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Vermicomposting in Solid Waste Management: A Review

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Abstract—*Vermicomposting is a bio-conversion process which is widely being used for solid waste management. In this bio-conversion process, earthworms feed on the organic waste to produce more earthworms, vermicompost and vermiwash as products. Earthworms which include Megascolex Mauritii, Eisenia Fetida, Eudrilus Eugeniae, Perionnyx Excavatus, Lampito Mauritii, Eisenia Andrei, Lampito Rubellus and Drawida Willis have been widely used for vermicomposting. Vermicomposting has been done for various wastes including animal, plant, pharmaceutical, food waste and sewage waste over vermicomposting periods ranging from 28-120 days using these earthworms. The process conditions during vermicomposting ranged from 18-67°C for temperature, pH 5.9-8.3 and moisture content 10.6-80%. Vermicompost yields of 30-50% have been achieved for various organic wastes and composting periods. The vermicompost and vermiwash produced were rich in nitrogen, phosphorous and potassium (NPK). The vermicompost obtained had NPK compositions ranging from 0.3-4.19%, 0.2-1.6% and 0.2-6.18% respectively. The vermiwash obtained had NPK composition ranging from 0.14-1.58%, 0.05-7.53% and 0.47-1.26% respectively. Vermicompost and vermiwash have been applied on cow pea, soy bean, maize and marigold as bio-fertilizers. Vermicomposting can be used for solid waste management and the production of bio-fertilizers.*

Key Words: Bio-fertilizers; Earthworms; Vermicompost; Vermiwash; Waste Management

I. INTRODUCTION

Vermicomposting technology is globally becoming a popular solid waste management technique [1-14]. Vermicomposting is the bioconversion of organic waste into a bio-fertilizer due to earthworms' activity [1-15]. The earthworms feed on the organic waste and the earthworms' gut acts as a bioreactor whereby the vermicasts are produced [16]. By the time the organic waste is excreted by the earthworms as vermicasts, it will be rich in nitrogen (N), phosphorous (P) and potassium (K) as well as trace elements depending on the feedstock type used [2; 4-14; 17-19]. The vermicomposting process is a mesophillic process and operating conditions such as temperatures, pH, electrical conductivity and moisture content levels must be optimized. Normally, the vermicomposting process takes place in vermi-reactors which include plastic, earthed pots and wood worm bins [8]

VERMICOMPOSTING PROCESS REQUIREMENTS

For the vermicomposting process to progress there is need for the earthworms, organic waste and operating conditions to be optimized.

A. Earthworms

Various earthworms have been used for vermicomposting and these include *Megascolex Mauritii, Eisenia Fetida, Eudrilus Eugeniae, Perionnyx Excavatus, Lampito Mauritii, Eisenia Andrei, Lampito Rubellus and Drawida Willis* [2-3; 4-15; 17-18; 20-22] (see Table 1). However, *Eisenia Fetida* has been noted as the earthworm of choice for vermicomposting and is adaptable to
changing conditions and has lower chances of compromising on the vermicompost process [4-14; 16; 23-41].The change in earthworms weight, length, reproduction rate and population density have also been used to measure the progress of vermicomposting [15; 18-19; 23; 25; 29; 35; 37; 41-48].

B. Feed stocks and vermicomposting periods

The organic waste is converted to a bio-fertilizer by earthworms' action over a certain period of time in a vermireactor [19]. In addition, the process conditions are closely monitored so they will not disturb the earthworm activity [4; 19]. The process conditions monitored include temperature, moisture content, pH and electrical conductivity [4; 22; 39].

Various feedstock have been employed in vermicomposting ranging from animal, plant, pharmaceutical, food and sewage waste over vermicomposting periods ranging from 28-120 days [25; 32; 41; 44-45; 49]. The NPK content in the vermicompost varied from 0.38-1.76%, 0.2-1.6% and 0.69-4.98% respectively depending on the type of waste used [4-14; 17; 22; 39; 48-49] (see Table 2). The temperature of the vermicompost ranged from 18-67°C, pH 5.9-8.3 and moisture content 10.6-80% during vermicomposting [19; 25; 29; 32; 34-35; 44-45; 48; 50]. Additionally the vermicompost electrical conductivity ranged from 0.70-80 000μscm^{-1} [4; 39; 41; 46; 47; 49]. Furthermore, vermiwash which is collected as leachate during vermicomposting is reported to have a pH of around 7.7 [16]. This vermiwash had NP content of 0.14% and 0.05% respectively [25].

II. VERMICOMPOSTING PRODUCTS

The process of vermicomposting produces earthworms as products by a process called vermiculture. Furthermore, vermicompost which is also termed vermicasts is produced together with vermiwash. The vermicompost and vermiwash can be utilized as bio-fertilizers [13].

