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Experimental study of biodegradability of organic waste with industrial waste combined with effluents: A comparison by vermicomposting technology

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Graphical abstract

Abstract

Vermicomposting is a mesophilic biooxidation and stabilization process of organic materials that involves the joint action of earthworm and microorganism. An experiment was conducted to prepare vermicompost using partially decomposed organic waste such as MSW, fruit waste, vegetable waste and yard waste by employing indigenous earthworm species. This research has been done for reducing the environmental issues, pollution problems due to solid waste and industrial waste i.e., wastewater and sludge by converting it into compost by using earthworms very successfully and economically. Non-toxic and organic industrial wastes could be potential raw material for vermicomposting. In the past few years, vermicomposting has been used for the management of industrial wastes and sludges and to convert them into vermicompost for land restoration practices. The earthworms used were Eudrillus euginea. In this study the industrial sludge and effluent from dairy industry was mixed with organic waste with different ratio. This process was done under the controlled conditions of pH, moisture content and temperature. In this process partially decomposed organic waste were broken down and fragmented rapidly by earthworms resulting in a stable non-toxic material with good structure which has a potentially high economic value as soil conditioner for plant growth. The results reveal the increased nutrient content, increased worm population and decreased processing days of the waste in the order of dairy waste with organic waste. The main objectives of this study include to find viable management techniques for organic as well as industrial waste and to make a detailed analysis of the route of stabilization with observations such as temperature, pH, EC, COD, TS, VS, AC and C/N. and to produce good quality biofertilizer fixed by nutritive values.

Keywords: MSW, vegetable waste, yard waste, fruit waste, dairy industry, eudrilluseuginae, decomposition, vermicomposting, etc

1. Introduction

Solid Waste is its major contribution; the complexity of the character of solid waste and its volume is greatly increasing due to increase of living requirements and population density. Hence the importance of efficient "solid waste management" is increasingly recognized (Rekha Agarwal

2021). Presently many cities are facing the problem of disposal of solid waste generated within the cities. Solid waste arising out of domestic, commercial industrial and agriculture products comprises biodegradable (organic) and non-biodegradable material (Ali ahamed 2022). Due to the phenomenal growth in the quantum and diversity of the waste materials generated by the human activity, potentially harmful effects on the environment and public health resulted (S. Sathiyavathi 2023). In view of the peculiar pollution potential of these effluents, it has become essential to dispose them safely (Supriya 2023). Among the biological process, the process vermicomposting is the best one in which certain earthworms can do the bio-remediation function like degrading and decomposing the waste from the agricultural and certain industrial waste (Nikam and Shah 2001).

Vermicomposting is the scientific method of making compost, by using earthworms. They are commonly found living in soil, feeding on biomass and excreting it in a digested form. Vermiculture means “worm-farming”. Earthworms feed on the organic waste materials and give out excreta in the form of “vermicasts” that are rich in nitrates and minerals such as phosphorus, magnesium, calcium and potassium. These are used as fertilizers and enhance soil quality. Vermicomposting has gained popularity in both industrial and domestic settings because, as compared with conventional composting, it provides a way to treat organic wastes more quickly (Rajeshkumar 2023). In manure composting, it also generates products that have lower salinity levels. Municipal solid waste has become a severe environmental problem due to rapid population growth, industrialization and urbanization. A number of decisions have been made to recycle and sort this waste on individual, community and government level but still large amounts of mixed industrial and household wastes are being dumped. Municipal solid waste management majorly affect the overall living standards of communities such as cleanliness, health and productivity (Bahçelioğlu *et al.* 2020, Ugwu *et al.* 2020). Proper management of solid wastes is mandatory and need urgent action for the persistence and appropriate functioning of societies.

Increases in economic growth and rapid urbanization are directly related to increase in per capita waste generation (Venkiteela 2020). Thus, municipal waste management is much expensive in urban areas (Rathore and Sarmah 2020). In low-income countries, waste management is the highest budget item comprising of about 20 percent of municipal budget, more than 10 percent in case of middle-income countries and about 4 percent for high-income countries. Complex waste management operations are costly and need funding along with basic necessities like clean water, health care, education and other utilities. This management system is administered by local authorities having limited funding and limited capability for planning, operational monitoring and contract management.

2. Vermicomposting

Vermicomposting is an aerobic composting process in which certain varieties of earthworms can be used to break down organic materials. Worms mechanically break down compostables and partially decomposed materials by eating them, and biochemical decomposition occurs via bacteria and chemicals in the worms’ digestive system (Indu Bhardwaj 2023). This organic matter then naturally gets converted into much finer particles like castings (faecal pellets from the earth worms). This compost is active microbially and important plant nutrients are found here in a form available to plants (Fatimah Alshehrei *et al.* 2021). Vermicomposting, on the other hand, is a bioxidation and stabilization process of organic materials that involves the action of earthworms and bacteria, but does not undergo thermophilic stage (Shahul Hameed *et al.* 2002). The great advantage of vermicomposting is that this can be done indoors and outdoors, thus allowing year-round composting (Rajeshkumar 2023). It also provides apartment dwellers with a means of composting. In a nutshell, worm compost is made in a container filled with moistened bedding and red worms (Lalam Manikanta 2023).

3. Advantages of vermicomposting

Further the advantages in various fields such as farmers, industries, environment and national economy are given as follows

Farmers (Singh *et al.* 2003)

- Self-reliant (less reliance on purchased inputs)
- Enhancement of soil productivity
- Saving of water
- Less problems of pest attack
- Self-employment
- Products with better taste and of high quality

Industries (Lakshmi Bai and Vijayalakshmi 2002)

- Cost effective pollution abatement technology

Environment (Lawrence Amal Raj 2003)

- Organic waste is no constraint
- More ground water recharge
- Lesser soil salination, lesser erosion
- No polluting chemicals need to be produced or used
- Less health hazards

National Economy (Scott Subler *et al.* 1998)

- Less expenditure of health department

4. Organic waste

Generally, 60% of the solid wastes are organic in nature. These wastes are often rich in plant nutrients. If left to rot on the sidewalks or waste lands, those wastes are a major source of pollution and diseases but when utilized properly, they can be turned into products of high economic value. Few organic wastes are, Municipal Solid Waste, Fruit Waste, Vegetable Market Waste and Yard Waste

