VOLUME 9 ISSUE 1 2023

ISSN 2454 – 3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 9, No. 1, 873-888 (2023)

International Journal of Zoological Investigations
Contents available at Journals Home Page: www.ijzi.net
Editor-in-Chief: Prof. Ajai Kumar Srivastav
Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Estimation of Physico-Chemical Changes of Different Combinations of Animal Dung with Kitchen Wastes by Earthworm *Eutyphoeus waltoni*

Siddiqui Nazia and Singh Keshav*

Vermibiotechnology Laboratory, Department of Zoology, D. D. U. Gorakhpur University, Gorakhpur 273009 (U.P.), India

**Corresponding Author*

Received: 28th February, 2023; **Accepted:** 21st April, 2023; **Published online:** 7th May, 2023

https://doi.org/10.33745/ijzi.2023.v09i01.097

Abstract: Enormous mass of organic wastes are produced continuously in the environment. Due to rise in the population, acute energy crisis and degradation of the environment is taking place. The improvement in the environment is very important, and it has become an accepted goal worldwide. Now, it is necessary to develop a relevant technology to recover the energy from these organic wastes because these organic wastes act as a non-conventional sources and available at no cost. By using the relevant technology million tons of plant nutrients can be produced out of these wastes. Vermicomposting is one of the best, cheap and environment friendly process by which the organic wastes can be converted into good manure with the help of earthworms. The aim of the present study was to investigate the physico-chemical changes of kitchen wastes mixed with different combinations of animal dung after the processing of earthworm *Eutyphoeus waltoni*. There was a significant decrease in pH, EC, TOC and C/N ratio while a significant increase in TKN, TK, TAP and TCa in different combinations of kitchen wastes mixed with animal dung after the processing of *Eutyphoeus waltoni* compared to the initial feed mixture. Significant reduction of organic carbon (56.88-59.40%) and C/N ratio (79.86-82.02%) in all the combinations of buffalo dung with kitchen waste and significant reduction of organic carbon (50.80-58.57%) and C/N ratio (68.14-72.52%) in all the combinations of goat dung with kitchen wastes were observed. The result showed that earthworms accelerated the mineralization rate and converted the manures into castings with a higher nutritional value. Since, these compost contains a high nutritive value and a low C:N ratio, they are suitable to use in the agricultural fields for better crop production.

Keywords: Animal dung, Banana peel, *Eutyphoeus*, Physico-chemical, Vegetable waste

Citation: Siddiqui Nazia and Singh Keshav: Estimation of physico-chemical changes of different combinations of animal dung with kitchen wastes by earthworm *Eutyphoeus waltoni*. Intern. J. Zool. Invest. 9(1): 873-888, 2023.

https://doi.org/10.33745/ijzi.2023.v09i01.097

Introduction

Over anthropogenic activities has increased the difficulty of successful disposal and management of organic wastes during the last few decades (Prakash and Verma, 2022). Simultaneously, animals also produce enormous mass of organic wastes which creates serious problem to the society (Wani and Rao, 2013). Typical methods of solid waste management such as landfilling, open dumping or open burning are indefensible due to its bad odour, production of toxic materials and gases from the wastes which creates negative impact on the environment, human health and bio-diversity (Lee *et al*., 2012; Perez-Godinez *et al*., 2017; Verma and Prakash, 2020a). By the scientific application, organic wastes can be transformed into the value added product which cannot only supply nutrients for plant growth but also improves the physical properties of the soil (Scotti *et al*., 2015). In India huge mass of kitchen wastes are produced every year (Gupta, 2005). Large amount of food scraps are generated for disposal in every home kitchen. These scraps creates odour problem when they are thrown in the garbage and produce harmful effects on the health and environment if they are not decomposed (Kaviraj and Sharma, 2003). To dispose these kitchen wastes, garbage disposal is very convenient, but it also throws away the potentially valuable resource (Chavan *et al*., 2017). Kitchen wastes is a good material for vermicomposting as it is a pure organic material which can be easily decomposed in comparison to other wastes (Febriyantiningrum *et al*., 2018). Million tons of animal dung are produced in India every year and creates serious environmental issues as well as odour problems to the surrounding areas (Garg *et al*., 2015). These wastes are rich in minerals like nitrogen, phosphorus, potassium etc. so they can be used as feed materials for earthworms.

