92-106 J. Nat. Hist. Mus. Vol. 27, 2013

EFFECTIVENESS OF VERMICOMPOSTING IN MANAGEMENT OF ORGANIC WASTES USING *EISENIA FOETIDA* AND *PERIONYX FAVATUS* IN CENTRAL ZOO JAWALAKHEL, NEPAL

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ABSTRACT

Management of Zoo wastes has been increasing problem in urban areas. The major part of the Zoo waste is organic material contributing from animal dungs, garbage and litter which can be converted into fertile compost. We used the vermicomposting techniques for converting the elephant dung, rhino dung, garbage and litter into compost in relatively short time compared to traditional method of composting. The physico-chemical and microbiological parameters of thus prepared compost were tested adopting standard scientific methods. The analysis showed that pH, organic matter content, moisture content, nitrogen, phosphorous, potassium and (Carbon:Nitrogen) C: N value are appropriate for utilizing in the farming. Thus vermicomposting is one of the viable options for converting huge amount of organic waste into high quality compost effectively.

Key words: elephant dung, rhino dung, garbage, litter, waste management

INTRODUCTION

Inadequate safe disposal of solid wastes resulting in garbage and sanitation situation in a chaotic state poses a risk to public health in Nepal. There are several methods for the management of solid waste and composting for the management of biodegradable waste. Composting is a biological conversion of solid organic waste into usable end products such as fertilizers, substrates for mushroom production and biogas. Moreover, their high organic matter content and biological activity make composts effective in a variety of applications, including erosion control, re-vegetation, bio-filtration and bio-remediation (Alexander 1999). Another bio-technique for converting the solid organic waste faster into compost is vermicomposting. Vermicomposting differs from conventional composting in several ways (Gandhi *et al.* 1997). It is a simple and low cost, an environment friendly biotechnology system for the processing or treatment of organic wastes (Hand *et al.* 1988), in which certain species of earthworms are used to accelerate the breakdown of organic matter and stabilization of soil aggregates (Dindal 1985) to enhance the process of conversion of waste to a useful byproduct. Since it contains water-soluble nutrients, vermicompost is an excellent, nutrient-rich organic fertilizer and soil conditioner (Ravichandran *et al.* 2001).

The Central Zoo located at Jawalakhel in the Kathmandu Valley, houses a wide variety of mammals, birds and reptiles. These animals, numbering over 900 of 123 different species including 31 species of mammals, 63 of birds, 9 of reptiles and 20 of fishes. The waste generated from the Central Zoo is mainly organic in nature. The herbivorous animals such as Asian elephants, rhinos, hippos etc. produce large quantity of organic waste. The excreta produced by Asian elephant, One-horn rhinoceros followed by litter and garbage can be the major raw material for vermicomposting. An elephant produces an average of 106 kg dung daily which is semi-digested and a one-horn rhino produce about 56 kg of waste daily which constitute the major component of Zoo waste. In addition to this, there are huge quantities of organic waste and fodder from enclosures, vegetable, kitchen waste and fallen leaves.

The elephant waste is often either burned or made to naturally decompose for converting into manure which takes more than six months. Such type of practices are creating different environment problems as well as threatening the biodiversity. Agricultural waste, horticultural waste, animal waste, silkworm litter, plant biomass (leaf litter), weeds, kitchen waste after removing non-degradable waste material such as glass, plastic, strong rubber and metal can be vermicomposted (Kale 1995). Wong and Griffiths (1991) studied vermicomposting in the management of pig-waste in Hongkong, and found that *Pheritima asiatica* can stabilize most of the solids arising from the treatment of pig waste, including raw pig manure, suggesting that vermicomposting has a high potential as a unit process in the management of pig waste in Hongkong. Some reports, in Nepal, about potential for vermicomposting (Pradhan and Tamrakar 1999), microflora analysis of vermicompost, vermicast and gut of red earthworms (Yami *et al.* 2003), foot rot disease control using fermented products of compost and vermicompost (Manandhar and Yami, 2008), utilization of organic solid wastes using *Eisenia foetida* (Tamrakar 2005, Pant and Yami 2008) are available including interplay of microbial (Baral *et al.* 2012) in the literature. Nevertheless, literature regarding the effectiveness of vermicomposting in managing the dung of elephant and rhino which constitute the major component of the zoo waste is scarce. Therefore, to overcome with the environment problems, we worked in converting organic waste into vermicompost in 2004. The waste from the central zoo was quantified and categorized. The vermicompost was prepared from elephant dung, one-rhino dung, litter and garbage separately using two species of worms *Eisenia foetida* and *Perionyx favatus*. Our study was aimed to prepare vermicompost from animal dung and other organic wastes to improve sanitation in the Zoo premises, apart from generating considerable revenue in order to achieve self-sustenance and to determine whether the vermicomposting can effectively manage the major component of Zoo wastes and can produce high quality compost or not.

