Vermicomposting

Dr. Gautam Kumar Meghwanshi
Department of Microbiology
MGS University, Bikaner

Introduction

- Vermicomposting is a mesophilic biooxidation and stabilisation process of organic materials that involves the joint action of earthworm and microorganism.
- Compared with composting, vermicomposting has higher rate of stabilisation and it is greatly modifying its physical and biochemical properties, with low C : N ratio and homogenous end product.
- It is also costeffective and ecofriendly waste management.
- Due to its innate biological, biochemical and physicochemical properties, vermicomposting can be used to promote sustainable ruminant manure management.
- Vermicomposts are excellent sources of biofertiliser and their addition improves the physiochemical and biological properties of agricultural soils.
- In addition, earthworms from the vermicomposting can be used as source of protein to fishes and monogastric animals.

COMPOSTING AND VERMICOMPOSTING INTEGRATION

- Composting is the process of aerobic decomposition of organic waste through microorganisms, whereas vermicomposting involves the combination of both the microorganisms and the earthworms.
- Some studies propose that vermicomposting process lacks the ability to kill pathogens, hence it is considered as the major drawback of vermicomposting process when compared with thermophilic composting.
- The optimum temperature for earthworms in vermicomposting process is considered up to 35˚C, whereas in conventional composting (including thermophilic composting), it may reach up to 70˚C.
- Therefore, vermicomposting process does not attain the favorable temperature to kill pathogens, and if the temperature exceeds 35˚C, it may lead to the death of earthworms which further stop the process of vermicomposting.
- Biologically, vermicomposts contain diverse nature of microbial populations that are more diverse and larger when compared with the thermophilic composts

- In this scenario, an integrated approach has been introduced composed of both composting and vermicomposting processes to achieve better output.
- There can be two possibilities that are generally proposed for integrated approach of composting and vermicomposting: (i) prevermicomposting followed by composting or (ii) precomposting followed by vermicomposting.
- By using the second approach, Gajalakshmi et al. [26] achieved better output by high-rate composting of water hyacinth before vermicomposting.

VERMICOMPOSTING THROUGH CODIGESTION OF ORGANIC WASTES

- Earthworms' have considerably less survival ability in industrial wastes, and they need some nutrient-rich organic source, such as cow dung, biogas plant slurry, and poultry droppings, (known as organic amendments) to be mixed with industrial wastes to enhance the vermicomposting by providing sufficient amount of nutrients and inoculums of microorganisms.
- A number of organic amendments are presented in Table 1.

Table 1. Initial physicochemical characteristics of some widely used organic amendments

Parameters	Organic amendments			
	Cow dung*	Cattle dung**	Poultry droppings†	Biogas slurry††
pH	7.01 ± 0.61	8.63 ± 0.02	7.7 ± 0.35	7.4 ± 0.01
Electrical conductivity (EC; ds/m)	0.967 ± 0.14	—	3.35 ± 0.32	—
Ash content (g/kg)	238.7 ± 2.7	—	—	—
Total organic carbon (TOC; g/kg)	416 ± 1.8	18.7 ± 0.58	405 ± 12	289.5 ± 2.7
Total Kjehldahl nitrogen (TKN; g/kg)	8.1 ± 0.5	1.20 ± 0.01	14.5 ± 0.8	19.8 ± 0.3
Total potassium (TK; g/kg)	3.65 ± 0.0021	0.21 ± 1.30	3.1 ± 0.1	—
Total available phosphorus (TAP; g/kg)	2.5 ± 0.003	0.58 ± 2.19	9.2 ± 0.6	2.85 ± 0.1
C:N ratio	51.35 ± 1.75	15.58 ± 0.35	27.9 ± 1.8	14.6 ± 0.4

- Cow dung has been reported as the most suitable Amendment.
- They amendments are also reported to help achieving the suitable C:N ratio. e.g. when cow dung was added to the waste of citronella plant, it significantly enhanced the process of vermicomposting with decrease in C:N ratio up to 87.7%.
- Addition of Amendments also help in vercomposting of toxic substrates like tannery waste, which otherwise are100% toxic for earthworms.