4.1. Municipal solid waste (MSW)

Municipal solid waste is total waste excluding industrial waste, agricultural waste and sewage sludge (Zhou 2022). These municipal solid wastes are the wastes that are obtained due to household activities. It is the composition of degradable waste such as fruit waste, vegetable waste and non degradable waste such as plastics, bottles, tins and any other discarded materials. Municipal solid waste is mainly from domestic and commercial areas. Generally, the solid wastes are of three categories namely, compostable organic matters that is compostable (85%) and non- compostable (15%), recyclable matter containing toxic substances and solids (Arti pamnani and meka srinivasarao 2014)

4.2. Vegetable waste (VW)

The urban and rural areas generally produce large amount of vegetable wastes (Aditi patel *et al.* 2019). The vegetable waste contains large number of nutritive values are wasted by the ordinary method of disposal. The methods such as open dumping or burning cause various environmental problems. Open dumping may cause odour problems and may invite rats, flies and other vermin, which causes nuisance. For avoiding such a problem of disposal, vermicomposting method is the most suitable alternative for vegetable market waste (Giovanni vallini and Antomispera 1998).

4.3. Fruit waste (FW)

The use of fruits produces two types of waste - a solid waste of peel / skin, seeds, stones etc – a liquid waste of juice and washes waters. In some fruits, the discarded portion can be very high percentage (e.g., mango 30-50%, banana 20%, pineapple 40-50% and orange 30-50%). Fruit waste, if not properly disposed, creates odour nuisance. Therefore, these fruit wastes must be collected and disposed by a method which is environmentally safe. Fruit waste is more acidic in nature because most of the fruits are rich in citric acid. The fruit waste contains large amount of organic material, which is highly biodegradable. By selecting the proper disposing techniques, the fruit waste can be disposed in an effective and useful manner. The most suitable method for this problem of fruit waste disposal, is the vermicomposting method (Ravichandran *et al.* 2001).

4.4. Yard waste (YW)

All yards produce waste from pruning, lawn mowing and other routine plant care activities. Yard waste consists of grass clippings, garden debris, leaves, flowers, twigs and branches etc. Yard waste refers to leaves, grass clippings, soft bodied plant materials, small limbs, tree waste and branches. The yard wastes are dumped into the landfill for the disposal. Before this, the degradable and the non-degradable materials in the yard waste should be separated (Shristi Priya *et al.* 2018). By this, the degradable materials can be reduced in its volume by the process of composting. And the nutrients in the yard waste can be recycled to plants.

4.5. Industrial waste

Industrial improvement has commonly been equated with environmental degradation which leads to environmental pollution (Roberto Scaffaro *et al.* 2023). From various industries, millions of tons of pollutants are produced into the environment every year. Some of the industries having the troubles of disposal wastes are discussed below

4.6. Dairy industry

With increase in demand for milk and milk products, many dairies of different sizes have come up in different places (Naveen Desai 2016). Keeping in mind the characteristics of the dairy waste and the increasing accumulation of organic wastes, it was thought imperative to select these wastes and recycle them into a more useful product, thus reducing the toxicity and abating pollution to some extent (AytenNamti *et al.* 2020)

5. Major phases of vermicomposting

The vermicomposting process classified into four major phases. The phases are explained as follows:

5.1. Phase I

In this phase the waste can be collected and separated the metal, glass etc from the organic waste and the organic waste is stored.

5.2. Phase II

In this phase earthworm beds are maintained and the earthworms are fed with the organic waste.

5.3. Phase III

During this phase the organic waste has been worked over by the earthworms, the vermicompost, cocoons, earthworms and the undigested material are separated.

Figure 1. Process of Vermicomposting

5.4. Phase IV

In this phase finally, Packaging of the vermicompost and reintroduction of undigested material into the vermipits is done.

- The end product of the process is vermicompost, which is the casting (excreta) of the earthworms. Vermicompost is rich in plant nutrients.
- One of the by-products is vermiwash, which is now being widely tapped; in simple terms, it is a solution of nutrients, obtained from the percolation of water through the vermicastings.

- Another by-product is the earthworms themselves. They are found to be a good source of protein (Neeta Sharma and Mira Madan 1988).

5.5. Phase V

In this phase all the packed vermicompost transported and packed for distribution (Figure 1).

6. Earth worms in vermicomposting

Earthworms function as shredder, breaking up large lumps of materials as they ingest them. Enzymes in the gut of earthworms and associated microbes bring about chemical break down of the ingested matter (Kavianand Ghatnekar1991). Earthworms can be regarded as the secondary decomposes in nature. The common species of earthworms one use are Eisenia foetida, Eudrillus eugenia and Perionyx excavates which have increasing effectiveness for composting organic wastes (Ndegwa *et al.* 2000). Eudrillus eugenia is the sought-after species for vermicomposting of agricultural, agro industry and urban solid waste in India (Figure 2).

Figure 2. Diagram of earthworm

7. Microorganism

Microorganisms play an important role in the vermial management of sludge (Bisesi 1990). It is a good source of protein. The microorganisms that break down organic wastes require favorable temperature, moisture and oxygen. It is commercially available in the market in the name of Pleurotus. Pleurotus is a saprophytic fungus, which lives on the dead and decayed organic matter (Dhaliwal *et al.* 1992). The microorganism helps in the rapid degradation. The fungus culture Pleurotus produces enzymes that help in the degradation of lignin and cellulose present in the waste. Thus, it makes the food easily available to the earthworms thereby reducing the processing days. This fungus is not readily available, but can be cultured easily and economically in a large amount (Sanjay Kumar Sharma *et al.* 2002).

8. Materials and methods feed materials

8.1. Municipal solid waste

The municipal solid waste was collected near Vellalore municipal depot, in Coimbatore. The quartering technology was used for sampling. The non-combustible matters were separated from the waste and the organic matters were dried at normal temperature and shredded into smaller pieces of 2.5 cm size manually.

8.2. Vegetable waste

The vegetable waste was collected from Uzhlavarsandai, at Saibaba Kovil and R.S puram in Coimbatore corporation limits. The wastes were dried at normal temperature and shredded into small pieces and stored in polythene bags for composting.

