International Journal of Recycling of Organic Waste in Agriculture (2023)12: 341-350
Doi: 10.30486/IJROWA.2022.1958871.1466

ORIGINAL RESEARCH

Potential of *Eisenia fetida* (Redworm) for the conversion of three varieties of organic waste

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Received: 16 May 2022 / Accepted: 01 October 2022 / Published online: 12 November 2022

Abstract

Purpose The aim of this study was to assess the potential of *Eisenia fetida* (Redworm) in composting different types of waste, namely tea waste (TW), vegetable waste (VW) (leaves of cauliflower), and mixed food waste (MFW).

Method The experiment was set up inside the Lab room during the summer. For vermicompost preparation, 27 equal size vermi beds of moist sawdust were prepared in a tub basin. The organic wastes were separately fed to earthworms along with 10 grams of bonemeal and 10 grams of eggshell powder as supplemented materials. The mature worms, offspring, and cocoons were then counted after 14 weeks of the experiment. Moisture and pH of vermicompost were measured in the laboratory.

Result The results show that *Eisenia fetida* preferred tea waste more than vegetable and mixed food waste. The total number of earthworms, including young, increased by 7.13 times in Tea waste with Bonemeal (TW-BM). In mixed food waste composting, the total number was increased by 3.06 times, and mature worms were increased by 0.21times in MFW-ES. However, all worms died in vegetable waste due to high pH and moisture. The productivity of vermicompost was higher in tea waste ranging from 39.86±0.59% (TW-C) to 43.64±2.75% (TW-ES).

Conclusion The study concluded that a large number of leafy vegetables are not suitable for the health of earthworms. Significant results were obtained regarding the number of mature worms, offspring production, changes in the total number of worms, number of cocoons, and productivity of vermicompost among three kinds of waste composted.

Keywords Cocoon, Food waste, Tea waste, Vermicompost

Introduction

Waste management has become a global issue due to rapid urbanization, population growth, modernization, industrial growth, and change in consumption patterns. Around 2.01 billion metric tons of solid waste is generated annually worldwide, and this quantity is expected to rise up to 3.40 billion metric tons by 2050 (Kaza et al. 2018). The major percentage of solid waste is shared by organic waste. Organic wastes are primarily by-products of municipal, industrial and agricultural activities. The organic portion of solid waste is a valuable resource that can be transformed into useful materials (Yu and Huang

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2009). It can be used in a various of ways, such as energy recovery, fertilizer, soil amendment, liquid fuels, electricity, and chemical production (alcohols, volatile organic acids etc.) (Westerman and Bicudo 2005). Organic waste management is a critical concern for maintaining a pollution-free environment. There are numerous methods for treating organic waste. In general, anaerobic digestion, composting, and vermicomposting technology are practised in the world. Out of these methods, vermicomposting is popularly used in the developed and developing world (Edwards 1998) including Nepal.

Vermicomposting is a biotechnological process which can be used for the management of various organic wastes. It uses particular earthworm species to improve waste conversion and the high-quality end product known as vermicompost (Chattopadhyay 2012; Bhat et al. 2018). Vermicomposting is an aerobic method that requires microorganisms and earthworms for the decomposition of organic waste like other composting methods. Based on feeding habitat, earthworm species are categorized into three groups namely, epigeic, anecic and endogeic (Briones et al. 2005). Out of these three groups, Epigeic earthworms have the most potential for vermicomposting, and *Eisenia fetida* is an important earthworm species for compost making due to its high reproductive rate, faster rate of organic matter decomposition and can withstand a wide range of environmental conditions. This species also has a short life cycle of 45-51 days, wide temperature (0-35 ^{0}C), and moisture tolerance range (70-90%) and can be handled easily (Dominguez and Edwards 2010). Due to such characteristic features, it is commonly used in the world. Earthworm species has capable of feeding various types of organic waste, such as cattle dung, fruit waste, agricultural waste, aquatic weeds, sewage, and industrial sludge. Earthworm is a hermaphrodite animal and reproduction is normally carried out through copulation and cross- fertilization. In general, there are four stages in earthworm life cycle namely, cocoon formation, incubation, hatching and growth (Nahmani et al. 2007; Žaltauskaite and Sodiene 2014). Sexual maturity in *Eisenia fetida* begins at the age of 4 weeks which is recognized by the formation of clitellum. It can mate and produce cocoons at the age of 35 days, and its life span is estimated at 4.5 years (Minnich 1977). Being a hermaphrodite animal, it has ability to produce cocoon by every individual. Cocoon production in earthworm begins at the age of 6 weeks and continue for 6 months. Number of cocoons produced by *Eisenia fetida* ranged from 0.35 to 0.5 per day and incubation time is 18-26 days. Worms' production per cocoon varied and ranged from 2.5 to 3.8 (Dominguez and Edwards 2010). According to Hatanaka et al. (1983), some earthworm species have capable to produce cocoons throughout the year when food reserve and other environmental conditions are suitable for worms. The earthworm *Eisenia fetida* can form one every 5 days (Hatanaka et al. 1983). However, the reproductive rate and cocoon formation are dependent upon the types of waste material used and other environmental conditions. Population density, temperature, humidity and energy content in feeding media also determine the cocoon formation. Due to direct relation between availability and quality of food with growth and reproduction of earthworms (Dabral et al. 2013), many researchers carried out the growth and reproductive potential of different earthworm species on various kinds of waste which is produced from household and industrial sector. Although various studies on the conversion potential of earthworm species mainly *Eisenia fetida,* in varieties of waste have been carried out, no studies have been conducted on tea waste, leaves of cauliflower and mixed waste that are supplemented with bonemeal and eggshell powder. To fulfil this knowledge gap, the study was carried out to evaluate the suitability of vermicomposting in three types of waste in terms of change in earthworm number, cocoon formation and output of vermicompost. The findings of this study could benefit municipalities, urban residents, and researchers. The study was primarily intended to investigate small-scale vermicomposting method in a tub basin as an experiment unit. The design is crucial in areas where there is a regular flow of waste generated by households.