Table 2. Vermicomposting with suitable organic amendment

Substrate	Waste	Worms
Cow dung	Distillery sludge	*Eisenia fetida*
Sawdust and cow dung	Guar gum	*Perionyx sansibaricus*
Cow dung	Waste of citronella plant	*Eudrilus eugeniae*
Cow dung	Preconsumed processing vegetable waste	*Eisenia fetida*
Cattle dung	Tannery sludge	*Eisenia fetida*
Cow dung	Sewage sludge	*Eisenia fetida*
Cow dung	Filter cake, trash, and bagasse	*Eudrilus eugeniae*
Cow dung	Food industry sludge	*Eisenia fetida*
Primary sewage sludge	Paper pulp mill sludge	*Eisenia andrei*
Sugarcane trash	Sewage sludge	*Eisenia fetida*
Sewage sludge	Polycyclic aromatic hydrocarbons	*Eisenia fetida*
Cow dung	Nonrecyclable postconsumer paper waste	*Eisenia fetida*
Poultry droppings	Textile mill sludge	*Eisenia fetida*
Anaerobically digested biogas plant slurry	Textile mill wastewater sludge	*Eisenia fetida*

Substrate	Waste	Worms
Cow dung/agricultural residues	Solid textile mill sludge	*Eisenia fetida*
Sugar mill filter cake	Horse dung	*Eisenia fetida*
Cow dung	Solid textile mill sludge	*Eisenia fetida*
Cattle dung	Crop residues	*Eisenia fetida*
Wheat straw, cow dung, and biogas slurry	Vegetable solid waste	*Eisenia fetida*
Cow dung	Water hyacinth	*Eisenia fetida*
Cattle manure	Dairy industry sludge	*Eisenia andrei*
Cattle dung	Beverage industry sludge	*Eisenia fetida*
Cattle dung	Sugar industry waste	*Eisenia fetida, Perionyx excavatus, and Eudrilus eugeniae*
Cow dung and agriculture residues	Leather processing sludge	*Eisenia fetida*
Sheep manure	Cotton industrial waste	*Eisenia fetida*
Cow manure	Oat straw	*Eisenia fetida*
Cow manure	Hospital wastes	*Eisenia fetida*
Cow dung	Fly ash	*Eisenia fetida*

VERMISYSTEMS AND VERMIDIVERSITY

Table 3. Different vermitechnology systems

Vermicomposting system	Description
Windrow	Long rows on ground up to depth of 50 cm, organic waste is placed and worms are introduced.
Continuous flow system	Container above the ground with mesh floor.
Stacking system	Several trays on top of one another. Mostly, three trays are used with 150 mm in depth.
Batching system	Compiled of boxes.
Wedge system	Horizontal feeding method, where at 45° angle feed is applied on the bedding.
Pits	Below the ground, 1-m-deep and 1.5-m-wide pits with varying lengths
Heaps	Above the ground, heaps are made with placement of polythene sheet on ground.
Tanks	Above the ground, tanks are made with normal bricks.
Cement rings	Cement rings are made with dimensions of 90 cm diameter and 30 cm height.

- In all these vermin systems, the diversification of worms may play a crucial role in overall processing of the vermicomposting.
- In this way, the selection of appropriate earthworm species for organic waste degradation is a great matter of concern and is important for getting better results.
- The adaptability to waste, minimal gut transit time, fast growth rate, and high reproductive potential of earthworms are some general characteristics which should be under consideration before starting the activity of vermicomposting.
- Earthworms are terrestrial invertebrates broadly categorized as anecic, endogeic, and epigeic (Table 4) on the basis of their behavior on natural environments

Table 4. Classification of earthworms

Type	Characteristics	Examples
Anecic	These construct permanent vertical burrows as in the soil (4 to 6 feet deep)	*Lumbricus terrestris*
	They feed on organic debris on the soil surface	*Lampito mauritii*
Endogeic	They mainly show horizontal burrows	*Aporrectodea calignosa*
	They feeding on mineral soil particles and decaying organic matter	
Epigeic	They do not build permanent burrows	*Eisenia fetida*
	They are usually found in areas rich in organic matter	*Eisenia andrei*
		Perionyx excavates
		Eudrilus eugeniae

The vermicomposting of organic waste using diverse range of earthworms is given in Table 5.

