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Vermicompostingof Waste Corn Pulp Blended with Cow Dung Manure using Eisenia Fetida

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Abstract**—**Waste corn pulp was investigated as a potential feedstock during vermicomposting using *Eisenia fetida*. Corn pulp is the major staple food in Southern Africa and constitutes about 25% of the total organic waste. Wastecooked corn pulp was blended with cow dung in the ratio 6:1 respectively to optimize the vermicomposting process. The feedstock was allowed to vermicompost for 30 days. The vermicomposting took place in a 3-tray plastic worm bin. Moisture content, temperature, pH, and electrical conductivity were monitoreddaily. The NPK content was determined at day 30. During vermicomposting, moisture content increased from 27.68% to 52.41%, temperature ranged between 19-25◦C, pH increased from 5.5 to 7.7, and electrical conductivity decreased from 80000μS/cm to 60000μS/cm. The ash content increased from 11.40% to 28.15%; additionally the volatile matter increased from 1.45% to 10.02%. An odorless, dark brown vermicompost was obtained. The vermicompost NPK content was 4.19%, 1.15%, and 6.18% respectively.

Keywords**—**corn pulp, *Eisenia fetida*, vermicomposting, waste management

I. Introduction

THERMOPHILLIC composting has been traditionally used for the treatment of organic waste and the production of organic fertilizers over decades [1]. Recently, a related technology, vermicomposting has become increasingly popular in many continents over the past two decades[2].Vermicomposting is the use of mesophillic earthworms to produce an organic fertilizer from organic waste[1]. The earth worms feed on the organic waste producing vermicasts, at the same time reproducing,increasing in size, and number[3].

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Vermicomposting is a bio-conversion process with the gut of the earthworms acting as the bioreactor[2]. The earthworms' gut is an effective tubular bioreactor with raw materials (feed) entering from one end and the product (vermicastings) coming out through the other end. The temperature is maintained by a novel temperature regulatory mechanism, accelerating the rates of bioprocess and preventing enzyme inactivation caused by high temperature. The earthworms' gizzard is colloidal mill in which the feed is ground into particles smaller than 2m, giving thereby, an increased surface area for microbial processing. Earthworm gut has nearly 73% of gram-ve, facultative anaerobic, *Vibrio*sp (an autochthonous micro flora) that are responsible for the degradation of ingested food. Mucous produced by the glands in the anterior region of the earthworm gut provides a favourable substrate for symbiotic microorganisms that decompose complex organic compounds.

The vermicomposting process is inexpensive and uses low technology[1]. In addition, vermicomposting is an attractive waste management at source strategy and can be implemented anywhere for solid waste management[2]. Recent applications of vermicomposting were done on grass and cow dung by Ansari and Rajpersaud[4] using *Eiseniafetida*.Organic waste is also the major contributor of greenhouse gases when disposed at disposal sites. The conversion of organic waste into vermicompost ensures limited, if any, generation of greenhouse gases subsequently reducing the ozone destruction potential of disposal sites.Since vermicomposting technology is a mesophillic process, moderate temperatures must be maintained; these activate and accelerate the decomposition process[4]. Temperatures below 45◦C are ideal for mesophillic processes [4]. In addition, earthworms that are used in vermicomposting are reported to be sensitive to pH of the organic waste[5]. A pH range of 5.0 to 9.0 is reported to be optimal for worm growth[5].The pH of the soil determines the rate at which nutrients are absorbed in the soil. Micronutrients tend to be unavailable to soil with high pH whereas macronutrients are not available at low pH[4]. Henceforth, it is necessary for the vermicompost to have a neutral pH for maximum absorption of nutrients.A low electrical conductivity of the vermicompost allows a slow release of mineral salts into the soil maximizing the absorption of the nutrients by the plants[6, 7].The moisture content of the vermi-compost plays a critical role for the optimal bio-conversion and mineralization of the organic waste. Optimal moisture content of 45-75% is ideal for earthworm growth and fast production of the vermicompost [2].