MATERIALS AND METHODS

In order to carry out the study, the consent was taken from the Central Zoo authority. The daily solid waste generation from different sections of the Zoo, composition of solid wastes and wastes generation per animals were surveyed. After quantifying the wastes generation and composition, the major categories of organic wastes consisting of elephant dung, rhino dung, garbage and litter were composted using vermicomposting technique within the premises of Central Zoo. The physico-chemical and microbiological parameters of thus prepared compost were analyzed to test the quality of compost using the standard scientific methods.

Waste collection

There were four sections and one nursery in Central Zoo. Each section had different types of animals and waste may vary with respect to composition and amount. The waste of each section was weighed sorting the waste in six broad categories: animal waste, litter and garbage, plastic, metals/ glass, meat and paper. The wastes were enumerated twice per week. As the waste generation reached its peak on Saturday and Sunday and declined on Monday, care was taken to avoid the bias. For those animals whose waste (excreta) was not collected daily, their daily waste was estimated on the basis of total waste generation of that animal in a week. The zookeepers were pre-informed to collect the waste separately in previous days. The waste was weighed separately using portable weighing machine to know the composition and average generation of total waste within the Zoo premises.

Vermicomposting

The shed behind the elephant captivity of the Central Zoo was chosen for the vermicomposting. The waste for composting was collected by zookeepers.The materials required for the vermicomposting such as plastic sheet and jute bags were provided by Zoo.

Preparation of bed

Since it was a small scale project the composting was carried out inside the shed without using any container. The plastic bags were placed at the base to avoid the worms passing on the ground. Thereafter good bedding was made placing a layer of straw, litter and grass clipping above the plastic bags layer. A thin layer of compost was also placed at the bottom. Moisture on the bedding was maintained to provide resting-place and help earthworms to suck the surplus amount of moisture. Three beds consisting each of 50 kg elephant dung, one- horned Rhino dung and litter and garbage were prepared. A little amount of Effective Microorganism (EM) and Bokashi was also added after placing the waste on the bed. A separate bed was prepared for the conversion of rhino waste into the compost using EM.

Inoculation of suitable species of the worms

In this study *Eisenia foetida* and *Perionyx favatus* were used for composting obtained from Pesticide Monitor Network Nepal, Tahachal. Approximately 1000 worms of each species were inoculated in one week old prepared bed with waste. To maintain the moisture content, water was sprinkled at weekly interval. The pile was covered with a jute bag soaked with water to maintain moisture and to avoid direct light and flies.

Measurement of physico-chemical parameters

Moisture content was calculated as weight loss after the moist sample is dried at 105 ^{0}C for 24 hours in hot air oven. A digital pH meter was calibrated with the help of standard Buffer solution of pH 4.2 and 9, and used to determine the pH of the compost. The organic matter content of the soil, dung and vermicompost samples were determined as described by Walkely and Black method (1934).

Nitorgen, Potassium and Phosphorous (NPK) analysis of compost samples was carried out in Soil Science Division, Nepal Agriculture Research Council, Khumultar. The total nitrogen content of compost was determined by using Kjeldahl method (1883) in which organic nitrogen compounds were converted into ammonium sulphate by digestion with concentrated sulphuric acid. The total phosphorous (P_2O_5 %) content in the fused aliquot (sample) was prepared with chlorostanous reduced molybdophosphoric blue colour method. The blue colour was measured by colorimeter. The Potassium (K_2O %) content in the fused aliquot was diluted and directly measured by Flame-photometer.

Carbon:Nitrogen (C: N) ratio was calculated from the values of Organic matter and Nitrogen Percent

$$\text{C:N ratio} = \frac{\text{Organic matter \%}}{1.8 \times \text{Nitrogen \%}} \qquad \text{(FRSRD 1980)}$$

Microbiological analysis of compost

The serial dilution method and Spread Plate method were used to study the number and colony characters of bacteria in the samples as described by Sharma and Ghimire (1996). Microscopic examination of bacteria by gram staining Huckers method (1921) was carried out following the procedure described by Bailey and Scott (Baron and Finegold 1990).The microscopic morphological features of the filamentous fungi provided the reliable criterion for the identification. For the microscopic morphology, the slides were prepared by using Cellophane Tape Method (Thirumurthy *et al.* 2002).