8.3. Fruit Waste

The fruit waste was collected from private departmental stores, and fruit stalls at Gandhipuram areas in Coimbatore. The wastes were dried in air at normal temperature, cut into small fractions manually and stored in polythene bags.

8.4. Yard waste

The yard waste was collected from farms, located at Mettupalayam near Coimbatore. It was the combination of grass and leaves. The wastes were dried at normal temperature and cut in to small fractions in a shredder mechanically and grass and leaves were shredded manually. It was stored in polythene bags for composting. The initial characteristics of organic waste were tested and given in Table 1

Table 1. Initial characteristics of organic wastes

Parameters	MSW	VW	FW	YW
Nitrogen	0.59	1.5	0.58	1.8
Phosphorus	0.298	0.05	0.2	0.035
Potassium	0.041	0.85	0.48	0.93
Calcium	0.2	3.8	0.21	2.1
Magnesium	0.11	0.8	0.15	7.9
Total Solids	61	60.5	63.5	66
Volatile Solids	55	58.5	79.8	86.5
pH	6.1	7.8	7.1	7.2
Carbon	25.5	20.8	29.5	32.5
Chloride	0.7	0.9	0.5	3.2
Sulphate	0.1	0.01	0.015	0.23
COD (mg/g)	650	0.875	680	670

All the values are in percent except pH, COD

9. Industrial waste

9.1. Dairy waste

The dairy sludge and effluent were collected from a milk dairy, Perur near Coimbatore. The dried cakes, which are left after the tertiary treatment were, used as dairy sludge for this study. The liquid wastes from a large dairy originate from receiving station, pasteurization plant, bottling plant, cheese plant, butter plant, casein plant, condensed milk plant, dried milk plant and ice cream plant. Wastewater also comes from water softening plant and from bottle and can washing plants. The effluent coming out from the cheese plant was used in this study. The effluent from the manufacture of cheese plant mainly comprises whey, washing from vats, drains, floors and other equipment.

9.2. Seeding Material

The microorganism fungus culture Pleurotus was bought from Tamil Nadu Agricultural University, Coimbatore. The fungus culture Pleurotus produces enzymes that help in the degradation of lignin and cellulose present in the waste. Thus, it makes the food easily available to the earthworms thereby reducing the processing days (Table 2).

Table 2. Initial characteristics of dairy effluent and sludge

Parameter	Dairy*	Dairy
Nitrogen	0.93	5.7
Phosphorous	0.03	0.88
Potassium	0.09	0.17
Chlorides	0.494	0.1187
Sulphate	0.0225	0.556
pH	7.6	6.4
EC (mΩ/cm)	3.6	2.3
Zinc	0.0003	Nil
Copper	0.0025	Nil
Iron	Nil	Nil
Cadmium	Nil	Nil
Manganese	Nil	Nil

**Diluted in 1:3 ratio (effluent: water) All the values in percent except pH, EC*

All the values in percent except pH, EC

9.3. Earthworms

Bouche (1997) classified earthworms into three types based on their habitat. Among this in India the earthworms Eisenia foetida and Eudriluseugeniae were identified as compost worms (Rajeshkumar 2021). The earthworm used in this study was Eudriluseugeniae of African variety which is suitable for our climatic condition (Table 3).

Table 3. Details of mix ratio

Waste Mix	C1	C2	C3	C4	C5
Organic waste (kg)	5.000	5.000	2.500	2.490	2.490
Industrial Sludge (kg)	-	-	2.500	2.490	2.490
M.O(Pleurotus) (kg)	-	-	-	0.020	0.020
Total (kg)	5.000	5.000	5.000	5.000	5.000

Industrial effluent and water were added in all combinations for providing moisture throughout the process. Industrial effluent was added in the process in 1:3 (Effluent: Water) ratio.

T11 - MSW and Dairy industry waste

C1- MSW and Water

C2- MSW and Dairy Effluent

C3- MSW, Dairy Sludge and Water

C4- MSW, Dairy Sludge, Microorganisms and Water

C5- MSW, Dairy Sludge, Dairy Effluent and Microorganisms

T21 - VW and Dairy industry waste

C1 - V W and Water

C2 - V W and Dairy Effluent

C3 - V W, Dairy Sludge and Water

C4 - V W, Dairy Sludge, Microorganisms and Water

C5 - V W, Dairy Sludge, Dairy Effluent and Microorganisms

T31 - FW and Dairy industry waste

C1 - F W and Water

C2 - F W and Dairy Effluent

C3 - F W, Dairy Sludge and Water

C4 - F W, Dairy Sludge, Microorganisms and Water

C5 - F W, Dairy Sludge, Dairy Effluent and Microorganisms

T41 - YW and Dairy industry waste

C1 - Y W and Water

C2 - Y W and Dairy Effluent

C3 - Y W, Dairy Sludge and Water

C4 - Y W, Dairy Sludge, Microorganisms and Water

C5 - Y W, Dairy Sludge, Dairy Effluent and Microorganisms

10. Experimental procedure

The worm bin was provided with the following layers are given in the Figure 3.

The base layer of 3cm thick pebbles followed by 3cm thick layer of coarse sand to ensure proper drainage in each bin. The third layer was filled with 2.5 kg of partially decomposed organic waste with 2.5 kg of industrial sludge for a thickness of 10cm in each reactor. Sludge is added to stabilize the feed composition. Earthworms of about 75 numbers were inoculated into the bin. Then a layer of green leaves was placed for a thickness of 2 cm to supply the necessary nutrients to the compost. Finally, 2 cm thick empty space was left at the top to collect the casting.