Materials and methods

Waste collection and Vermi bed preparation

Three different types of waste, namely, tea waste (cooked), vegetable waste, and mixed food waste, were used for vermicomposting. These wastes were brought from vegetable markets and residential sectors. Leaves of cauliflower were used as vegetable waste in this experiment and mixed food waste included rice, cooked tea, peelings of banana, potatoes and radishes. The waste was sorted and shredded into small pieces about the size of 1 inch. Red worms were purchased from Centre for Eco learning and sustainable development organization.

Experimental set-up and analysis

The experiment was carried out in Centre for Eco learning and sustainable development organization in Kathmandu, Nepal, (N 27.69673^0 E 085.29946^0 Elevation, 1289 m) with an average room temperature of 23-26 ^{0}C during summer season (June-September). In this experiment, 27 tub basins (diameter 0.35 m, depth 0.13 m) of equal-sized were chosen. 3 replicates for control, 3 replicates for bonemeal treatment and 3 replicates for eggshell treatment of tea waste were prepared. Similar replicates were also made for vegetable waste and mixed food waste. The codes for each treatment were given names as TW-C = Tea waste (Control)

TW-BM= Tea waste with bonemeal powder (Treatment)

TW-ES= Tea waste with eggshell powder (Treatment)

VW-C = Vegetable waste (Control)

VW-BM= Vegetable waste with bonemeal powder (Treatment)

VW-ES= Vegetable waste with eggshell powder (Treatment)

MFW-C= Mixed food waste (Control)

MFW-BM= Mixed food waste with bonemeal powder (Treatment)

MFW-ES= Mixed food waste with eggshell powder (Treatment)

For bedding material, sawdust was employed. It was moistened before being placed in the bottom of the basin. Each basin was loaded with 300 matured worms. Every week, earthworms were fed organic waste such as tea waste, cauliflower leaves waste and mixed food waste. Each week 300 grams of waste was added to each basin and covered with cotton fabric. Except in the control group, 10 grams of bonemeal powder and eggshell powder were added as enriched material during feeding. The feeding was continued for 12 weeks. After 12 weeks, the prepared vermicompost was left for 2 weeks more for complete maturation. From each tub basin, vermicompost was harvested and counted mature worms first, secondly young/offspring worms and finally, cocoon. For counting cocoons, empty cocoons were avoided. The mature worms were enumerated by following formulas (1) and (2):

Calculation for changes in earthworm population

$$\%\ \text{Increase} = \frac{\text{Final Number} - \text{Original Number}}{\text{Original Number})} \times 100 \quad (1)$$

$$\% \text{ Decrease} = \frac{\text{Original Number} - \text{Final Number}}{\text{Original Number)}} \times 100 \quad (2)$$

Calculation for productivity of vermicompost

For the determination of final vermicompost, all matured worms including offspring were sorted out and vermicompost was weighted by digital balance. The productivity of vermicompost was calculated by following formula (3): Productivity of vermicompost

$$= \frac{\text{Harvested vermicompost}}{\text{Total mass of feed (gram)}} \times 100\%$$

The Input and output ratio is determined by following formula (4): Input and output ratio

$$= \frac{\text{Initial weight of waste}}{\text{Final weight of vermicompost}}$$

Measurement of moisture content and pH in samples

The moisture and pH in samples were measured in 8 weeks of composting period.