RESULTS AND DISCUSSION

Daily waste generation

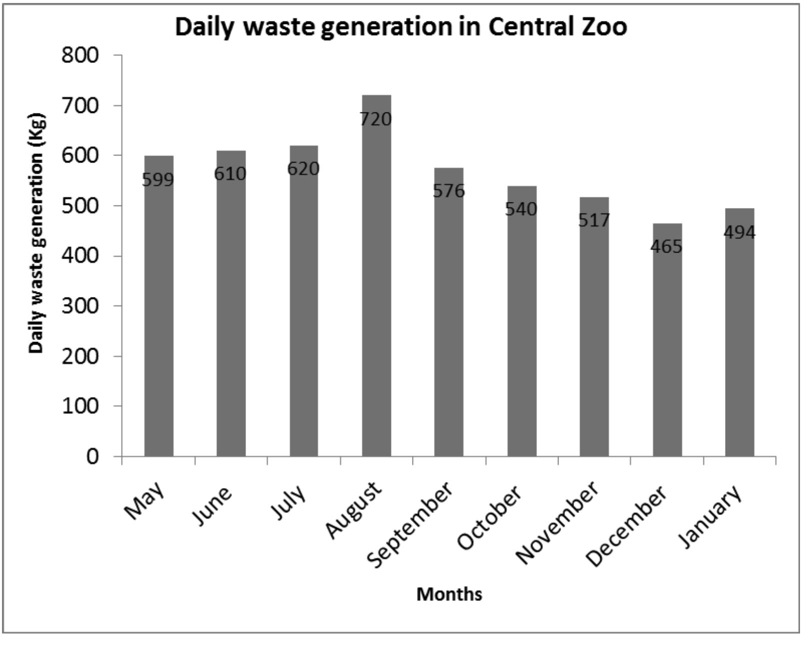

Figure1. Daily waste generation in Central Zoo.

The amount of waste generated was found to vary with the month of the year. As shown in figure 1, the waste generation was highest in August (720 kg/day) and lowest in December (465kg/day). The mean waste generation was 571.55±45.37kg (8 d.f, $t_{0.05}$). The generation of the waste was the function of the animal number and the weather condition. In the days of high wind and high rainfall, the amount of the litter and garbage was more. The amount of waste generation was also found to be influenced by the day of sampling. Because the number of visitors was high on Saturday and Sunday, the waste generation was also high. Since Zoo closes on Monday for visitors least amount of waste is generated on this day.

Composition of waste

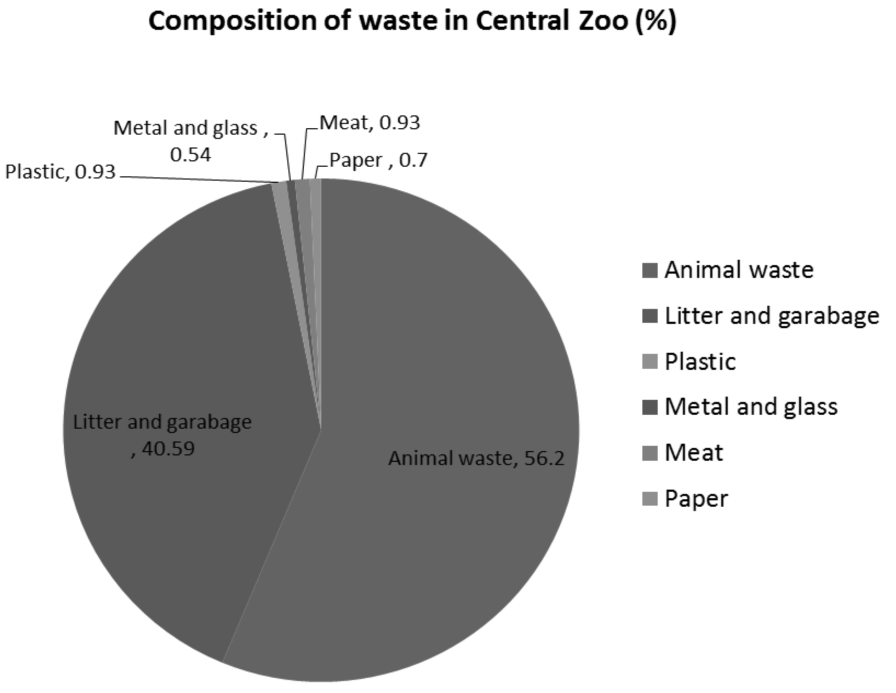

Figure 2. Composition of waste in Central Zoo.