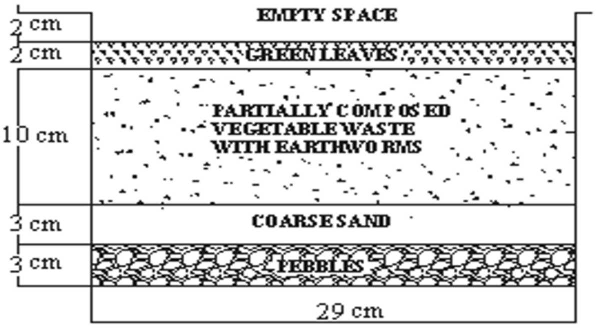

Figure 3. Worm bin setup

Different combinations of trials were made in each industrial and organic waste. The organic waste was partially decomposed by natural aeration method for 10 to 15 days before composting because the fresh organic waste feed will be heated up which may create problem in the earthworm activity. The industrial sludge was dried before mixing with organic waste. The industrial effluent and water were added in the ratio of 1:3 to the waste mix for providing moisture to the process. When partially decomposed, organic wastes with industrial waste mix were fed to the earthworms, and they started feeding on the wastes mix. The fungus culture Pleurotus was added to the mix to enhance the speed of the process. The number of worms added depends on the amount of waste and sludge loaded. 75 worms are enough for a 5 kg of waste mixture. The moisture content is maintained between 40-50% (Albanell *et al.* 1988). The worms are simply scattered over the top of the bin. Worms are highly sensitive to light and hence they move down into the bedding.

This muscular gizzard of the digestive track acts as a crusher and breaks up larger particles into fine ones (Maboeta and Van Rensburg 2003). The degradable process is further enhanced by the symbiotic microbes and enzymes of the guts. During this process, about 5% of the digested matter is assimilated and the rest is ejected out as vermicast. The main basis lies on the voracious feeding habit and high fecundity of the earthworms (Ndegwa *et al.* 2000). After about 20-40 days, the volume of material decreases, and the original bedding is no longer recognizable. The castings are left on top surface as minuscule black pellets (Dr. B. Hemalatha 2022). At this time, the compost found at the top surface is collected and sieved in 2.5mm sieve. The cocoons and the young ones are separated which can be used for any other fresh culture bed. The castings are dried and are tested for their micro and macro nutrients which represent their fertilizer value.

11. Results and discussion

The physical and chemical parameters pH, temperature, EC, COD, TS, VS, AC, C/N variations with time are shown in Figure 4 (a) to (h).

11.1. Temperature, pH, EC

In all the combinations of wastes, there was a considerable reduction in temperature for the two weeks and started declining after. Soluble salt level (salinity) in a sample is estimated based on the measurement of EC by mixing water with the sample. The compost obtained in the combination shows the EC less than 2, there by suggesting as topsoil substitute. They do not have any negative effect on plant growth (AretiKamilaki *et al.* 2001).

11.2. COD, VS, AC and C/N

The parameters COD, VS and AC were the actual indicators of the termination of the entire reaction, showing their efficiencies (Sharma *et al.* 2002). The COD and VS values got subsequently reduced as the biodegrading of wastes occurred. AC increased as the process proceeded due to decrease in VS. C/N ratio below 20 is indicative of an acceptable maturity for the vermicomposting process has been adopted in literature (Kadalli *et al.* 2004).

From the above results the higher reduction in COD, C/N were obtained in C2 (MSW and dairy effluent) combination.

The parameters pH, temperature, EC, COD, TS, VS, Ash content, C/N variations with time are represented in Figure 5 (a) to (h)

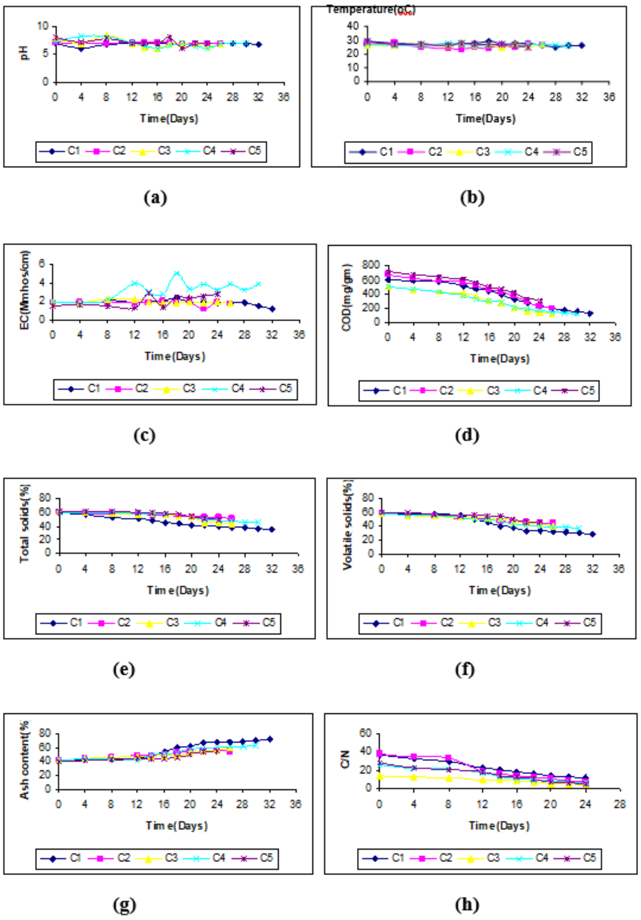

Figure 4. Variation of (a) pH, (b) temperature, (c) Electrical Conductivity, (d) COD, (e) Total Solids, (f) Volatile Solids, (g) Ash content and (h) C/N for MSW with Dairy waste

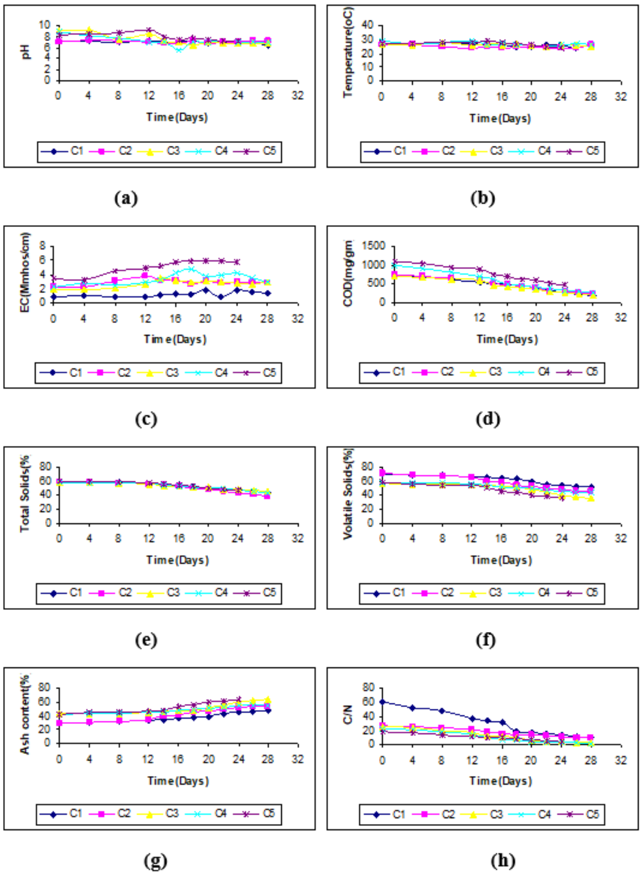

Figure 5. Variation of (a) pH, (b) temperature, (c) Electrical Conductivity, (d) COD, (e) Total Solids, (f) Volatile Solids, (g) Ash content and (h) C/N for VW with Dairy waste