The earthworm species most often used are Red Wigglers (*Eisenia fetida* or *Eisenia Andrei*), but *Lumbricus rubellus* (a.k.a. red earthworm or dilong (China)) are another breed of worm that can be used but adapt less well to the shallow compost bin than *Eisenia*. European nightcrawlers (*Eisenia hortensis*) also may be used. Users refer to European nightcrawlers by a variety of other names, including dendrobaenas, dendras, and Belgian nightcrawlers. *Lumbricus terrestris* (a.k.a. nightcrawlers (US) or common earthworm (UK)) are not recommended as they burrow deeper than most compost bins can accommodate. Blueworms (*Perionyxexcavatus*) may be used in the tropics. However, *P. excavatus* worms are not suitable for worm compost bins in most of the contiguous United States. These species commonly are found in organic-rich soils throughout Europe and North America and live in rotting vegetation, compost, and manure piles. They may be an invasive species in some areas. As they are shallow-dwelling and feed on decomposing plant matter in the soil, they adapt easily to living on food or plant waste in the confines of a worm bin.

In Harare, Zimbabwe, each household generate 2.7kg per day of waste as indicated by the Municipality. Harare has an average population of 2.8 million. An average household is 6 people and this totals to 1,260 tons of waste per day. 47% of the waste is biodegradable and 25% of it is waste corn pulp, which is the staple food in Southern Africa. The potential of converting waste corn pulp into vermi-compost needs to be investigated.Previous studies have been done on kitchen waste by Chaudhuri*et al.*[8] comprising of potato and onion skin, leaves and part of cabbage, cauliflower and carrots, banana skin, egg shells, and boiled rice. However, nocomprehensive study has been done on organic waste mainly composed of corn pulp;hence vermicomposting of wastecorn pulp from the Institute canteen remains was investigated.

II. Materials And Methods

A. Materials

The materials that were used included corn pulp, cow dung, earthworms,and the worm bin.Feedstock with 1 part cow dung manure and 6 parts waste corn pulp per weight was prepared. The waste corn pulp was obtained from the Harare Institute of Technology canteen whilst the cow dung manure was obtained from a nearby farm.Cow dung is reported to influence the rate of vermicomposting by increasing the amount of macronutrients as well as increase the vermicompost nitrogen content[6, 9]. Cow dung also provides microbes which accelerate the decomposition process[4].

Red wriggler(*Eisenia fetida*) earth wormswere used for vermicomposting. *Eisenia fetida* are non-burrowingearth worms and are reddish in colour. They have a life span of about 28 months.*Eisenia fetida* species eat about 90% of organic waste and thrives best at temperatures of 25-40◦C and moisture levels of 40-45% [4].*Eisenia fetida* species are capable of ingesting and excreting organic material at a faster rate compared to other non-burrowing species[9].

The vermicomposting process was done in a lab scale black plastic worm bin obtained from Full Cycle, South Africa. The dimensions of the worm bin were:length 53cm, width 34.6cm, and depth 18.5cm. The worm bin hadthree chambers. The chambers had 7mm holes to allow movement of worms from one chamber to the next after vermicomposting in that tray.

There were also10 x 3mm outlets at the four corners of each chamber to facilitate collection of the vermiwash throughout the vermicomposting process. The worm bin was four legged to allow free air circulation in the organic waste.The worm bin was covered with a lid to prevent the entry of unwanted insects and predators.The covering of the lid also stimulated the growth and reproduction of theworms[10]. Additionally, the lid was punched to allow easy of air circulation. The worms migrated to the preceding chamber where new feed was introduced after converting all the waste to vermicasts in that chamber. The worm bin was maintained at standard room temperature and pressure.

B. Methods

The feedstock was vermicomposted whilst temperature, pH, moisture content, and electrical conductivity were monitored daily. The ash content, volatile matter, and fixed carbon were determined at the beginning and end of the process. Thenitrogen (N), phosphorous (P), andpotassium (K) content was determined at the end of the vermi-composting. Trace elements in the vermicompost were also determined.The readings were taken three times a day and an average value was used.

10kg of the feedstock was placed in the worm bin. The whole vermicomposting period lasted for 30 days. The material was turned to provide sufficient aeration and ensure adequate decomposition of all parts. In addition, movement of the worms during vermicomposting improved the feedstock aeration. A 10-12cm layer of the organic waste was placed in the worm bin at the bottom chamber whereby the vermicomposting process was initiated. Worms were introduced to the waste at a rate of 1kg/m^2 as indicated by Indrajeet*et al.*[10]. Moisture content and volatile matter analyses were done using an AND moisture analyser. The %Moisture content (M) was determined by heating 5g of sample at 105◦C for 30 minutes and then recording the difference in weight. The %Volatile matter (VM) was determined by heating 5g of sample at 105◦C for 3 minutes and then recording the difference in weight. The %Ash content (AC) was determined by completely incinerating the 5g sample using a burner. The total %Fixed carbon was determined as: 100% - %(M + VM + AC).pH and electrical conductivity measurements were done usinga Hanna HI 9810 instrument. The nitrogen, phosphorous, and trace elements content were determined using an ultra violet visible spectrophotometer. The potassium content was determined using a flame atomizationabsorption spectrophotometer.