The waste composition was divided into six groups; animal wastes, litter and garbage, plastics, metal/glass, meat and paper. In present study, animal waste was found 56.20% followed by litter and garbage (40.59%), plastics (0.93%), and paper (0.9%) (fig. 2). This data assured that about 97% wastes can be converted into compost. The solid waste generated in kg by individual herbivore animal was also estimated. The anatomy of an elephant's stomach is simple and digests only 50% of the food consumed (WWF 2003). Staple diet includes Kuchhi (grass rolls) that consists of molasses, salt and rice painstakingly wrapped in the banana stalks or rice stalks. The elephant is also fed with green grass and fodder. Therefore, the highest amount of waste generation per animal was found in elephant (106 kg per individual). The elephant dung was found fibrous and light odoured during the study. The second highest amount of waste generation I was found in one-horned rhino (76 kg /day). The rhinoceros waste was found to be less fibrous than elephant and high in water content. The excreta of the blue bull, elephant and rhino were in the form of dung but the dung of spotted deer, black buck and barking deer were observed in the form of pellets.

Amount of waste and time required for composting

Table1. Weight and time for preparation of compost from different sources.

SN	Raw materials for composting	Weight of raw materials (kg)	Weight of compost (kg)	Ratio	Time taken for the maturation of compost in days
1.	Elephant dung	50	22	2.27:1	42
2.	Rhino dung	50	26	1.92:1	56
3.	Litter and garbage	50	12	4.16:1	75
4.	Rhino dung with EM	50	24	2.08:1	70

Time required for the maturation of the compost and weight of compost produced from different sources is given in the table 1. During this study, it was found that the food best accepted by the earthworm was elephant dung because it was lighter, easy to maintain aerobic condition, partially decomposed and frequent spraying of water help to maintain moisture balance. However, the number of worms was not found increased compared to rhino dung vermicomposting. In equal number of worms and equal amount of foods, the elephant dung was converted into mature compost within 42 days. In contrast, rhino dung took 56 days, and litter and garbage in 75 days. Without using the worms but in presence of EM, the rhino dung was found to be converted into mature compost in 70 days. Our finding on maturation time of elephant and rhino dung vermicomposting was similar to Rodale (1975), who stated two months or less for conversion period. As stated by Bhattarai (2003), maturation of vermicompost using *Eisenia foetida* took 75 to 90 days when mixing farm waste of plant origin with animal dung. Contrary to this, our study showed that the time elapsed for the maturation of vermicompost using *Eisenia foetida* for all three types of compost was shorter. The compost produced from elephant dung, rhino dung and litter and garbage is found in the ratio 2.27:1, 1.92:1 and 4.16:1 respectively. The amount of compost produced from the rhino dung was highest, while the amount of compost produced from litter and garbage was found to be the lowest.

Physico-chemical parameters of dungs and composts

Table 2. pH analysis of vermicomposts.

Sources	Sample size (n)	Mean pH value	Std. deviation (SD)	95% confidence interval for mean	
				Lower bound	Upper bound
Elephant dung	4	8.375	0.0500	8.2954	8.4546
Rhino dung	4	8.5	0.0816	8.3701	8.6299
Elephant vermicompost	4	8.225	0.0957	8.0727	8.3773
Rhino vermicompost	4	7.075	0.0500	6.9954	7.1546
Rhino dung compost with EM	4	7.475	0.0957	7.3227	7.6273
Litter & garbage compost	4	7.925	0.0957	7.7727	8.0773

As shown in table 2, it was found that, to some extent, the earthworms have the capability of changing the compost condition, and thus ease their own life. The experiment by Albanell *et al.* (1988) with sheep manure using earthworm showed the change of pH value from 9.1 to 7.2 in 12 weeks. In the present study also, the pH value of all three types of vermicompost and rhino compost with EM was slightly decreased from alkaline condition to towards neutral.

The moisture content influences activities, metabolism, population and growth of the worms. Common earthworms live in soils containing 12% to 34% moisture (Edward and Lofty 1972).

Table 3. Moisture content of vermicomposts.

