may be used in agriculture.(Cao et al., 2021).

2. AGRICULTURE WASTE

Waste is the substance that we discard after its initial use. One of the main solid waste sources in developing nations like India is agricultural waste. Because of the high demand for agricultural products, waste is also increasing.

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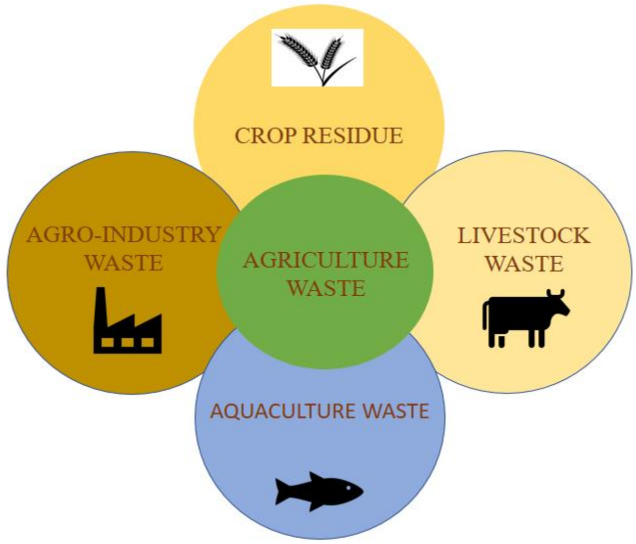

Fig 1:The diagram showing different types of agriculture waste.

2.1. Agriculture crops residue

The amount of agricultural waste produced worldwide is significant, making crop leftover management crucial (Clay et al., 2019).The things that remain in an agricultural field after harvesting are known as agricultural crop residues (Maji et al., 2020). In terms of quantity produced, the top four crops in the world are sugarcane, corn, rice, and wheat. More than 42% of the calories consumed by all people are found in rice, corn, and wheat combined. On the other hand, one of the most commonly used and manufactured oils in the world is palm oil, which is derived from the oil palm tree. The cultivation and manufacturing processes that utilise these crops as raw materials result in solid wastes such oil palm empty fruit bunch (OPEFB), corncob, rice straw, rice husk, and wheat straw. Since crops are the most produced and eaten agricultural items in the world, there is an abundance of solid waste linked with them (Taherzadehet al.,2019).

2.2. Livestock

In addition to producing meat, milk, and eggs, the livestock and poultry industries also produce significant amounts of solid and waste water that may or may not be good for the environment.

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Excreta from cattle or poultry, along with related feed losses, beddings, wash water, and other waste products, are rich resources that, when used properly, can replace a sizable portion of inorganic fertilizers (Ogbuewuet al.,2012).Animal wastes are usually thought as the waste products that live animals excrete. But depending on how the waste is produced, it might also contain hay, straw, wood shavings, or other organic debris sources. Benefits of applying excreta to soil include enhanced soil tilth, increased capacity to hold water, and some nutrients for plants. Concentrated excreta or high application rates to unmanaged soils can result in elevated salt concentrations and significant pollution, either on- or off-site. Animal waste has a lot of good ingredients that, if recycled properly, can be used to grow crops,create energy, and feed animals. Animal wastes are a common source of environmental concern because they release a lot of CO and ammonia into the atmosphere, which can cause acid rain and the greenhouse effect, as well as unpleasant odors. It might also contribute to the spread of infectious diseases and contaminate water sources. The odors being released and polluted water sources from improperly planned water disposal could lead to social unrest. Large farms cannot effectively utilize their wastes unless they dispose of their wastes properly, replenishing the soil with nutrients while preventing pollution and the spread of diseases and pathogens.

2.3. Agro-industry waste

Out of all the horticulture crops, fruits and vegetables are the most widely used products. They are eaten both raw and minimally processed because they contain nutrients and compounds that are good for your health. The production and manufacturing of horticultural crops, particularly fruits and vegetables, have increased very significantly to meet the rising demands brought about by population growth and changing dietary habits. Increased growth and production, coupled with inadequate infrastructure and handling techniques, have caused enormous losses and waste of these essential food items, as well as the residues, byproducts, and component portions of them. According to estimates from the United Nations, at least one-third of the world's food production—roughly 1.3 billion metric tons—is lost or wasted annually (FAO 2014). Horticultural commodities have the highest rates of loss and waste of any food type, up to 60% (Maji et al., 2020).