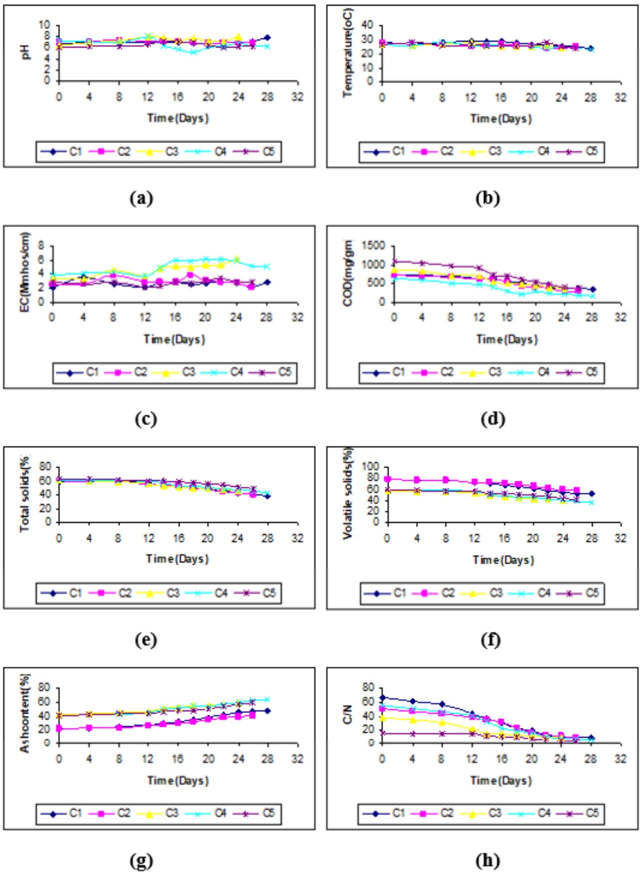

Figure 6. Variation of (a) pH, (b) temperature, (c) Electrical Conductivity, (d) COD, (e) Total Solids, (f) Volatile Solids, (g) Ash content and (h) C/N for FW with Dairy waste

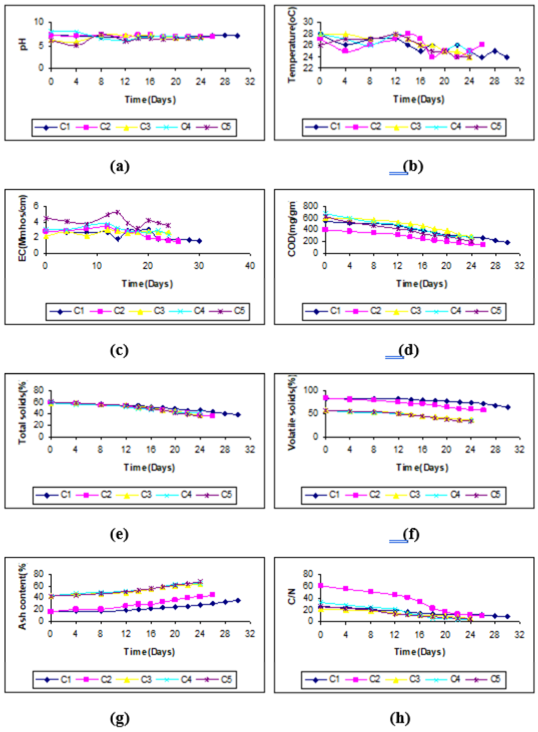

Figure 7. Variation of (a) pH, (b) temperature, (c) Electrical Conductivity, (d) COD, (e) Total Solids, (f) Volatile Solids, (g) Ash content and (h) C/N for YW with Dairy waste

From the five different combinations in VW with dairy industry waste, combination C5 (VW, dairy sludge, dairy effluent and microorganisms) degrade faster and effectively than other combinations.

The physical and chemical parameters for five different combinations are represented in Figure 6 (a) to (h).

From the above results, the higher degradation of VS, TS was obtained in combination C4 (FW, dairy sludge and microorganisms) than the other combinations.

The physical and chemical parameters for five different combinations of yard and dairy waste mix are shown in Figure 7 (a) to (h)

From the above results, the YW with dairy waste the combination C5 (YW, dairy sludge, dairy effluent and microorganisms) shows the higher degradation parameters than the other combinations (Tables 4 to 7).

Table 4. Macro and Micronutrients of MSW and Dairy Waste before and after Vermicomposting process