For decomposing organic waste into odour-free humus like material, vermicomposting technology has been verified in literatures (Suthar, 2009; Garg *et al*., 2012; Cestonaro *et al*., 2017; Sudkolai and Nourbakhsh, 2017). In the list of integrated waste management, vermicomposting is considered as a potential tool which stabilizes the organic waste material by the joint performance of earthworms and micro-organisms. Though biochemical degradation of organic matter is carried out by the microbes, earthworms are the important operators of the process by conditioning the substrate as well as altering the biological activity (Aira *et al*., 2007). It is a bio-technological process in which organic wastes are converted into vermicompost by the help of earthworms. This process is eco-friendly, aerobic and less expensive (Gunadi *et al*., 2002). Earthworms are also helpful in treating waste water through vermifiltration technology (Singh and Fatima, 2022). In the agricultural field of different localities of eastern Uttar Pradesh, *Eutyphoeus waltoni* is found abundantly (Singh and Kumar, 2014). *Eutyphoeus waltoni* is an anecic species which is found over a large area in India and can be a relevant species to use as biomarkers of soil pollution (Singh and Singh, 2015). Anecic earthworms are also known as humus formers and have the capability of organic waste consumption which can also modify the structure of the soil.

Keeping in view the above facts, the present study was conducted to evaluate the changes in physico-chemical composition of waste mixtures including vegetable wastes and banana peels mixed with buffalo and goat dung in different ratios after the processing of the earthworm *Eutyphoeus waltoni*.

Materials and Methods

Collection and rearing of the earthworm Eutyphoeus waltoni:

The cultured earthworm *Eutyphoeus waltoni* from the vermiculture Laboratory, Department of Zoology, Deen Dayal Upadhyaya, Gorakhpur University, Gorakhpur were used for the experiment. For this, vermibed were prepared by using garden litter with cow dung on a cemented surface in the laboratory. Young cultured earthworms were used for the experiments.

Collection of animal dung and kitchen wastes:

Animal dung (buffalo and goat) were collected from the local farm houses of different areas. Kitchen wastes were procured from the local residential colonies of the Gorakhpur district. These organic wastes were spread in a layer and exposed to sunlight for 10 days to remove various harmful organisms and noxious gases and then used in the experiment (Garg *et al*., 2005).

Experimental setup:

The experiment was conducted on cemented surface. According to the method of Nath and Singh (2009), two kilograms (Kg) of each five different combinations of buffalo dung i.e. Buffalo Dung + Vegetable Waste (BD+VW; 1:1), Buffalo Dung + Vegetable Waste (BD+VW; 2:1), Buffalo Dung + Banana Peel (BD+BP; 1:1), Buffalo Dung + Banana Peel (BD+BP; 2:1), Buffalo Dung + Vegetable Waste + Banana Peel (BD+VW+BP; 1:1:1) and Buffalo Dung (BD) alone as well as goat dung i.e. Goat Dung + Vegetable Waste (GD+VW; 1:1), Goat Dung + Vegetable Waste (GD+VW; 2:1), Goat Dung+Banana Peel (GD+BP; 1:1), Goat Dung+Banana Peel (GD+BP; 2:1), Goat Dung+ Vegetable Waste+ Banana Peel (GD+VW+BP; 1:1:1) and Goat Dung (GD) alone were prepared in beds of (30 x 30 x10 cm^3) at room temperature (27±2 °C) in the dark. The vermicomposting beds were turned over manually every 24 h for 2 weeks in order to eliminate volatile substances. After this dried sample of each vermibed were collected. Thereafter 20 young *Eutyphoeus waltoni* were inoculated into each bed. In order to provide optimal environmental conditions for worms, the moisture of all the treatments were maintained at 60-70% by sprinkling water during the experiment. After vermicomposting for 90 days, sample from each vermibed were collected again and composting was terminated because the residuals of bedding materials in the treatments had been eaten up by *Eutyphoeus waltoni.* The collected dried and homogenized samples were grind into fine particles for further analysis. Each experiment was replicated six times.