After the 30 days, the worms remaining in the tray with the ripe vermicompost were handpicked and transferred to the tray with the new feedstock. There is however, a chance that earthworm cocoons remained inthe vermicompost and were lost during harvesting. The vermicompost was then sundried and stored.

III. Results and Discussion

A. Changes in ash content, volatile matter and fixed carbon

The ash content significantly increased during vermicomposting by 147% (see Table I).

This was possibly due to the conversion of the substrate into vermicasts during the vermicomposting process[5]. This is also indicated by the increased volatile matter by 591% (see Table I) which is a good measure of the degradation of the organic waste [2]. Additionally, thiscan be related to the decrease in the fixed carbon value from 59.47% to 9.42% which is also a measure of adequate vermicomposting. However, some of the material was changed to the weight of the earthworms and some of the organic waste was converted to the vermiwash.

TABLE I
CHANGES IN ASH CONTENT, VOLATILE MATTER AND FIXED CARBON

Parameter (%)	Feedstock	Vermicompost
Volatile matter	1.45	10.02
Moisture content	27.68	52.41
Ash content	11.40	28.15
Fixed carbon	59.47	9.42

B. Variations of process parameters

The process parameters that were monitored during the vermicomposting period include moisture content, electrical conductivity, temperature, andpH. This was necessary to ensure optimal processing of the organic waste to the vermicompost. The moisture content increased from 27.68% to about 52% as the vermicomposting period increased (see Figure 1). This was probably due to vermiwash that was being continuously produced during the process. The values obtained were in line with those reported from literature[2].Increase in moisture content in the required range increased the earthworm bio-conversion rate of organic waste to vermicompost[2].

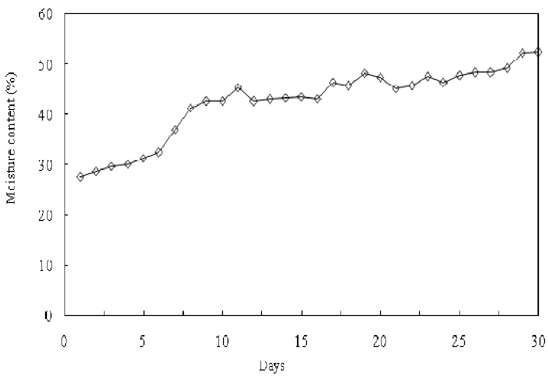

Fig. 1 Moisture content changes

There was a general decrease in the electrical conductivity of the vermicompost during the 30 day vermi-composting period (see Figure2). The values decreased from 80000μS/cm to 60000μS/cmwith an overall 25% decrease. The trend was probably due to the increase in moisture content from 27.68% to about 52.41% as illustrated in Figure 1. Lower vermicompost electrical conductivity is reported to be ideal for plant growth as this allows maximum nutrient absorption by plants[4].

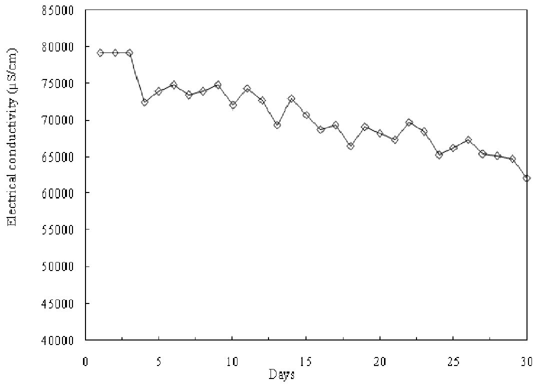

Fig. 2 Electrical conductivity changes

Moderate vermicomposttemperatures were achieved during the 30 day period. Temperatures ranged between 19◦C to 25◦C as indicated in Figure3. These temperatures are good for optimum vermicomposting and earthworm growth [2, 11]. The variations in temperature changes can be attributed to the metabolic reactions that were occurring during the vermicomposting process and also changes in the surrounding temperatures. The moderate temperatures also prevent enzyme inactivation during the bioconversion of the organic waste to vermicasts.