	MSW and Dairy Industry Waste									
	C1		C2		C3		C4		C5	
	Before	After	Before	After	Before	After	Before	After	Before	After
pH*	6.9	6.8	7.1	7.0	7.8	6.7	7.32	6.9	7.95	7
Nitrogen	0.55	1.54	0.58	2.3	1.63	1.87	0.8	1.9	0.92	1.9
Phosphorus	0.35	0.6	0.35	1.4	0.5	0.8	0.9	1.34	0.9	0.5
Potassium	0.4	0.8	0.42	1.2	0.03	0.23	0.3	0.35	0.28	1.07
Total Solids	59.2	35.12	59.3	50.6	60.43	43.23	60.35	44.8	61.24	50.01
Volatile Solids	57.1	29.23	57.9	45	58.74	40.23	57.94	37	59.79	46
Calcium	0.5	1.7	0.45	4.88	0.178	1.61	0.109	1.65	0.048	1.98
Magnesium	0.315	0.315	0.315	0.51	0.087	0.31	0.07	0.5	0.075	0.4
Chlorides	0.4	0.41	0.51	1.17	3.53	4.8	3.05	5.74	3.92	4.98
Sulphates	0.15	0.15	0.02	Nil	0.05	0.023	0.024	0.012	0.006	0.08
Carbon	20.5	20.5	22.1	14.5	22.57	6.81	21	10.8	25.8	9.35
Sodium	0.025	0.025	0.02	0.21	0.01	0.06	0.1	0.21	0.05	0.07
Boron	Nil	Nil	Nil	0.3	Nil	Nil	Nil	Nil	0.0041	0.005
Iron	0.2	0.2	0.15	1.0	0.03	0.45	0.3	0.57	0.2	0.5
Manganese	Nil	Nil	Nil	0.083	0.017	0.029	0.028	0.058	0.002	0.038
Zinc	0.023	0.0023	0.023	0.12	0.011	0.10	0.018	0.101	0.001	0.1
Chromium	Nil	Nil	Nil	0.000023	Nil	0.0002	Nil	0.00012	Nil	0.00011
Copper	0.00013	Nil	0.0003	0.0024	0.00021	0.0008	0.0022	0.00079	0.0002	0.00073
Cadmium	0.00029	Nil	0.0001	0.0005	0.00037	0.00024	0.0037	0.00056	0.0057	0.00054

**Except pH all the values in percent*

Table 5. Macro and Micronutrients of VW and Dairy waste before and after Vermicomposting process

Parameters (%)	Vegetable Waste and Dairy Industry Waste									
	C1		C2		C3		C4		C5	
	Before	After	Before	After	Before	After	Before	After	Before	After
pH	7.2	6.5	7.1	7	9.06	6.8	8.86	7	8.32	7
Nitrogen	0.8	2.18	1.38	3.06	0.9	2.45	0.9	2.42	1.39	1.42
Phosphorus	0.05	1.1	0.05	1.25	0.95	1.6	0.95	1.15	0.51	0.69
Potassium	0.98	1.08	0.98	1.15	0.39	0.44	0.11	0.27	1.9	2.12
Total Solids	58.2	43.23	58.4	38.2	58.77	39.21	58.48	43.2	59.9	43.2
Volatile Solids	70.6	52.12	70.8	45	57.05	30	57.3	44.12	58.23	44.12
Calcium	4.35	0.38	4.35	5.96	0.1025	2.09	0.94	0.76	0.1165	0.094
Magnesium	0.56	0.19	0.56	2.01	0.053	0.44	0.612	0.4	0.058	0.068
Chlorides	1.35	4.9	1.4	5.36	4.75	5.24	3.14	4.01	5.74	6.99
Sulphates	0.06	0.012	0.05	0.005	0.065	0.012	0.07	0.01	0.05	0.001
Carbon	48.6	21.8	37.42	27.17	22.85	5.25	20.5	4.35	24.5	6.25
Iron	0.02	0.68	0.03	0.6	0.21	0.52	0.2	0.5	0.28	0.62
Zinc	0.0001	0.002	0.0009	0.05	0.002	0.102	0.00112	0.05	0.0018	0.112
Manganese	Nil	Nil	Nil	Nil	0.0021	0.048	0.007	0.0465	0.0023	0.052
Copper	Nil	Nil	Nil	Nil	0.0004	0.035	Nil	Nil	0.00038	Nil
Chromium	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.04
Cellulose	3.09	2.8	3.9	1.54	3.1	1.4	3.2	1.28	2.89	1.3
Hemi Cellulose	1.79	1.67	1.9	1.32	1.75	1.31	1.8	1.3	1.8	1.52
Lignin	46.2	31	46.2	20.17	39.2	15.24	38.28	17.6	37.2	20.2

**Except pH all the values in percent*

Table 6. Macro and Micronutrients of FW and Dairy waste before and after Vermicomposting process

Parameters (%)	Fruit Waste and Dairy Industry Waste									
	C1		C2		C3		C4		C5	
	Before	After	Before	After	Before	After	Before	After	Before	After
pH	6.8	7.8	7.2	7.0	6.5	8.1	7.24	6.21	6.01	6.2
Nitrogen	0.72	1.37	0.75	1.88	1.1	1.9	0.39	1.65	1.7	2.15
Phosphorus	0.3	0.68	0.31	1.21	0.39	0.54	0.4	0.79	0.3	0.71
Potassium	0.55	1.02	0.5	1.08	0.7	1.53	0.4	2.37	0.37	0.43
Total Solids	59.2	38.82	59.6	40.1	60.78	45.67	60.75	43.2	62.71	49.2
Volatile Solids	78.432	52	78.9	59	58.31	40	59.11	36	59.65	41
Calcium	0.385	0.27	0.38	4.2	0.63	0.44	0.87	0.76	0.34	1.7
Magnesium	0.255	1.16	0.28	1.27	0.98	0.68	0.63	0.52	0.87	0.7
Chlorides	0.62	0.73	0.62	0.81	5.79	8.49	3.01	4.74	5.85	6.24
Sulphates	0.019	0.02	0.018	0.009	0.012	0.085	0.1	0.062	0.025	0.005
Carbon	48.5	11.35	38.61	16.82	42.1	16.32	21.5	9.75	26.25	7.25
Lignin	25.2	31.49	25.1	17	25.21	39.61	22.1	43.1	26.6	32.6
Cellulose	21	17.16	21	11.1	19.8	11.26	26.1	12.6	20.1	14.21
Protein	3.85	8.57	3.85	25.25	5.29	20.61	5.1	15.21	4.2	16.61
Iron	Nil	Nil	0.03	0.5	0.00281	0.34	0.002	0.6	0.0021	0.41
Zinc	Nil	Nil	0.0018	0.027	0.00019	0.061	Nil	Nil	0.00028	0.019
Manganese	Nil	Nil	Nil	Nil	0.004	0.072	Nil	Nil	0.002	0.0563
Chromium	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Copper	Nil	Nil	Nil	Nil	0.00002	0.00029	Nil	Nil	Nil	Nil
Boron	Nil	Nil	Nil	Nil	0.00061	0.00081	0.0003	0.00053	Nil	Nil

**Except pH all the values in percent*

Table 7. Macro and Micronutrients of YW and Dairy waste before and after Vermicomposting process