2.4. Aquaculture

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Feeds are being used more frequently to increase production as a result of the expansion of aquaculture.The amount of feed that is used in a system is the main factor that determines how much waste is generated in it. This section of the report, which is a summary of the data supplied by, discusses the wastes that arise from the use of aquaculture feeds. Metabolic waste is one of the main wastes produced in aquaculture and can be suspended or dissolved. Roughly thirty percent of the feed used will end up as solid waste on a well-managed farm. The temperature outside affects feeding rates. A rise in temperature causes people to eat more, which increases the amount of waste produced.Production unit water flow patterns play a critical role in waste management because they minimize fish feces fragmentation and enable the settleable solids to settle and concentrate quickly. This can be crucial because it allows for the rapid capture of a large proportion of the non-fragmented feces, which will significantly lower the amount of dissolved organic waste (Obi at el.,2016).

3. AGRICULTURE WASTE MANAGEMENT

3.1. Agriculture Waste Management System

Agricultural waste requires selective yet efficient management techniques among many other types of wastes. An effective strategy for managing the vast amounts of agro-wastes generated annually requires careful analysis and classification of their composition, types, and sources. Given that agricultural waste poses a significant environmental threat, it is imperative that waste be managed in a way that is environmentally friendly. This is the reason behind the adoption of a sustainable waste management strategy that encompasses greener production, waste minimization, prevention, and environmentally sound practices like composting, biodegradation, recycling, reuse, and reduction as well as the creation of zero-emission industrial ecosystem (Koul et al.,2022).

The optimal way to use, handle, and store waste is through the implementation of a well-planned Agricultural Waste Management System (AWMS) (Bhatt et al., 2018).Six main categories, each with a distinct and descriptive objective, make up the system. Production, Collection, Transfer, Storage, Treatment, and Utilization are these separate components (Taherzadehet al., 2019).

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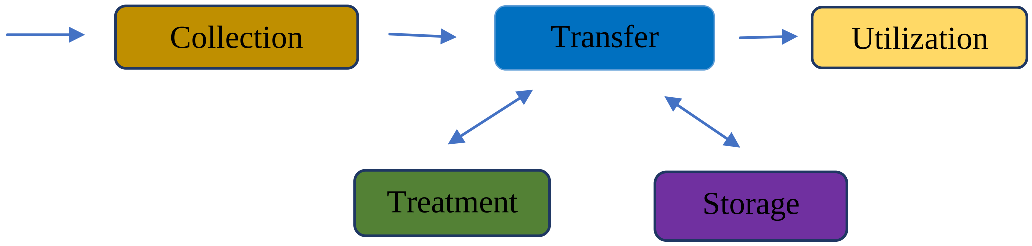

Fig 2:The image illustrates the different stages of agriculture waste management system.

a) Production:

The first and crucial step in designing a waste management system involves analyzing the quantity, mass,type, origin location, density, consistency, and composition of agricultural waste. To comprehend the waste production cycle effectively, it is advisable to identify the geographical region of waste generation and the corresponding seasonal zones affecting agricultural activities (Bhatt et al., 2018).

The production rate of crops in the field or the generation of processed food production through agriculture is somewhat directly correlated with the amount of waste produced. The goal is to minimize waste right from the production's outset by implementing innovative measures tailored to specific types of waste (Atinkut at el., 2020). Various parameters need careful consideration for waste reduction. For instance, when dealing with crop residues, it is essential to maintain accurate data on the annual production rate of residues associated with subsequent crops.