Chemical analysis:

The pH and electrical conductivity were determined by using a double distilled water suspension of each sample in the ratio of 1:10 (w/v) which had been agitated mechanically for 30 min and filtered through Whatman no. 1 filter paper; Total Organic Carbon (TOC) was measured after igniting the sample in a Muffle furnace at 550 °C for 50 min by the method of Nelson and Sommers (1982). Total Kjeldahl Nitrogen (TKN) was measured by Micro-Kjeldhal method of Bremner and Mulvaney (1982) after digesting the sample in digestion mixture (H_2SO_4 and $HClO_4$, 9:1 v/v). Total Available Phosphorus (TAP) was analyzed by using the calorimetric method with molybdenum in sulphuric acid and Total Potassium (TK) was determined after digesting the sample in diacid mixture conc. Of $HN0_3$:$HClO_4$ (4:1 v/v) using a flame photometer (Garg *et al*., 2005).

Statistical analysis:

All the experiments were replicated six times for the purpose of obtaining consistency in the result and finding out the mean with standard error. Analysis of variance was used to analyze the significant difference between the combinations; Student t test (significance accepted at $P<0.05$) was performed to identify the homogenous type of bedding with respect to reproduction and growth from the control.

Results and Discussion

The pH of all the vermibed after the processing of *Eutyphoeus waltoni* was significantly decreased with respect to the initial feed mixture (Tables 1, 5; Figs. 1, 5). The pH of final composted material of buffalo dung and goat dung with kitchen wastes by *Eutyphoeus waltoni* showed variations compared to the initial feed mixture. Maximum decrease of 25% (8.28 ± 0.03 to 6.21 ± 0.03) and minimum decrease of 13.13% (7.85 ± 0.03 to 6.82 ± 0.08) were observed in BD+VW (1:1) and BD+BP+VW (1:1:1), respectively, between all the combinations of buffalo dung and kitchen wastes. Among all the combinations of goat dung and kitchen wastes maximum decrease of 18.35% (8.45 ± 0.07 to 6.90 ± 0.03) in the combination of GD+VW (1:1) and minimum decrease of 4.37% (7.11 ± 0.10 to 6.80 ± 0.05) in the combination of GD+VW+BP (1:1:1) were recorded. Various researchers have reported similar results during the processing of wastes by earthworms (Elvira *et* *al*., 1998; Garg and Gupta, 2011). These changes in the pH of various feed material may occurred due to the degradation of organic solid wastes. Decrease in pH of different mixtures of feed material occurred due to the mineralization of nitrogen and phosphorus into nitrites/nitrates as well as phosphates (Short *et al*., 1999; Ndegwa *et al*., 2000). Low pH in the final product after the processing of earthworms may also result due to the formation of fulvic acid and humic acid (Chauhan and Singh, 2012).

The final EC (Electrical Conductivity) of all the vermibed after the processing of *Eutyphoeus waltoni* was significantly decreased with respect to the initial feed mixture (Tables 1, 5; Figs. 1, 5). The EC of final products of buffalo dung and goat dung with kitchen wastes showed variations compared to the initial values. Maximum decrease of 46.75% (3.23 ± 0.09 to 1.72 ± 0.01) and minimum decrease of 41.61% (2.74 ± 0.01 to 1.60 ± 0.01) were observed in BD+BP (1:1) and BD+VW (2:1), respectively, among all the combinations of buffalo dung and kitchen wastes. In the experiment the EC of initial feed mixtures of goat dung with kitchen wastes ranged from 2.15 to 2.65 ds/m, while after the processing of the earthworm *Eutyphoeus waltoni* it ranged from 1.16 to 1.38 ds/m which may occurred due to high organic matter loss and release of mineral salts. Maximum decrease of 52.42% (2.48 ± 0.01 to 1.18 ± 0.01) and minimum decrease of 35.82% (2.15 ± 0.01 to 1.38 ± 0.01) were observed in the combination of GD+VW (2:1) and GD alone, respectively. 28% to 46% EC in the final vermicompost had been reported by previous researchers (Garg *et al*., 2006). During the management of bio sludge of the beverage industry, it was reported that EC significantly declined for about 28.69% in the final vermicompost (Singh *et al*., 2010).