Parameters (%)	Yard Waste and Dairy Industry Waste									
	C1		C2		C3		C4		C5	
	Before	After	Before	After	Before	After	Before	After	Before	After
pH	7.2	7.1	7.2	7.0	6.22	7.0	8.02	7.0	6.19	6.6
Nitrogen	1.48	3.02	0.8	3.63	1.29	1.36	0.65	0.93	1.1	1.78
Phosphorus	0.05	1.02	0.05	1.2	0.36	0.48	0.3	0.47	0.85	1.47
Potassium	0.468	1.02	0.668	1.18	0.5	1.63	0.3	1.22	0.28	0.34
Total Solids	58	38.21	58.2	39.61	58.18	37.21	58.98	43.21	59.68	38.21
Volatile Solids	83	64.21	84.8	60.6	56.56	37.13	57.65	37.21	57.63	35.63
Calcium	0.34	2.38	1.34	5.77	0.14	0.11	0.1045	1.65	0.2250	0.212
Magnesium	1.49	0.15	0.49	2.5	0.065	0.05	0.0812	0.06	0.056	0.044
Chlorides	1.58	2.04	1.58	3.21	4.75	5.49	2.09	4.49	7.53	8.21
Sulphates	0.044	0.04	0.044	Nil	0.052	0.039	0.06	0.032	0.005	8.62
Carbon	38.2	24.09	48.6	34.2	26.83	7.16	21.3	3.7	27.58	Nil
Iron	Nil	0.31	0.03	0.42	0.042	0.45	0.043	1.2	0.072	0.43
Zinc	0.0023	0.031	0.0035	0.0042	0.00192	0.019	0.0082	0.0235	0.002	0.11
Manganese	Nil	Nil	0.0072	0.028	0.003	0.029	0.0027	0.053	0.005	0.027
Chromium	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Copper	Nil	Nil	Nil	Nil	Nil	Nil	0.00175	0.0025	Nil	Nil
Lignin	42	39	44	17	39	30	38.5	28.3	33.2	21.61
Cellulose	1.83	1.8	1.84	1.66	1.75	1.43	1.65	1.45	2.1	1.92
Protein	0.41	0.21	0.46	0.04	0.71	0.12	0.71	0.31	0.93	0.29

**Except pH all the values in percent*

In all the combinations there is increase in nutrients after composting. Alone and Bhide (2002) discussed the heavy metal standards for vermicast. The observed results are within the standard limits prescribed. From the above results, the MSW and dairy industry waste in combination C2 (MSW and dairy effluent) strengthens the vermicast with high nutrient content. The quality of vermicast obtained is high compared to other combinations. From the five different combinations in VW with dairy industry waste combination C5 (VW, dairy sludge, dairy effluent and microorganisms) is proved that vermicast is characterized with high nutrient content than other combinations. The FW with dairy industry waste in combination C4 (FW, dairy sludge and microorganisms) more efficiently converted the vermicast into one high quality and quantity fertilizer. The YW with dairy industry waste in combination C5 (YW, dairy sludge, dairy effluent and microorganisms) exemplifies the high nutrient content.

12. Conclusions

The experimental study of biodegradation of organic waste and industrial waste using techniques of vermicomposting was carried out and its statistical analysis have established the following significances. The industrial waste was separately tried for vermicomposting method, but the attempt failed. The survival and tolerance of earthworms in sludge or any extreme environmental depend on several factors such as high alkalinity, salinity, chlorides and heavy metal. The trials with industry wastes were failed because of the mortality of earthworms in laboratory experiments. Hence an attempt to make combined disposal of organic waste and industrial waste proved lucrative not only for the industry but also for the disposal of organic waste.

- The dairy waste mixed with the organic waste such as MSW, vegetable waste, fruit waste, yard waste can be effectively treated by vermicomposting process.
- The highest nutrient content and chemical parameter reductions were obtained in the combination of vegetable waste than the other organic waste.
- The quantity of waste processed also higher in this dairy with vegetable waste combination.
- The worms' growth also comparatively increased in the dairy with vegetable waste combination.
- In Nutrient content, the combination of yard waste with dairy waste produced highest amount.

References

Aditi patel, Waseem raja, Sachin Parmar, snehalpopli (2019), 'Vegetable market waste management and potential uses', International journal for scientific research and Development ISSN 2321–0613 vol7, issue 5.

Ali ahamed, zubair aslam, korkmaz belliturk. (2022). "Vermicomposting by Bio-Recycling of Animal and Plant Waste: A Review on the Miracle of Nature", Journal of Sciences, volume 8, issue 2, pp 175.

Arti pamnani, Mekasrinivasarao. (2014). 'Municipal solidwaste management in India: A review and some new results', International journal of civil Engineering and Technology (IJCIET), vol 5, issue2, pp. 01–08.

Aytennamti, HanifeAkca, Muhittin Onur Akca. (2020). 'Vermicomposting of agro industrial waste by product of the sugar industry', 9(4), pp. 292–297.

BisesiL.H. (1990). Vermial and microbial management of biological sludges under dynamic conditions of temperature and seasonal changes, Biological Wastes, Vol.32, pp. 99–109.

Dhaliwal R.P.S., GarchaH.S. and PhutelaR.P. (1992). 'Early fruiting and improved yields by Jaccase mutants of PleurotusFlorida', Mushroom Res., Vol.1, pp.73–78.

Dr. B. Hemalatha. (2012). "vermicomposting of fruit waste and industrial sludge", International Journal of Advanced Engineering Technology, Vol.III, Issue II, pp. 60–63.

Dr. B. Hemalatha. (2012). "Recycling of industrial sludge along with municipal solid waste –vermicomposting method, International Journal of Advanced Engineering Technology, Vol.III, Issue II, pp. 71–74.

Dr.B. Hemalatha. (2013). "Vermiculture for organic waste", International Journal of Advanced Engineering Technology, Vol. IV, Issue, I, pp. 46–47.

Dr.B. Hemalatha. (2013). "Comparative evaluation of biodegradability of yardwaste and fruitwaste with industrial effluents by vermicomposting", International Journal of Advanced Engineering Research and Studies, Vol. II, Issue II, pp 36–39.

Dr.B. Hemalatha. (2022). "Vermicomposting Process of Organic Waste and Paper Mill Sludge", International Journal of Innovative Science and Research Technology, Volume 7, Issue 12, pp. 1191–1197.