A. Earthworms

Different quantities of earthworms have been inoculated in different organic wastes and the earthworm response in terms of growth and reproduction rate has been monitored (see Table 1). Earthworm activity during vermicomposting has been monitored by looking at the earthworm biomass gain, cocoon production, weight gain, increase in worm length and worm number as well as the growth rate [42; 47]. Additionally, parameters such as temperature, feed type, earthworm stock density and feedstock loading rate have been studied to see their influence on earthworm activity [24].
The earthworm growth rate during vermicomposting is calculated according to Equation 1 [35]:

$$G = \frac{B2 - B1}{T X n} \qquad (1)$$

Where:
G = Earthworm growth rate (mg/worm/day)
B_1 = Initial biomass of worm (mg)
B_2 = Maximum biomass obtained by worm (mg)
T = Number of days in which biomass is attained
N = Number of earthworms inoculated
The earthworm biomass gained per unit feed mixture (mg/g) is calculated according to Equation 2 [35]:

$$\frac{B2 - B1}{W} \qquad (2)$$

Where:
W = Total quantity of organic waste taken (g)
In addition, the earthworm reproduction rate is calculated according to Equation 3: [35]:

$$R = \frac{C}{E} \qquad (3)$$

Where:
R = Earthworm reproduction rate
C = Total number of cocoons produced
E = Total number of earthworms
The earthworms produced can also be further used in vermifiltration [54-55]. Vermifiltration technology involves the use of earthworms as bio-filters in wastewater treatment [54-55]. In addition, these earthworms from vermicomposting can also be used in vermi-remediation, which involves the removal of heavy metals in soils [54-55].

B. Vermicompost

Vermicompost is an odourless, dark brown bio-fertilizer obtained from the process of vermicomposting [1; 4; 51-52]. The vermicompost obtained are also termed vermicasts as they are expelled as casts from the earthworm gut. Various types of organic waste have been reported to produce vermicompost and a range of nitrogen (N), phosphorous (P) and potassium (K) content were obtained (see Table 3). The quality of the vermicompost is measured by the vermicompost biodegradability coefficient [35].

The vermicompost biodegradability coefficient, (K_b) of the vermicompost is calculated according to equation to Equation 4 [35]:

$$Kb = \frac{(OMi - OMf)\ X\ 100}{OMi\ (100 - OMf)} \qquad (4)$$

Where:
OM_f = Organic matter content at the end of the vermicompost process
OM_i = Organic matter content at the beginning of the vermicompost process

The difference in percentage is accounted for by the increase in earthworms' number, earthworm length, earthworm weight and the vermiwash liquid produced [16; 33; 39].

C. Vermiwash

Vermiwash is a leachate that is produced during the vermicomposting process and is dark brown in colour [2; 5; 8-10; 13; 16; 25; 36; 50; 53; 57-58]. The nutritional composition of vermiwash obtained from different organic waste in terms of NPK and trace elements composition is summarized in Table 4. Very few authors have embarked on the potential of vermiwash as a bio-fertilizer. Vermiwash can also be used as a foliar spray whereby it acts as a pesticide in sustainable agriculture [58-59].

III. USE OF VERMICOMPOST AND VERMIWASH AS BIOFERTILISERS

Vermicompost and vermiwash are rich in NPK, and trace elements has been studied [8-10; 19; 61]. Their potential use as bio fertilisers has been investigated as well as their impact on soil properties.

A. Effect of vermicompost and vermiwash on soil properties

B.

The effect of vermicompost and vermiwash from different organic waste's influence on the soil chemical properties were studied by few researchers [8-10; 19; 61; 65]. The influence of applying vermicompost and vermiwash on soil properties such as pH, electrical conductivity, NPK and trace elements composition has been critically investigated. Vermicompost and vermiwash significantly increases the soil NPK and trace elements composition.

C. Effect of vermicompost and vermiwash on plant growth

The effects of vermicompost and vermiwash on various plants have been studied. Vermicompost and vermiwash influence on plants such as cow pea, soy bean, maize and marigold has been examined (see Table 5). Factors such as plant yield, plant height, number of flowers, number of leaves and roots as well as the biochemical composition of the plant leaves were used as measure of the effectiveness of the vermi-products (see Table 5). Upon applying vermicompost and vermiwash as bio fertilisers, the above factors showed a marked improvement.

IV. CONCLUSION

Vermicomposting is an advantageous technology for waste management. Vermicomposting results in earthworms, vermicompost and vermiwash as products. The vermi-products can be used as bio-fertilizers whilst the earthworms can be used for further vermicomposting and other technologies like vermifiltration and vermi-remediation.