Moreover, efficient waste management involves categorizing residues based on their composition to strategize effective handling. It is also recommended to consider potential by-products derived from residues for processing or treating waste accordingly. Water, a crucial requirement for any agricultural activity, should be managed in stages. Additionally, off-streams from fields must undergo analysis for possible pesticides and fertilizers that could harm the environment (Kuthialaet al., 2022).

b) Collection

From a thorough analysis of production parameters, the subsequent phase involves gathering waste from its source or region of origin. The manner and approach employed in collecting agricultural waste are crucial steps in classifying waste into specific and suitable treatment or management categories. Various elements within the waste collection process in Agricultural Waste Management Systems (AWMS) encompass collection schedules, labor needs, equipment expenses and setup, the methodology of collection, and the utilization of external resources (Kuthialaet al., 2022).

c) Transfer

Following the collection phase, the subsequent stage in waste management involves the transportation or movement of the waste. This transfer process is not a singular requirement but rather needs to be executed through various steps within the management system. The transfer is essential to move waste from the collection point (e.g., the field or the food processing industry where primary agricultural activities occur) to the storage containment (which varies based on the type and characteristics of agro-waste, whether solid, liquid, or gas). Subsequently, the waste is further transferred to a treatment facility, where different types of waste undergo distinct treatment methods, such as chemical, physical, or biological treatment. After treatment, the processed waste is then transferred to a utilization site, where it is improved and used to create beneficial products (e.g., the use of lignocellulosic agricultural residue as energy sources like biofuel, biogas, or natural manure) (Atinkutet al., 2020).Therefore, the management system needs to provide a detailed and clear understanding of the waste composition, which undergoes multiple transfers before reaching its final utilization as a beneficial product oreco-friendly disposal. This includes a clear delineation of the transfer method, transportation costs, necessary equipment, and the time required, all while considering environmental implications(Kuthialaet al., 2022).

d) Treatment

The pivotal step in Agricultural Waste Management Systems (AWMS) is the treatment phase. In agricultural waste management, the main aims of treatment are to reduce the waste's chances of pollution and improve its suitability for alternate uses as a modified value-added product. This procedure guarantees the preservation of the environment as well as the addition of value to agricultural byproducts.Designing the appropriate treatment for different types of waste necessitates a thorough analysis of thecharacteristics of waste, such as its type, size, composition, the specific treatment needed, the cost of treatment, and the development of a definitive design protocol (Bhatt et al., 2018). The treatment procedure may involve pre-treatments and advanced treatments, depending on the type of waste being addressed.The process of treating waste includes both transforming it into a useful resource and altering its characteristics to make it more conducive to degradation by nature. Treatment methods range from traditional approaches to contemporary techniques, and the selection of a specific treatment process relies on the suitability and characteristics of the waste under consideration (Bhuvaneshwariet al., 2019). Conventional methods of waste treatment include practices such as landfills or dumping, incineration, and composting. In contrast, contemporary and environmentally friendly alternatives for waste treatment involve the use of biological or microbial technologies to produce bio compounds like biochar, and biodiesel and bioethanol. Another modern approach includes extracting beneficial organic compounds and employing processing technologies to produce recycled manure, animal feed, and even human food (Mannaet al., 2018).Various states in India, including Tamil Nadu and Assam, have embraced the practice of using crop residues as animal feed and are actively pursuing energy generation from these residues. In contrast, states like Haryana, Punjab, and Uttar Pradesh continue to rely on conventional treatment and disposal methods, such as incineration or burning. This approach not only has negative impacts on the environment but is also an economically unviable method of managing waste (Kuthiala et al.,2022). The incineration of crop residues leads to the release of greenhouse gases (GHGs), thereby contributing to the phenomenon of global warming. Additionally, it causes an increase in particulate matter, air pollution, the formation of smog, loss of biodiversity, depletion of soil fertility, and poses risks to human health (Lohan et al., 2018). The progress in innovative technologies for waste treatment has introduced various practices that can be broadly classified into three major types: Physical, Chemical, and Biological. The adoption of each method depends on the type, composition, and source of the waste (Afolalu et al., 2021). The treatment phase in Agricultural Waste Management Systems (AWMS) should follow a certain hierarchy, moving from minimizing pollution to maximizing recovery, all while prioritizing environmental safety (Taherzadeh et al., 2019).

e) Utilization

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In the schematic representation of the final stage in the AWMS (agriculture waste management) protocol, the process involves reusing or recycling waste products through the preceding treatment step, commonly known as utilization. The fundamental principle of utilization is to restore and reuse waste components in order to create a new value-added product (Agrawal et al., 2018).