E. Bahçelioğlu, E.S. Buğdaycı, N.B. Doğan, N. Şimşek, S.Ö. Kaya, E. Alp. (2020). Integrated solid waste management strategy of a large campus: A comprehensive study on METU campus, Turkey, J. Clean. Prod., 121715

Fatima Alshehrei, Fuad Ameen. (2021). 'Vermicomposting: A management tool to mitigate solid waste', Saudi journal of biological science, vol. 28, issue 6, pp 3284–3293.

Giovanni Vallini and Antonio Pera. (1998). 'Green compost production from vegetable waste separately collected in metropolitan garden-produce markets', Biological waste, 29, pp. 33–41.

Indu Bhardwaj, Vijay Kumar, Richa Verma. (2023). Vermicompost and Rhizobacteria in Organic Agriculture: A Review of their Impacts on Plant Growth and Soil Health, Journal of eco-friendly agriculture, vol 18, No2, pp 219–229.

Kavian M.F. and Ghatnekar S.D. (1991). 'Bio management of dairy effluents using culture of red earthworms (Lumbricusrubellus)', Indian Journal of Environmental Protection, Vol.11, pp.680–682.

L.K. Venkiteela. (2020). Status and challenges of solid waste management in Tirupati city, Mater. Today Proc. (2020).

Lakshmi Bai L. and Vijayalakshmi G.S. (2002). 'Vermi remediation of sugar factory waste', Indian Journal of Environmental Protection, 22(8), pp. 905–909.

Lalam Manikanta, Saidu Vijay Sai Sudheer, Abhijat Dhasmana and Bandaru Sudheer. (2023). "The science of vermiculture: Use of earthworms in organic waste management", The Pharma Innovation Journal, 2023, 12(1), 137–140.

Lalam Manikanta, Saidu Vijay Sai Sudheer, Abhijat Dhasmana and Bandaru Sudheer. (2023). "The science of vermiculture: Use of earthworms in organic waste management", The Pharma Innovation Journal, volume 12(1), 137–140.

Lawrence Amal Raj G. (2003). 'A simple vermiculture technique', Invention Intelligence (Sep-Oct).

Naveen Desai, Anuradha Tanksali, Veena S. Soraganvi. (2016). "Vermicomposting – Solution for Milk Sludge, International Conference on Solid Waste Management, 5IconSWM 2015, Procedia Environmental Sciences, 35, 441–449.

Nedgwa P.M., ThompsonS.A. and Das K.C. (2000). 'Effects of stocking density and feeding rate on vermicomposting of biosolids', Bioresource Technology, Vol.71, pp.5–12.

Neeta Sharma and Mira Madan. (1988). 'Effects of various organic wastes alone and with earthworms on the total dry matter yield of wheat and maize', Biological wastes, Vol.25, pp.33–40.

Nikam R.K. and Shah S.S. (2001). 'Solid waste Management', Proceedings of ENVIRO 2001, National conference on control of Industrial Pollution and Environmental Degradation, at PSG college of Technology, Coimbatore, India, pp 107–112.

P. Rathore, S.P. Sarmah. (2020). Economic, environmental and social optimization of solid waste management in the context of circular economy, Comput. Ind, Eng. (2020), p. 106510.

Rajeshkumar, Shankar jha, shiveshwar pratap singh, Mukesh kumar, Ragini kumara. (2023). "Organic waste recycling by vermicomposting amended with rock phosphate impacts the stability and maturity indices of vermicompost,journal of Air and waste management Association volume 73, 2023, issue 7, pp553–567.

Rajeshkumar, Younis ahmad, Hajam and riya sharma. (2021). "A study on the rate of earthworm", Asian Journal of Advances in Research, volume 4(1), pp 1143–1152.

Ravichandran C., Chandrasekaran G.E. and Christy Priyadharsini F. (2001). 'Vermicompost from different solid wastes using treated dairy effluent', Indian Journal of Environmental Protection, Vol.21, No.6, pp 538–542.

Rekha Agarwal. (2021). 'Solid waste and their management'(van sangyan) ISSN2395 -468X, vol8, No7 Issue July 2021.

S. Sathiyavathi, S. Thamarai Selvi. (2023). Study of Vermicomposting with Coirpith, Eggshell, Vegetable Waste and Onion Peel, International Journal for Multidisciplinary Research (IJFMR), Volume 5, Issue 2, pp1-2.

Sanjay Kumar Sharma. (2002). Application of vermiculture in the management of municipal waste and agro residues' , National Seminar on Solid Waste Management - Current Status and Strategies for future, Bangalore, India, pp. 112–114.

Shahin Sadeghi ahangar, Amirhossein sadati, and Masoud Rabbani. (2021). 'Sustainable design of municipal soild waste management systemin an intergrated closed-loop supply chain network', Journal of industrial and production Engineering, vol38, No5, 323–340.

Shahul Hameed P., Gokulakrishnan K., Rajasekaran M., Thangavel K. and Raja P. (2002). 'Vermicomposting of solid waste from Tannery Industry', National Seminar on Solid Waste Management - Current Status and Strategies for future, Bangalore, India, pp-104-105.

Shristi Priya, JnisaShrestha, Dhurva.P, Gauchan and Janardan, Lamichhne. (2018). 'Vermicomposting in organic agriculture: Influence on the soil nutrients and plant growth', International journal of Research e-ISSN 2348–6848, vol5, issue 20.

Singh N.B., Khare A.K., Bhargawa D.S. and Agrawal S. (2003). 'Vermicomposting of tomato skin and seed waste', IE Journal-EN, 84, pp.30–34.

Subler S., Edwards C.A. and Metzger J. (1998). 'comparing Vermicomposts and compost', Biocycle, 39, pp. 63–66

Supriya P, Sumit R, Kuniyal JC and Kapil K. (2023). ”Vermicomposting: A Sustainable Solution for Waste Management Volume 4, - Issue 3. pp1–7.

Zhou, Y., Xiao, R., Klammsteiner, T., Kong, X., Yan, B., Mihai, F.C., Liu, T., Zhang, Z. and Awasthi, M.K. (2022). Recent trends and advances in composting and vermicomposting technologies, A review. Bioresource Technology, p.127591.