Table 5. Vermicomposting of organic wastes using diverse earthworms

Organic waste	Worms	Time (Days)
Coffee pulp	*Eisenia fetida*	98
Soybean straw, wheat straw, maize stover, chick pea straw and city garbage	*Perionyx excavatu*	180
Pig waste	*Pheretima asiafica*	—
Coffee pulp	*Eudrilus eugeniae*	112
Pig manure	*Eisenia fetida*	252
Cattle dung	*Perionyx excavatus*	75
Cow and horse manure	*Drawidia nepalensis*	240
Spent mushroom compost	*Eisenia fetida and Eisenia andrei*	90
Sewage sludge	*Eisenia fetida*	126
Paper mill sludge	*Lumbricus terrestris*	—
Neem leaves	*Eisenia fetida*	—

- *Eisenia fetida*, also termed as banded worms, are the most widely used species for the degradation and stabilization of different types of organic wastes, including neem leaves, dung of cow, buffalo, horse, donkey, sheep, goat, and camel, biogas slurry, cow dung, vegetable market waste, wheat straw, kitchen waste, agroresidues, and institutional and industrial wastes, cow manure, and textile mill sludge mixed with poultry dropping.
- Generally, *Eisenia fetida* is widely used all over the globe, whereas *Eudrilus eugeniae* is popular in tropical and subtropical countries

ROLE OF VERMICULTURES IN VERMICOMPOSTING

- Earthworms play an important role in organic waste system by colonizing organic waste along with consumption, digestion, and assimilation of high rates of organic wastes.
- They also have the ability to tolerate a wide range of environmental stresses with high reproductive rates.
- In an organic waste system, earthworms ingest, grind, and digest organic waste with the help of aerobic and anaerobic microflora present in the gut of earthworms.
- The physical and biochemical actions are performed in waste system by earthworms.
- The example of physical actions includes substrate aeration, mixing, and actual grinding.
- Biochemical actions by earthworms include microbial decomposition of substrate in the intestine of earthworms

- As a result of this activity, rapid mineralization and humification process start, which convert the unstable organic matter into relatively stable and microbially active material.
- During this stabilization process, chelating and phytohormonal elements are released, which make the organic matter into stabilized humic substances with high microbial content .
- Earthworms ingest organic waste as well as soil which pass through their body where it mixes with digestive enzymes and reduced by the grinding action.
- The material that is excreted by the worms after digestion is nutrient rich and termed as “castings.”
- All these roles are better played in moist soil and well-aerated soils with low acidic value.

- Vermicomposts produced after digestion and excretion by earthworms are actually nutrient-rich organic soil amendment and has considerable potential in crop production.
- Vermicomposts are peat-like material with high porosity, aeration, drainage, water-holding capacities, and low C:N ratios.
- The resulting worm castings (worms manure) are reported to be rich in microbial activity, plant growth regulators, and fortified with pest repellents.
- The enzymes secreted through the digestive epithelium of gut of earthworms are cellulase, amylase, invertase, protease, and phosphatase, responsible for enhanced N, P, and K contents in vermicomposts.
- Earthworms get their nourishment from microbes, whereas microbial activity is influenced by the casts produced by worms