3.2. The 3R hierarchy in agriculture waste management

It is said that the 3Rs, Reduce, Reuse, and Recycleshould be applied in a hierarchical order to maximize waste minimization efficiency.The "3Rs", reduce, reuse, and recycleare referred to as the trash hierarchy because they group waste management techniques based on how desirable they are.The 3Rs—Reduce, Reuse, and Recycle—are arranged in a hierarchy that ranks their

importance for trash management. Even if the waste hierarchy has changed over the past ten years, the majority of waste minimization techniques still rely on its fundamental idea. This hierarchy seeks to maximize item utility while reducing waste production. The trash hierarchy, which prioritizes reduction over reuse and recycling, promotes sustainable practices that reduce environmental impact and increase resource efficiency. It is a cornerstone principle that underpins waste management activities across the globe typically, the 3R approach is represented by a pyramid hierarchy where each strategy's increasing environmental benefits includearranged top to bottom (Yousuf et al.,2013).

Figure 3: The diagram showing the representation of 3Rs.

Figure 4: The Diagram illustrates the 3Rs Hierarchy in waste management system.

4. AGRICULTURE WASTE UTILIZATION

4.1. Photochemical production with agro-waste

Since ancient times, people have been aware of the medical benefits of plants. Global demand for phytochemicals is rising, most likely due to increased knowledge of the

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harmful effects of allopathic medications. Since ancient times, people have been aware of the medical benefits of plants. Global demand for phytochemicals is rising, most likely due to increased knowledge of the harmful effects of allopathic medications. Plant extracts can be applied directly, or the target biomolecule can be identified, described, and purified before being employed for the intended pharmacological effect. Natural products have remained interesting despite the market's abundance of synthetic pharmaceuticals because they continuously yield novel molecules with intriguing structural motifs that can be used as sources for novel therapeutic leads. This high plant utilization leads to the production of a massive amount of plant waste, which eventually contaminates the environment. With the goal of maximizing the value of waste and fostering environmental sustainability, investigating the potential creation of economically viable methods for extracting valuable materials from plant waste and their potential uses are taking place (Rao et al.,2019).

4.2.Biofuel production

Crop residues have a high carbohydrate content, making them a suitable feedstock for the synthesis of biofuels. It is possible to determine the potential capacity of producing biofuel from agricultural residues using certain algorithms.China contributes around 32% of the potential global capacity for producing biohydrogen from rice straw, according to experimental results from a study using ethanol organosolv pretreated rice straw to manufacture biohydrogen using *Enterobacter aerogenes*. With the proposed organosolv technique, the projected 249 million tonnes of rice straw that may be collected annually for biofuel production could produce approximately 355.78 kilotonnes of hydrogen and 11.32 million tonnes of lignin. These numbers demonstrate China's significant contribution to the production of renewable energy and the promise of cutting-edge techniques like ethanol organosolv pretreatment for increasing the productivity of biofuels made from agricultural leftovers(Maji et al., 2020).

4.3.Animal feed

There are only a few sources of protein, so it is difficult to supply enough animal feed in many developing nations, even with significant efforts to find substitute supplements. Crop leftovers, which are frequently used, have high fiber content but shortages in protein, carbohydrates, and fat. This situation emphasizes the continuous challenges of effectively providing for the nutritional demands of cattle, requiring creative solutions to overcome the constraints imposed by available feed supplies.As a result, future demands for meat protein may not be satisfied by the conventional strategy of raising livestock productivity by adding grains and protein concentrate to pasture and fodder. Grain and protein used for animal feed will compete with their use for human consumption. One way around these issues is to feed the leftovers to domesticated animals (Obi et al.,2016; Lakshmi et al.,2017).