Sources	Sample size (n)	Mean moisture content (%)	Std. deviation (SD)	95% confidence interval for mean	
				Lower bound	Upper bound
Elephant dung	4	36.55	0.9146	35.0945	38.0055
Rhino dung	4	39.01	0.5753	38.0944	39.9256
Elephant vermicompost	4	24.9325	0.5243	24.0982	25.7668
Rhino vermicompost	4	30.6625	0.2321	30.2931	31.0319
Rhino with EM compost	4	29.6075	0.7699	28.3823	30.8327
Litter & garbage compost	4	30	0.8165	28.7008	31.2992

Lunt and Jacobson (1944) recorded moisture content to be 31.4% in the casts and 27.4 % in the topsoil. As shown in table 3, the results elicited that moisture content was ranged from 24.93 to 30% in different vermicomposts and 29.60 % in rhino compost with EM. The moisture content decreased in final vermicast in comparison to the original dung of elephant and rhino. Microorganisms need moisture to assimilate nutrients. The higher the moisture content the greater the chance for growth of microorganisms. But excessive moisture above 60% can lower the internal temperature, which inhibits the oxygen flow creating the anoxic condition.

Organic matter analysis

Table 4. Organic matter measurement.

Sources	Sample size (n)	Mean organic matter (%)	Std. deviation (SD)	95% confidence interval for mean	
				Lower bound	Upper bound
Elephant dung	4	31.37	0.9501	29.8581	32.8819
Rhino dung	4	41.295	0.4900	40.5153	42.0747
Elephant vermicompost	4	26.9425	4.8388	19.2428	34.6422
Rhino vermicompost	4	26.915	0.9295	25.4359	28.3941
Rhino with EM compost	4	30.955	0.6204	29.9678	31.9422
Litter & garbage compost	4	8.295	0.73944	7.1184	9.4716

As tabulated in table 4, the organic matter content of vermicomposts decreased compared to the initial dung. This is supported by the result of the experiments carried out by Albanell *et al.* (1988) in which the organic matter was found to be decreased. The mean organic matter content in elephant vermicompost, rhino vermicompost and rhinocompost with EM was decreased by 14.12%, 34.82% and 25.04% respectively compared to organic matter in respective initial dung. The organic matter content of litter and garbage vermicompost was found very low compared to the value given by (Maharjan 2004, Pandey 2004, Tamrakar 2005).

Total nitrogen (%) analysis

Table 5. Total nitrogen (%) analysis.

Sources	Sample size (n)	Mean total Nitrogen %	Std. deviation (SD)	95% confidence interval for mean	
				Lower bound	Upper bound
Elephant dung	4	1.2425	0.0050	1.2345	1.2505
Rhino dung	4	1.63	0.0082	1.617	1.643
Elephant vermicompost	4	1.2825	0.0126	1.2625	1.3025
Rhino vermicompost	4	1.43	0.0081	1.417	1.443
Rhino with EM compost	4	1.6175	0.0050	1.6095	1.6255
Litter & garbage compost	4	0.83	0.0316	0.7797	0.8803

The nitrogen content in the elephant vermicompost was increased by 3.22% than in the elephant dung. The nitrogen content in the rhino vermicomposting and rhino compost with EM was decreased by 12.26% and 1.22% respectively compared to the nitrogen content of rhino dung (table 5). The decrease in nitrogen content in rhino compost may be due to the rapid decomposition of nitrogenous organic material and volatilization of the end product. As compared to the result of Tamrakar (2005) in the vermicomposting of the waste from Kathmandu valley using *Eisenia foetida,* the nitrogen content of various vermicompost was found to be higher except in the vermicompost of litter and garbage. The low content of nitrogen in the vermicompost of litter and garbage may be due to the richness of nitrogenous wastes and poor in carbon content, which result in the loss of nitrogen.

Analysis of available phosphorous

The analysis of available phoshorous (P_2O_5)% in the dungs and compost revealed that, percentage of phosphorous increased in the vermicompost of the elephant but decreased in the vermicompost of rhino dung (table 6). The phosphorous content in the elephant vermicompost increased by 28.50% than in the elephant dung. The phosphorous content in the rhino vermicompost decreased by 37.76% compared to the phosphorous content of rhino dung but the phosphorous content of the rhino vermicompost with EM found to be increased by 5.31% compared to rhino dung.

Table 6. Analysis of available phosphorous (%).