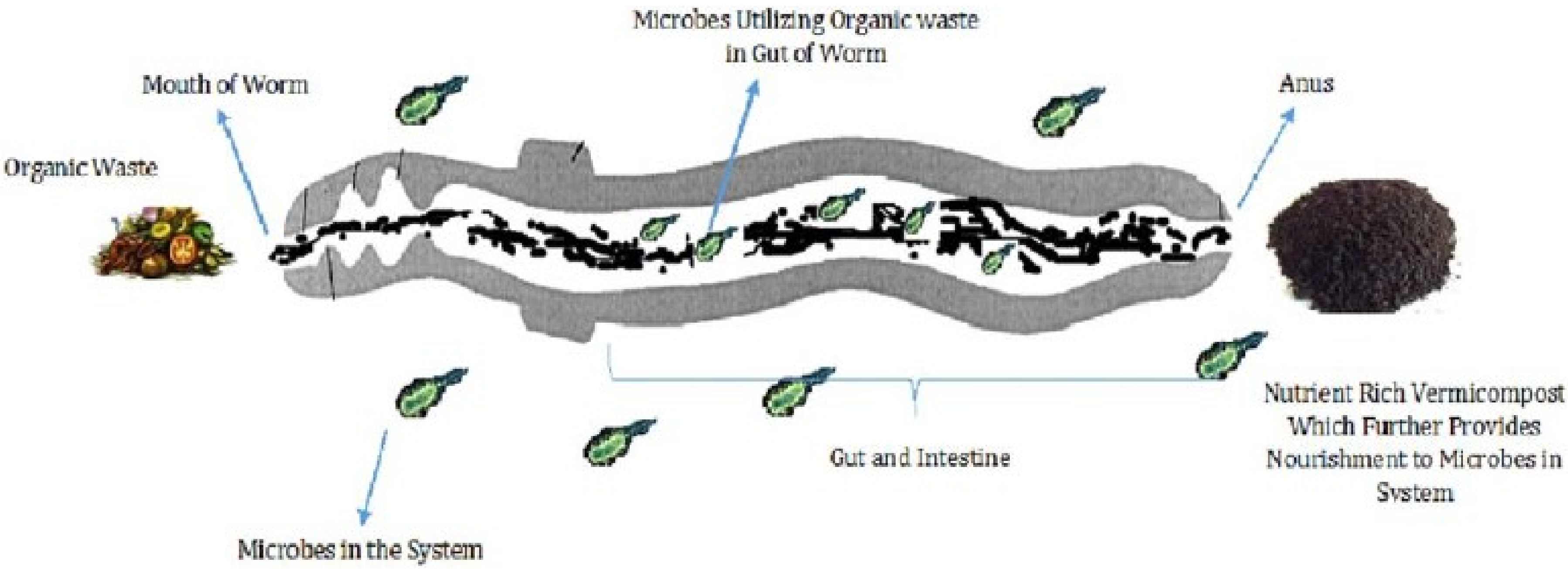

Figure 1. Mutualistic relationship shown by earthworm and microbes.

Table 6. Factors with optimal range for vermicomposting

Parameters	Optimal range for earthworms growth and cocoon production
Stocking density	27–53 worms per kg and 4–8 worms per g/feed
Temperature	25–37°C
Feeding rate	1.25 kg feed/kg worm/day
Moisture	65–70%
C:N Ratio	25
pH	4.2–8.0

FACTORS AFFECTING VERMICOMPOSTING

Feeding

- Enhances growth and reproduction of earthworms and production rate of cocoon.
- The feeding rate is influenced by moisture, particle size, and substrates organic content and feed pretreatment.
- High organic matter reduces the activity of worms, therefore enhancing anaerobic activity of microorganisms which creates anaerobic and foul odor conditions.
- Toxic metals if present in the organic feed become fatal for worms.
- Different types amendments such as cow, sheep, horse, and goat dung may result in better vercomposting producing a better organic manure.

pH

- Neutral pH is suitable for the proper working of worms, but the favorable range reported is 4.5–9.0.
- It mostly depends on earthworm sensitivity and physicochemical characteristics of the waste.
- The difference in physicochemical characteristics of waste mainly alters the pH of vermicomposting process.
- The microbial activity changes physicochemical characteristics of waste during decomposition process along with mineralization of nitrogen and phosphorus into nitrites/nitrates and orthophosphates.
- Some intermediates are produced during vermicomposting, such as ammonium and humic acids, alter the change of pH.

- Types of substrates also affect the pH of the vermicomposting system and the overall pH in vermicomposting process drops from alkaline to acidic nature.
- This is due to the evolution of CO_2 and the accumulation of organic acids

Temperature

- The optimum temperature range may be 25–37˚C which favors the activity, growth, metabolism, respiration, reproduction, and cocoon production for earthworms and also favors the microorganisms associated with earthworms.
- Different earthworm species showed different responses against temperature. For example, *Eisenia fetida* grows optimally at 25 ˚C with 0–35 ˚C temperature tolerance, whereas *Dendrobaena veneta* showed optimum growth at lower temperature and found less tolerance of extreme temperatures.
- *Eudrilus eugeniae* and *Perionyx excavatus* also showed optimum growth at about 25˚C; however, their tolerance temperature range was generally found between 9 and 35˚C.