4.4.Anaerobic digestion

Manures in particular are good sources of methane gas produced from agricultural waste. The gas works best when used for heating, such as when operating broilers, heating water, drying grains, etc. Two times during the anaerobic digestion of agricultural waste, microbial fermentation takes place to produce gas with a high methane content.Bacteria that produce acid break degrade volatile materials into organic acids. These acids are subsequently used by methane-producing microbes to create methane-rich gas. The interaction between acid-forming and methane-generating bacteria in organic waste treatment systems is symbiotic, as demonstrated by the sequential process of breakdown and methane production. Huge poultry, swine, and diary waste can be treated and disposed of with anaerobic digestion, which reduces the stench issue. It stabilizes the waste, leaving the digestion sludge largely odor-free while still having the original waste's fertilizing potential (Obi et al.,2016).

4.5.Pyrolysis

Agricultural waste can be subjected to both intermediate and high temperature pyrolysis processes. This technology can be applied to energy recovery as well as the preparation of chemicals from biomass. The processing of alcohol for fuel, ammonia for fertilizers, and glucose for food and feed—either directly or by means of the creation of yeasts for SCP—are all of special relevance to agriculture. Although most pyrolysis research has focused on urban waste, agricultural and forestry waste products can also benefit from these techniques. Similar to straw, agricultural residue is widely dispersed and has a low density. It is clear that there are issues with gathering, moving, and storing this material in sufficient quantities to run a sizable pyrolysis unit. The Georgia Tech Engineering Experiment Station has developed a mobile pyrolytic unit as one method of solving this issue. Built on two trailers, their mobile unit could be shifted to smaller sawmills or other locations that provided waste biomass. A mobile unit with a 100 t/day capacity could be installed at a specific farm to process collected and stored straw. After that, the straw could be processed to produce fuel that is suitable for use on farms or sold. The system's engine and generator were run by the gas produced during the process, which was also utilized to heat the input feed dryer. Drier capacity would be reduced and methods for handling and storing the gas would be needed in agricultural applications where the straw has been air dried and stored (Timbers at el.,1977).

4.6.Direct combustion

Among the earliest methods of converting biomass that humans have discovered is the simple burning of agricultural waste for fuel. "The fast chemical reaction (oxidation) of biomass and oxygen, the release of energy, and the simultaneous formation of the ultimate oxidation products of organic matter – CO_2 and water" are the elements of total combustion of agricultural waste. When oxidation happens quickly enough, energy is usually released as thermal and radiant energy, the amount of which is determined by the enthalpy of combustion of the biomass. The biomass wastes from agriculture must be solidified in order for the thermal conversion process to effectively use them. Typically, it is burned to produce charcoal, heat, cook food, create steam, and power machinery and electric appliances.Approximately 95% of the biomass energy utilized today comes from combustion, which continues to be the most common method among all the procedures that may be used to turn agricultural waste into fuels or energy(Obi at el.,2016).

4.7.Aerobic fermentation

The aerobic composting process is an aerobic fermentation process because it uses a microbial agent. The type of organic wastes can influence the choice of organic substrate for the fermentation process. The substrate for the fermentation of organic waste can be made ofcoconut husk, rice husk, rice bran,sawdust and other powdered materials. The bacillus is dried to create the microbial fertilizer inoculum, which is long-lasting and resistant to high temperatures, carbon shortages, and oxygen. When the organic waste has a moisture content of roughly 30%, it can be packaged as finished organic fertilizer right away after the fermentation process. Thefinal organic fertilizer can be used in conventional agriculture to enhance the quality of the soil and make it more conducive to the production of "green food (Mengqiet al., 2021).

4.8.Composting

Composting is the best way to utlise agriculture waste. In contrast to other agricultural waste treatment techniques, composting not only eliminates odors, harmful substances, and bacteria, but the finished product can also be used as a soil amendment, boosting soil fertility and improving soil structure as well as crop nutrient geochemical processes (Zeng et al., 2010).