Twenty-seven vermicompost samples were taken from control and treatment unit and kept in sample bag. The samples were tested in the laboratory. For the measurement of moisture content, an individual sample was weighted and kept in oven for 24 hours at 105 ^{0}C. After 24 hours, the sample was again weighed to find out moisture content by formula (5). pH was measured by pH meter. The ratio of sample and potassium chloride solution was made 1:5. The solution was stirred (glass stirrer) for 1 minute and waited for 1 hour. The calibrated pH meter was dipped in sample solution and value was noted until constant reading was obtained.

Calculation for Moisture content (formula 5):

$$= \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100\%$$

For statistical analysis, all results were given as the average value of a single measurement on each of three replicates. Data were subjected to Independent T-Test (between control and treatment) and one way analysis of variance (among three kinds of waste) at significant difference $P<0.05$. These tests were used to differentiate the statistical difference for change in number of mature worms, offspring and cocoon formation and output of vermicompost production.

Results and discussion

Moisture and pH content in vermicompost samples

The rate of earthworm growth is closely correlated with the moisture content of organic wastes. According to a comparison study on the vermicomposting process and earthworm growth at various temperature and moisture ranges, 65 to 75 percent of moisture is the most acceptable range for all vermicomposting temperature ranges (Suthar 2006). Similarly, vermicomposting process is significantly influenced by the pH value. The suggested pH range for compost is between 6.5 and 7.5 (Edwards 1998). Moisture content and pH of samples were measured and presented in Table 1. The results showed that higher moisture was recorded in vegetable waste compost which exceeded 90%. The percentage moisture content was then followed by mixed food waste and tea waste samples. Similarly, pH ranged from 7.12±0.11 (TW-C) to 9.8±0.06 (VW-ES). Independent T-Test showed that, p-value in all combinations were well below 0.05 (Table 1); thus use of individual bonemeal powder and eggshell had role to affect on the quality of vermicompost samples.

Table 1 Moisture content and pH recorded during vermicomposting (8 weeks) and its p-Value

Samples	Moisture Content (%)	pH	P-Value for moisture	P-Value for pH
TW-C	75.5±0.59	7.1±0.11		
TW-BM	72.2±0.66	7.4±0.08	0.003	0.025
TW-ES	70.4±0.36	7.6±0.06	0.001	0.002
VW-C	93.6±0.58	8.8±0.08		
VW-BM	91.3±0.17	9.1±0.07	0.003	0.017
VW-ES	90.4±0.24	9.8±0.06	0.001	0.001
MFW-C	83.0±0.75	7.9±0.09		
MFW-BM	81.0±0.81	8.3±0.13	0.034	0.013
MFW-ES	80.2±0.08	8.4±0.06	0.003	0.001

All values are the average ± standard deviation

Change in number of matured earthworms, and off-spring and cocoon formation

The change in number of the earthworms in the vermicomposting system was analyzed in three different kinds of waste namely tea waste, cauliflower leaves and mixed food waste. The matured worms, offspring and cocoon were counted separately after 14 weeks from twenty-seven tub basins.

The higher number of matured earthworms in this study was recorded in tea waste composting, followed by mixed food waste (Table 1). In tea waste composting, the matured worms were increased by nearly 45% (TW-ES) and in MFW-BM, it was around 41%. This result showed that the use of eggshells in tea waste and bone-meal powder in mixed food waste could increase the number of matured worms. Similarly, the number of off-spring produced was higher in Tea waste vermicompost than in other types of waste. The offspring in TW-BM and TW-C were counted as 2123±734.55% and 1621.33±201.45%, respectively (Table 2). Annapoorani and Sindhu (2019) found a similar type of result in the mixture of tea dust and cow dung that the number of adult earthworms was increased. Rupani et al. (2013) obtained positive results in the majority of organic waste. The number of young earthworms was highest in kitchen waste (115), followed by newspaper waste (108), and the lowest in hair waste (61). Newspaper had the highest juvenile stage, followed by hair, kitchen waste, garden waste, eggshells, and mixed waste had the lowest. In present study, all worms died due to high moisture and high pH during vermicomposting of vegetable waste (Fig. 1 and 2). Moisture content in all control and treatment were above 90% and pH ranged from 8.89±0.08 (VW-C) to 9.80±0.06 (VW-ES) in present study (Table 1). Similar result was also found by Gunadi and Edwards (2003) that earthworms could not survive in fresh mixed fruit and vegetable waste and the worms died in 60 days of vermicomposting due to high moisture. The moisture tolerance and pH tolerance range for earthworms are 70-90% (Dominguez and Edwards 2010) and 5-9 respectively (Edwards 1998). In addition to moisture, the weight of earthworms could be reduced by accumulation of ammonia content in vermireactor during tomato waste composting (Fernández-Gómez et al. 2010). The data obtained from present study showed that the waste material in vermicomposting can influence the number of earthworm and its offspring. The finding in this study is also supported by finding of Gezahegn and Girum (2017) that reproductive potential and biomass production of earthworms were determined by quality of waste material. The growth and reproduction is also dependent upon the size of container where earthworm is cultured (Domínguez and Edwards 1997). Cocoon formation and offspring observed in vermicompost bed reflects the growth and reproduction of earthworm. Copulation process was generally seen in the tea waste composting (Fig. 3).