- From this studies, we may conclude that different earthworm species showed diverse response against diverse temperature ranges.
- Vermicomposting systems, when compared with composting process, are greatly affected by extreme temperature conditions, that is, low or high temperature.
- For example, higher temperatures in vermicomposting systems are responsible for the loss of nitrogen as NH_3 volatilization
- On the other hand, lower temperatures in vermicomposting process fail to destroy pathogenic organisms

Moisture

- The growth rate of earthworms has been related to the moisture level in the vermicomposting system.
- An optimum moisture range between 50 and 80% has been considered for efficient vermicomposting; however, up to 90% of moisture level has also been considered efficient for vermicomposting process.
- Low-moisture conditions delay sexual development of earthworms. The optimum moisture content for *Eisenia fetida* has been reported as 70–80%.
- Some species of earthworms like *Lumbricus terrestris* survive well in dry conditions, whereas others like *Allolobophora chlorotica*, *Allolobophora caliginosa*, and *Aporrectodea rosea* did not survive in dry conditions.

Stocking Density

- The density of earthworms is influenced by several factors including initial substrate quality and quantity, temperature, moisture, and soil structure and texture.
- The copulation frequency of earthworms is high at low population density, whereas it decreases when the density approaches the carrying capacity of the substrate.
- It has been reported that the stocking density of 1.60 kg worms/m^2 is optimum for vermicomposting.
- It has been reported that *Eisenia andrei* grew slowly on higher population density with lower final body weight.

C:N Ratio

- The C:N ratio plays a critical role in cell synthesis, growth, and metabolism of earthworms. For proper nutrition, carbon and nitrogen should be present as substrates in appropriate and correct ratio.
- C:N ratio is one of the most important indicators of waste stabilization, which is widely used in the index for compost maturation.
- The improved compost maturity is reflected with a C:N ratio less than 20 when the initial C:N ratio of the substrate is 25.
- As a result of rapid mineralization and organic matter decomposition, carbon is lost as CO_2 in microbial respiration, and at the same time, nitrogen is increased by worms in the form of mucus, and the nitrogenous excretory material results in overall decrease in C:N ratio.
- However, initial nitrogen contents in the substrate are mainly responsible for the final N content of vermicompost and overall the extent of decomposition. The decrease in pH also plays an important role in nitrogen retention, as at high pH, nitrogen is lost as volatile ammonia

GROWTH AND COCOON PRODUCTION

- The growth rate of worms and the production rate of cocoon during the vermicomposting process are vital for sustainable progress of the process.
- Physicochemical and nutrient characteristics of the feed and substrate are the main factors in determining the growth of earthworms.
- High feeding generally results in high production rates of cocoon which is also a reflection of the quality of the waste.
- Sometimes, there are factors which may lead to decrease in cocoon production and growth rate of worms.
- For example, the production rate of cocoon and the reproduction rate of worms decrease with the increasing concentration of distillery sludge in the vermicomposting system owing to the presence of higher growth-retarding compounds like metals, higher salt concentration, and grease in the initial feed of worms.

- The reduction in worm’s efficiency was attributed to the presence of toxic metals. The toxic copper ions enter the cocoon by diffusion as cocoon membrane is permeable, and these copper ions interact with the proteinaceous material and reserve for developing embryos of worms.
- Similarly, chromium ions across the cell membrane reduce the transport capability of essential metabolites due to electrode potential reduction, which might be the cause of toxicity for developing embryo.
- Lead also affects during cocoon production by entering into cocoon through clitellar muscles and disturbs embryo development.

- Stocking density of worms in vermicomposting system is another important factor which affects both growth rate and rate of cocoon production.
- The higher stocking density results in reduced earthworm growth and cocoon production even at appropriate physicochemical conditions.
- The worm population of 27–53 worms per kilogram and 4–8 worms per gram/feed mixture is optimum as stocking density for effective vermicomposting system.
- It has been reported that the production rate of cocoon and the performance of earthworm were high at high-stocking density load, whereas the individual biomass production was high in low-stocking density
- loads.