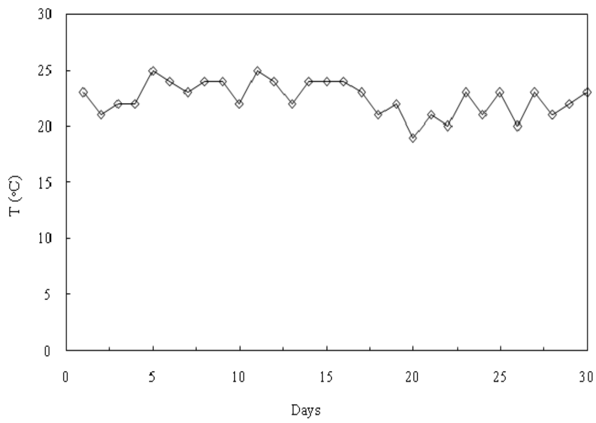

Fig. 3 T**e**mperature changes

There was a slight rise in the vermicompost pHfrom 5.5 to 8.0 then a decrease to7.7 during the 30 day vermicomposting period as indicated in Figure4.The vermi-compost changed from being acidic to basic. This increase was possibly due to nitrogenous waste excreted by the earth worms. The pH eventually decreased to 7.7. This was because of the vermiwash released in the process. This vermiwash increased the moisture content thus neutralising the pH of the vermicompost[4]. The same trend was obtained by Singh *et al.*[5] when their pH increased from 4.3 to 8.2. ThepH obtained in this study was optimal for application in the soil as well as earth worm growth [5, 12].

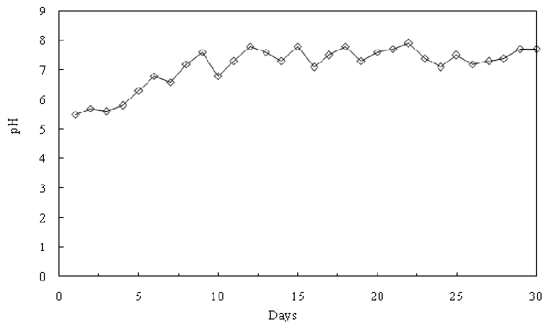

Fig. 4 pH changes

C. Composition of the vermicompost from corn pulp

The composition of the vermicompost was based on the NPK content as well as the available trace elements.The vermicompost produced from the waste corn pulp was rich in nitrogen (N), phosphorous (P), and potassium (K) content (see Table II). The waste corn pulp vermicompost contained total nitrogen of 4.19%. This nitrogen content value could have been due to nitrogenous metabolic products of earthworms which were returned to the vermicompost as casts and urine[9].The total phosphatein the vermicompost was1.15%.This phosphate content is attributed to the mineralisation and mobilisation of phosphorous due to earthworm activity. Earthworms play an important role in the release of phosphates on organic matter[4].

The potassiumcontent in the vermicompost was 6.18% during the vermi-composting process. This increasein nutrients is boosted by the earthworm activity on the corn pulp[4]. Muthukumaravel*et al*.[9] had the same trend in NPK when they vermicomposted a mixture of soil, cow dung and vegetable waste using *Megascolex mauritii*, however, the nitrogen and potassium content from the waste corn pulp were on the high side. The remaining 88% of the vermicompost can be used as a soil filler to reduce leaching of nutrients.The vermicompost also contained trace elementsthat are necessary for plant growth (see Table II). Iron (Fe) was the major trace element with 162.3ppm and is essential for chlorophyll formation in plant leaves. Magnesium (Mg) whichis essential for the strength of stemswas 6.58ppm. Additionally, the vermi-compost contained 4.85ppm sodium (Na) which is essential for the balance of salts.

TABLE II
VERMICOMPOST FROM WASTE CORN PULP COMPOSITION

Nutrient	Vermicompost composition
N (%)	4.19
P (%)	1.15
K (%)	6.18
Na (ppm)	4.85
Mg (ppm)	6.58
Cu (ppm)	0.57
Zn (ppm)	1.35
Fe (ppm)	162.30
Mn (ppm)	1.62

IV. CONCLUSION

The vermicompost produced from waste corn pulp was dark brown and odorless.The optimum operating conditions for the process were moisture content (27.68-52.41%), temperature (19-25◦C), pH (5.5-7.7), and electrical conductivity (60000-80000μS/cm).The vermicompost NPK composition was 4.19%, 1.15% and 6.18% respectively. The vermicompost major trace elements were Fe, Mg, and Na with a composition of 162.32ppm, 6.58ppm, and 4.85ppm respectively. The results show that vermicomposting technology can be successfully applied in Southern Africa as a solid waste management strategy with corn pulp as the major organic waste.

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