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Table 1: Earthworm growth activities for various earthworm species used for vermicomposting

Reference	Organic waste used	Type of earthworm used	Parameters monitored on earthworms
[15]	Wood waste	*Drawida Willis*	Weight
[18]	Sugarcane bagasse	*Eudrilus Eugeniae*	Weight and size
[19]	Temple waste	*Eudrilus Eugeniae*	Weight and number of cocoons produced
[23]	Sewage sludge and waste paper	*Eisenia Fetida*	Number of worms
[24]	Bio solids	*Eisenia Fetida*	Stocking density and length
[29]	Vegetable market solids	*Eisenia Fetida*	Biomass gain and cocoons produced
[34]	Food industry waste	*Eisenia Fetida*	Biomass gain and cocoons produced
[35]	Household solid waste and cow dung	*Eisenia Fetida*	Biomass gain, number of worms and cocoons produced
[37]	Waste coffee	*Eisenia Fetida*	Biomass gain
[41]	Herbal pharmaceutical waste	*Eisenia Fetida*	Weight, biomass gain, cocoons produced and earthworm population
[43]	Animal waste	*Eisenia Fetida*	Weight, growth rate and biomass gain
[45]	Herbal industry waste and cow dung	*Eudrilus Eugeniae*	Weight and number of worms
[46]	Soybean husk	*Eudrilus Eugeniae*	Biomass gain, number of worms and number of cocoons
[47]	Rice husk	*Eudrilus Eugeniae*	Growth rate and weight

Table 2: Feed stocks used in vermicomposting and periods of vermicomposting

Reference	Organic waste vermicomposted	Vermicomposting Period
[2]	Leaves and cow dung	30
[4]	Cow dung, waste corn pulp	30
[5]	Various food wastes	30
[15]	Wood waste	40
[16]	Grass and cow dung	45
[18]	Sugar cane bagasse	48
[19]	Temple waste	30
[20]	Cow dung humus and soil	45
[24]	Bio solids	25
[25]	Sewage sludge, waste paper	28
[27]	Pig manure	252
[29]	Kitchen wastes and agro waste	50-60
[32]	Farmyard garbage	120
[33]	Grass, cow dung, water hyacinth	60
[34]	Food industry wastes	117
[36]	Cow dung	60
[37]	Waste coffee	72
[38]	Plant wastes and cow dung	45
[40]	Buffalo dung	50
[43]	Animal waste	50-70
[45]	Herbal industry wastes and cow dung	62
[47]	Rice husk	63
[48]	Municipal waste	60
[49]	Various waste	45
[51]	Household kitchen wastes	40
[52]	Agro waste and domestic refuse	45
[53]	Leaf litters	60

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Table 3: Quality of Vermicompost produced and process conditions employed

Reference	Organic waste used	T (◦C)	pH	Moisture Content (%)	Electrical Conductivity (μScm^{-1})	N%	P%	K%
[4]	Cow dung and waste corn pulp	19-25	5.5-7.7	28-52	60000-80000	4.19	1.15	6.18
[17]	Soil, cow dung and vegetable waste		7.5-8.3			1.45-1.76	0.57-1.60	1.98-4.98
[19]	Temple waste	25	8	80		1.58	0.33	0.28
[22]			7.2			1.65	1.2	0.92
[39]	Grass and cow dung	26-28	6.81		5.0-25	1.0-3.0	0.2-0.6	1.0-3.0
[44]		29	7.8		10.6	0.38	0.87	0.69
[48]	Municipal waste	32.4	7.1			1.2	0.9	1.4
[49]	Various organic waste	35	7.2	50-60	4.2	1.32	0.45	0.75

Table 4: Vermiwash from different organic wastes at various process conditions

Reference	Organic waste used	Vermicomposting period (days)	pH	Electrical Conductivity (dsm^{-1})	N	P	K
[2]	Leaves and cow dung	30	7.5	0.02-2.12			
[4]	Cow dung and waste corn pulp	30	6.8-8.4	42.7-59.7	1.58%	7.53%	1.26%
[5]	Various food wastes	30			0.58%	0%	0.47%
[16]	Grass and cow dung	45	7.7		0.02ppm	48.86ppm	245ppm
[25]	Sewage sludge and waste paper	28			0.14%	0.05%	
[36]	Cow dung	60	7.5	9.8			
[58]	Coconut leaf and cow dung		7.6-8				

Table 5: Effect of vermicompost and vermiwash on plant growth

Reference	Vermi-product applied	Plant grown	Plant factors monitored
[2]	Vermiwash	Rice	Number of leaves, height, leaf and root length
[10]	Vermicompost and vermiwash	Zea Mays	Plant height, number of leaves and cob weight
[16]	Vermicompost	Okra	Biochemical properties, yield and fruits
[19]	Vermicompost	Flowering plants	Height, flowering time, number of flowers
[22]	Vermicompost	Tomatoes	Number of leaves, branches and fruits
[36]	Vermiwash and vermicompost	Lemon grass	Yield
[38]	Vermicompost	Yellow mustard	Number of roots, shoots, branches, leaves, pods and flowers
[40]	Vermicompost	Paddy, maize and millet	Plant height
[45]	Vermicompost	Potted peas and marigold	Weight of shoots and roots, number of flowers, yield, chlorophyll content and carotene
[48]	Vermicompost	Chilli pepper	Plant height, leaf length, fruit yield and chlorophyll content
[57]	Vermiwash	Pak choi	Plant height and root length
[58]	Vermiwash	Cow pea, maize and okra	Yield
[61]	Vermicompost	Medicinal plant	Weight of shoots and roots, flowers, yield, chlorophyll and carotene content
[63]	Vermicompost	Corn	Number of roots and shoots