Table 1: Different agriculture waste utilization (Kuthiala et al., 2022)

S.No	Agro-waste	Utilization
1.	Livestock waste	Compost, manure, natural fertilizer
2.	Rice husk	Additive in building material, bio-energy
3.	Legume straws	Livestock feeds
4.	Rice straw, sawdust, bagasse	Biofuels
5.	Flower oil, peanut cake, rice bran	Bio surfactants
6.	Corn cobs, rice hulls, coconut oil cakes	Antibiotics (Oxytetracycline)
7.	Sugarcane fibres and banana peels	Pulp for papermaking
8.	Bagasse, corncob, chitin Lime peels, apple pomace, wheat bran	Bioplastics and bio-composites
9.	Lime peels, apple pomace, wheat bran	Immobilization carriers for SSF

4.9.Vermicomposting

Vermicomposting is typically described as the aerobic decomposition of solid organic residues, utilizing the optimal biological activity of both earthworms and microorganisms (Garg et al., 2009). Vermicomposting encompasses the decomposition of organic wastefacilitated by earthworms. It has demonstrated effectiveness in handling various waste types, including sewage sludge, wastewater solids, brewery materials, paper waste, urban residues, food and animal waste, as well as horticultural (Dominguez et al., 2004). Earthworms must go through a series of consecutive phases in order to digest food and produce vermicompost.First, the organic matter is crushed into a fine powder in the gizzard of the earthworm.After that, microbes and other fermenting materials, as well as hydrolytic enzymes like cellulase, amylase, lipase, protease, urease, and chitinase, aid in the additional breakdown of organic debris inside the earthworm's gut. The end result is the expulsion of this processed material in the form of "casts," ultimately recognized as "vermicompost" (Gupta et al., 2019). The benefits of vermicompost include enhancing soil nutrients, improving nutrient availability for plants, enhancing soil structure and drainage, promoting plant growth, and acting as a biocontrol agent by suppressing plant diseases and insect pests. Consequently, vermicompost stands out as an effective method for addressing environmental pollution issues and managing them efficiently (Alwaneen et al.,2016).

Table 2: Various types of Waste Materials and Earthworm species Used in Vermicomposting (Gupta et al., 2019).

S. No	Waste material	Earthworm species
1.	Agricultural waste	*Eudriluseugeniae*
2.	Domestic waste + cow-dung	*Perionyxexcavates, Perionyx sansibaricus*
3.	Bagasse, sugar cane trash	*Drawidawillsi*
4.	Pig manure, food wastes, leaf wastes, yard wastes, bark wastes, chicken manure	*Eisenia foetida*
5.	Sericulture waste	*Perionyx excavates*
6.	Sheep manure + cotton industrial waste	*Eisenia foetida*
7.	Sugar cane residues	*Pheretima elongate*
8.	Organic matter, moistened peat moss, crushed leaves, dried yard waste	*Eisenia foetida, Lumbricusrubellis*
9.	Agriculture waste and sugar cane waste	*Eudriluseugeniae, Perionyx excavates*
10.	Deciduous forest waste, cow-dung	*Eisenia foetida, Perionyx excavatus and Dicogasterbolaui*

11.	Vegetable waste + floral waste	*Eudriluseugeniae, Eisenia foetida, Perionyx excavates*
12.	Organic wastes	*Lumbricusrubellus, Eisenia jetida, Eisenia andrei, Dendrobdenarubida, Eudriluseugeniae, Perionyx excavatus and Eiseniellatetraedra.*

5. CONCLUSION AND FUTURE PRESPECTIVE

Agriculture waste are the residues from the agriculture products. These residues include crop residue, livestock waste, poultry waste and aquaculture waste. Proper management are done to control the agriculture waste to form useful substance which include manure, biofuel, bioplastic, etc. For that collection, transfer, treatment and utilization are needed. Various utilization methods are there for the good use. Vermicomposting is the one of the best methods forutilizing the agriculture waste. It is eco-friendly and organic. It is used as organic fertilizer which is way better than chemical fertilizer. Through this we can save environment also.

The future of agriculture waste management using vermicompost seems promising, driven by a combination of environmental concerns, sustainable farming practices, and ongoing research and innovation in the field. As the importance of sustainable agriculture continues to grow, vermicomposting is likely to play a major role in addressing the challenges of waste disposal in the agricultural sector. It can also increase the job opportunity and reduce the usage of chemical fertilizer. Collaboration between researchers, agricultural communities, and governmental bodies on a global scale can facilitate the exchange of knowledge and best practices in vermicomposting, leading to widespread adoption and improved waste management.

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