- Substrate type also affects the growth rate of worms and the production rate of cocoon.
- Effects of different animal dungs like from cow, buffalo, horse, donkey, sheep, goat, and camel have been studied and varying results have been obtained. Mainly the dung which were better source of nutrients supported higher growth rates of worms and rate cocoon formation.
- However, presence of toxic substances along with feed interfered with both growth and cocoon formation.
- Other factors affecting these growth rate and rate of cocoon production were **Temperature** – apropriate range was 25–37˚C This has been attributed to accelerated sexual maturity of earthworms with increasing temperature up to 30C.
- **Moisture**- The optimal moisture content of 65–70% was considered good for worm growth and cocoon production
- BIOGAS PRODUCTION USING VERMICOMPOST

BIOGAS PRODUCTION USING VERMICOMPOST AND USE OF BIOGAS SLURRY

- Biogas is produced as a result of anaerobic digestion or codigestion of animal wastes or organic wastes.
- Mostly, it is used in lighting and cooking by farmers in agriculture based countries, which is produced in reactors known as biogas digesters, and millions of people around the world get benefited by this low-cost and environment-friendly technology.
- Generally, biogas is a composition mixture of 48–65% methane, 36–41% carbon dioxide, up to 17% nitrogen, <1% oxygen, and 32–169 ppm hydrogen sulfide, and traces of other gases.
- In anaerobic digestion process, the yield of biogas is affected by many factors, among which substrate composition is one important factor.
- Actually, it is the pretreatment requirement in anaerobic codigestion process which enhances the production of biogas; however, pretreatments are rarely discussed in the literature since the last decade.
- Currently, intensive research has been carried out to explore the pretreatment options for anaerobic codigestion and production of biogas.

- Previously, pretreatment involved mechanical (33%), thermal (24%), and chemical (21%) methods; however, the focus has now been diverted toward **biological pretreatments**, and the use of **vermicompost** is one sound option.
- In fact, the chitin present in initial substrate composition in anaerobic process is hard to be degraded by anaerobic microorganisms.
- The vermicomposting process enhances the degradability of chitin by hydrolysis to free N-acetyl-D-glucosamine by a chitinolytic system consisting of two hydrolases, chitinase and N-acetyl β-glucosaminidase which act consecutively.
- The vermicompost also provides large surface area to enhance nutrient retention for anaerobic microorganisms responsible for biogas production.

- Degradation of chitin by vermicomposting made the conditions favourable for anaerobic microorganisms to readily attack the vermicomposted enwrapped degradable organic matters and improved the methane production.
- Improvement in Methane production using codigestion with vermicomposting of corn stalks has been reported when compared to the anaerobic digestion process used alone.
- The improvement in cellulose destruction was also observed by the addition of vermicompost.
- On the other hand, the byproduct of biogas termed as “biogas slurry” can effectively be used for the substrate amendment in vermicomposting systems.

INDUSTRIAL PERSPECTIVE OF VERMICOMPOSTING

- Owing to the environmental issues and pollution problems associated with conventional treatment methods for the treatment of industrial wastes, vermicomposting has been growing as an emerging cost-effective and environmentally sound treatment option for a wide range of industries.
- Vermicomposting can effectively be used for industrial solid waste, including palm oil mill, paper pulp, winery/beverage, sugar, textile, food, thermal power plant, dairy, tannery, distillery, oil extraction , guar gum, and sago industries.
- Vermicomposting systems are less energy consuming, economically feasible, and cost effective over conventional treatment technologies and have more potential of nutrient recovery.
- According to a report. 20–25 million US dollars is required for the constructionof engineered landfills and dumping of first load.
- On the other hand, vermicomposting provides profit when compared with capital investment in terms of better growth of crops and sales of vermicompost.

- The marketing and economic cost effectiveness of vermicompost has been studied by Devkota.
- The authors collected information on the production and marketing of vermicompost from vermicompost producers of Chitwan, Nepal.
- The authors suggested that vermicompost total production cost was Rs. 15.68 per kilogram compost and Rs. 0.40 per earthworm with a net profit of Rs. 9.32 per kilogram.
- Total variable and gross cost was found to be 4.30 and 2.55, respectively, in view of undiscounted benefit cost ratio. The payback period of capital investment was suggested to be 1.72 years.
- This study revealed high feasibility enterprise for vermicompost production.

References

- Gajalakshmi, S., Ramasamy, E., & Abbasi, S. (2002). Vermicomposting of paper waste with the anecic earthworm Lampito mauritii Kinberg, Indian Journal of Chemical Technology, 9, 306–311.