The number of cocoons in vermicompost samples with different types of waste with control and treatment are shown in Table 2. The cocoon was yellow in color and looked like a seed of lemon (Fig. 4). The production of cocoon was also distinctly varied depending upon the types of waste and suitable environmental conditions. The highest number (284.67±60.99) of cocoon was found in TW-C and the lowest number was found in MFW-ES (9.0±15.58). The highest number of cocoon formation in tea waste might be due to suitability of feeding materials with sugar content.

Table 2 Number of matured worms, offspring and cocoon produced

Control and treatment	Initial number of matured worms	Final number of matured worms	% changed	Number of Offspring produced	Total number of worms	% Changed in worm number	Number of cocoons
TW-C	300	413.67±38.94	37.89	1621.33±201.45	2035±225.41	578.33	284.67±60.99
TW-BM	300	317.67±81.002	5.9	2123±734.55	2440.66±655.15	713.55	239.33±61.24
TW-ES	300	434.67±111.84	44.9	329.67±166.83	764.33±67.30	154.66	164.00±56.32
VW-C	300	0	0	0	0	0	0
VW-BM	300	0	0	0	0	0	0
VW-ES	300	0	0	0	0	0	0
MFW-C	300	387±68.28	29	161.33±23.50	584.33±75.14	94.77	0
MFW-BM	300	422.67±36.82	40.9	138.33±137.77	561±117.75	87	0
MFW-ES	300	365.00±31.22	21.6	855±124.37	1220±146.16	306.66	9.0±15.58

All values are the average ± standard deviation

Annapoorani and Sindhu (2019) obtained a similar results that tea dust with cow dung mixture was a good substrate for active cocoons and young ones. However, there was no cocoon formation in vegetable waste and mixed food waste compost except MFW-ES. The possibility of cocoon formation might be influenced by different factors. Getachew et al. (2018) found that the variation of cocoon formation was influenced by the interaction between different types of species and substrate used.

The highest number of cocoons formation were found in Keshmando worm species which were fed on khat than species of *Eisenia fetida* fed on fresh food. Besides that, the most locally available agricultural waste i.e., maize straw responded to enhanced cocoon formation for all seven substrate types investigated. Similarly, Cocoon production was maximum in potato treatment and minimum in banana treatment (Huang et al. 2016). The earthworms demonstrated varying degrees of growth and reproduction in all substrates with the lowest performance in industrial waste (Getachew et al. 2018). In addition to this, the use of additives such as biochar from bamboo biomass can also increase the growth and reproduction of earthworm which was revealed by Gong et al. (2018). Chitrapriya et al. (2017) concluded that bonemeal mixed with cow dung was suitable feeding material for the growth of *Lampito mauriti.*. In this study, a significant difference was obtained in tea waste composting treated by eggshell powder in terms of the number of offspring and total number of worms ($p<0.05$) (Table 3). Similarly, the number of offspring, and total number of worms were significantly different in mixed food waste treated with eggshell powder. From ANOVA test (Table 4), all parameters namely, number of mature worms, number of offspring, total number of worms, number of cocoon and amount of vermicompost were significant among three kinds of waste.