Sources	Sample size (n)	Mean available Phosphorous (%)	Std. deviation (SD)	95% confidence interval for mean	
				Lower bound	Upper bound
Elephant dung	4	2.2125	0.0100	2.2045	2.2205
Rhino dung	4	1.8875	0.1723	1.8795	1.8955
Elephant vermicompost	4	2.8475	0.0129	2.8323	2.8627
Rhino vermicompost	4	1.17	0.0263	1.0295	1.3105
Rhino with EM compost	4	1.98	0.0822	1.9575	2.0025
Litter & garbage compost	4	1.1225	0.0289	1.0624	1.1826

As compared to study by Tamrakar (2005) the phosphorous content of various vermicomposts was found to be higher including rhino compost with EM.

Table 7. Analysis of potassium (%).

Sources	Sample size (n)	Mean potassium (%)	Std. deviation (SD)	95% confidence interval for mean	
				Lower bound	Upper bound
Elephant dung	4	2.705	0.0100	2.6891	2.7209
Rhino dung	4	3.8075	0.1723	3.5333	4.0817
Elephant vermicompost	4	3.7425	0.0129	3.7225	3.7625
Rhino vermicompost	4	2.0975	0.0263	2.0557	2.1393
Rhino with EM compost	4	4.075	0.0827	3.9441	4.2059
Litter & garbage compost	4	4.26	0.0289	4.215	4.305

The potassium content of elephant dung was increased by 38.51%, while in the vermicompost of rhino dung it was decreased by 45%. The potassium content in the rhino compost with EM increased by 7.10%. The potassium content of litter and garbage vermicompost was found highest (4.26%) (table 7). The potassium content of all composts was found higher than the result revealed by Tamrakar (2005).

The C:N ratio analysis

The C:N ratio of the organic matter added to the soil is of primary importance to the source of mineralization. Generally the material with a C:N ratio of 20:1 or lower can directly provide mineral nitrogen (Satchell *et al.*1971). Earthworms gradually lower the C:N ratio as they break down material during their metabolism. This lowering the C:N ratio is achieved mainly by release of carbon during respiration (Edwards *et al.* 1985). In this study C:N ratio was found to be lowered from 14.70:1 to 10.85:1 in the vermicompost of elephant dung and from 14.9:1 to 10.95:1 in the vermicompost of rhino dung. The C:N ratio was decreased from 14.9:1 to 11.30:1 in the rhino compost with EM.

Microbiological analysis

Table 8. Total bacterial count from different types of compost.

SN	Compost from different sources	Total bacterial count (CFU/gm)
1.	Elephant vermicompost	7.32×10^5
2.	Rhino vermicompost	6.96×10^6
3.	Litter and garbage compost	4.05×10^4
4.	Rhino compost using EM	8.15×10^3

The total bacterial count was measured by counting the colonies observed in the culture plate of different dilutions and expressed in terms of colony forming units (cfu) (table 8) The total bacterial count from compost of different sources varies from 8.15×10^3 in the rhino compost using EM and highest 6.96×10^6 in the vermicompost of rhino.

Table 9. Total fungal count from compost of different sources.

SN	Compost of different sources	Total fungal count (cfu/gm)
1.	Elephant vermicompost	4.32×10^3
2.	Rhino vermicompost	3.96×10^4
3.	Compost from litter and garbage	1.25×10^3
4.	Rhino compost using EM	1.15×10^3

Similarly, the total fungal count was found varied from 1.15×10^3 in rhino compost using EM and highest in the rhino dung vermicompost which was 3.96×10^4. This result clearly revealed that vermicompost was superior in microbial count compared to other composts.

The present study contributes to the microbiological understanding of commercial composts, whose fungal component is often overlooked despite the favorable and unfavorable effects of fungi in the situations in which composts are employed.

The Central Zoo which is located in Jawalakhel, Lalitpur, Nepal accommodates many wild faunas which produces large amount of wastes daily. Most of the waste is organic which can be converted into valuable compost. Among the organic waste, most are produced by elephant, One-horned Rhinoceros and litter and garbage. We used vermicomposting technique for managing the waste of elephant, One-horned Rhino and litter and garbage and conclude that vermicomposting is one of the effective method to convert those wastes generated by giant animals into high quality compost effectively in relatively short period of time. This technique can be practicised in large scale in Elephant rearing centers of the country such as in Hattisars (Elephant Centres) of Nepal located in different parts of the country.

ACKNOWLEDGEMENTS

The first author acknowledges National Trust for Nature Conservation (NTNC) for providing partial funding for this study. The authors acknowledge the Central Department of Environmental Science, Tribhuvan Univeristy and Soil Science Division, Nepal Agricultural Research Council, Khumular. Lalitpur for providing the laboratory facility to analyse the samples.

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