Table 3 Association between control and treatment

Parameters	TW-BM	TW-ES	VW-BM	VW-ES	MFW-BM	MFW-ES
Number of mature worms	0.138	0.774	0	0	0.47	0.639
Number of offspring	0.318	0.001	0	0	0.79	0.001
Total number of worms	0.368	0.001	0	0	0.883	0.002
Number of cocoons	0.415	0.066	0	0	0	0.374
Weight of vermicompost	0.03	0.081	0.144	0.486	0.403	0.037

Table 4 ANOVA Test in three kinds of waste

Parameters	F	P -value
Number of mature worms	38.407	0.001
Number of offspring	26.156	0.001
Total number of worms	41.236	0.001
Number of cocoons	34.512	0.001
Amount of vermicompost	118.59	0.001

Productivity of vermicompost

The colour of vermicompost produced from three kinds of waste are varied. The vermicompost produced from tea waste had dark in color and homogenous which was similar to the result reported by (Dominguez and Edwards (2010) and Ramnarain et al. (2019). However, vermicompost produced from vegetable and mixed food waste were little brown in colour and heterogenous in nature (Fig. 5). The productivity of vermicompost is presented in Table 5. The results showed that maximum productivity was recorded in tea waste composting, namely, TW-C (39.86±0.59), TW-BM (42.30±1.80) and TW-ES (43.64±2.75).

The study conducted by Ramnarain et al. (2019) showed that the maximum productivity was 32.70% for rice and straw combination, followed by 25.90% for rice straw and 23.20% for grass.

In the present study, for vegetable waste composting, the productivity was low, 9.03±2.96% recorded in VW-C which means that the input and output ratio was wide. This might be due to the higher amount of moisture present in raw materials as well as leaching and evaporation during vermicomposting period.

Fig. 1 Worm died due to high pH and moisture in vegetable waste

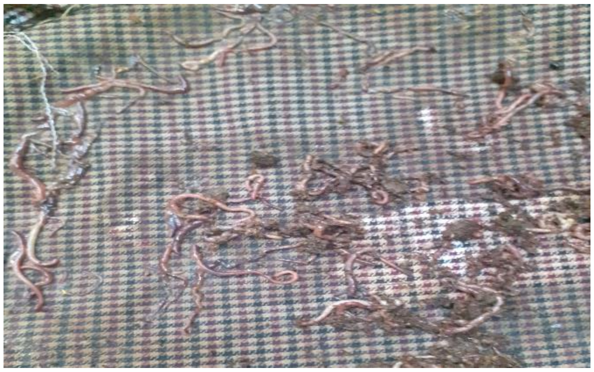

Fig. 2 Worms died on covering material

Fig. 3 Worms copulation in tea waste

Fig. 4 Cocoon of worm in tea waste

Fig. 5 Colour and texture of three kind of vermicompost (control)

Table 5 Input and output ratio of waste and vermicompost

Control and treatment	Initial wt. of organic waste (grams)	Saw dust (grams)	Enriched materials (grams)	Total Feeding materials (grams)	Final compost (grams)	Productivity of vermicompost (%)	Ratio of Input and Output
TW-C	3600	300	-	3900	1555±22.91	39.86±0.59	2.50±0.04
TW-BM	3600	300	120	4020	1700.66±72.56	42.30±1.80	2.36±0.10
TW-ES	3600	300	120	4020	1702.33±107.43	43.64±2.75	2.29±0.14
VW-C	3600	300	-	3900	363.33±118.98	9.03±2.96	12.03±4.49
VW-BM	3600	300	120	4020	493.66±36.69	12.65±0.93	7.92±0.60
VW-ES	3600	300	120	4020	418.33±36.17	10.40±0.90	9.65±0.79
MFW-C	3600	300	-	3900	823.33±131.37	18.54±6.75	4.81±0.70
MFW-BM	3600	300	120	4020	915.33±108.51	22.76±2.70	4.43±0.52
MFW-ES	3600	300	120	4020	1078.66±57.58	26.82±1.43	3.72±0.19

Conclusion

Tea waste is important source of food material for the earthworm. The number of matured worms, offspring and cocoon formation were comparatively higher in tea waste than in other types of waste. In Tea waste with bonemeal powder, maximum offspring were counted (2123±734.55) and in eggshell supplemented tea waste, the mature worms were increased by around 45%. Similarly, the higher number of mature worms were recorded in mixed food waste supplemented with eggshells which was around 41%. However, fresh leafy vegetable waste (cauliflower leaves) is not good for feeding material because of its high moisture content. All worms died within 12 weeks of experiment. A significant difference ($P<0.05$) in offspring number and total number of worms between TW with TW-ES and MFW with MFW-ES were obtained in present study. The productivity of vermicompost was higher in tea waste as compared to other waste. Significant results were obtained in terms of number of mature worms, offspring production, changes in total number of worms, number of cocoons and productivity vermicompost among three kinds of waste. Further research must be emphasized on vermicomposting of other types of vegetable waste.

Acknowledgement Authors are grateful to the Centre for Eco learning and sustainable development for providing earthworms and place for experimental set-up. We would like to thank Ms. Divya Laxmi Bajracharaya, founder of Agricultural Technology Centre, for her guidance and necessary lab facilities.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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