The TOC (Total Organic Carbon) content in all the feed mixture declined after the processing of *Eutyphoeus waltoni* (Tables 2, 6; Figs. 2, 6). It has been reported that earthworms change the condition of the feed mixture which later enhances the loss of carbon from the feed mixture by microbial respiration in the form of CO_2 (Elvira *et al*., 1996; Aira *et al*., 2007; Hait and Tare, 2011). The TOC of final products of buffalo dung with kitchen wastes showed significant decrease compared to the initial values. Max decrease of 59.40% (543.65 ± 0.11 to 220.75 ± 0.05) and minimum decrease of 56.88% (554.40 ± 0.69 to 239.09 ± 1.06) were observed in the combination of BD+VW (2:1) and BD+VW (1:1), respectively. Among all the combinations of goat dung with kitchen wastes maximum decrease of 58.57% (441.33 ± 0.07 to 182.86 ± 0.11) and minimum decrease of 50.80% (548.39 ± 0.47 to 269.85 ± 0.63) were observed in GD alone and GD+VW (1:1), respectively. Wani *et al.* (2013) reported the reduction of TOC while doing the vermin-composting of garden waste, kitchen waste and cow dung using the earthworm *Eisenia fetida* at the end of the process. It was also observed during vermicomposting of municipal solid waste that a large fraction of TOC can be degraded to CO_2 (Sharma, 2003). In an earlier research the reduction of TOC from 24% to 60% during the process of vermicomposting has been observed (Yadav and Garg, 2010). The TOC content reduced due to the loss of CO_2 by the activity of earthworms (Suthara and Singh, 2008).

TKN content in all the feed mixtures of buffalo dung and goat dung with kitchen wastes is illustrated in Tables 2, 6 and Figures 2, 6. A considerable increase in the TKN content was observed in all the feed mixtures of buffalo and goat dung with kitchen wastes. Among all the combinations of buffalo dung and kitchen wastes maximum increase of TKN was observed in the combination of BD+VW (1:1) which is 58.04% (8.85 ± 0.08 to 21.09 ± 0.04) and minimum increase of TKN was observed in the combination of BD+BP+VW (1:1:1) which is 50.88% (8.41 ± 0.03 to 17.12 ± 0.03). The TKN of final products of goat dung with kitchen wastes after the processing of *Eutyphoeus waltoni* showed significant increase compared to the initial values. Maximum increase of 37.41% (7.90 ± 0.08 to 12.62 ± 0.02) and minimum increase of 33.65% (5.62 ± 0.01 to 8.47 ± 0.01) were observed in the combination of

Table 1: Concentration of pH and EC in initial feed mixtures and final vermicompost of buffalo dung mixed with kitchen wastes in different combinations

Combinations	pH			EC (ds/m)		
	IFM	VC	% decrease	IFM	VC	% decrease
BD	8.83 ± 0.06	6.65 ± 0.03*	24.69	2.93 ± 0.01	1.62 ± 0.01*	44.71
BD+VW (1:1)	8.28 ± 0.03	6.21 ± 0.03*	25.00	3.29 ± 0.01	1.91 ± 0.01*	41.95
BD+VW (2:1)	8.61 ± 0.06	6.43 ± 0.10*	25.32	2.74 ± 0.01	1.60 ± 0.01*	41.61
BD+BP (1:1)	7.88 ± 0.07	6.48 ± 0.03*	17.77	3.23 ± 0.09	1.72 ± 0.01*	46.75
BD+BP (2:1)	8.01 ± 0.05	6.63 ± 0.06*	17.23	2.85 ± 0.01	1.53 ± 0.01*	46.32
BD+BP+VW (1:1:1)	7.85 ± 0.03	6.82 ± 0.08*	13.13	2.45 ± 0.01	1.31 ± 0.00*	46.54

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, BD = Buffalo Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

Table 2: Concentration of TOC and TKN in initial feed mixtures and final vermicompost of buffalo dung mixed with kitchen wastes in different combinations

Combinations	TOC (g/kg)			TKN (g/kg)		
	IFM	VC	% decrease	IFM	VC	% increase
BD	513.91 ± 0.47	209.14 ± 0.06*	59.31	6.31 ± 0.02	14.27 ± 0.03*	55.79
BD+VW (1:1)	554.40 ± 0.69	239.09 ± 1.06*	56.88	8.85 ± 0.08	21.09 ± 0.04*	58.04
BD+VW (2:1)	543.65 ± 0.11	220.75 ± 0.05*	59.40	7.97 ± 0.03	17.45± 0.03*	54.33
BD+BP (1:1)	537.35 ± 0.21	228.51 ± 0.07*	57.48	8.10 ± 0.01	17.10± 0.02*	52.64
BD+BP (2:1)	525.84 ± 0.06	217.45 ± 0.09*	58.65	7.25 ± 0.03	16.62± 0.02*	56.38
BD+BP+VW (1:1:1)	523.64 ± 0.06	212.92 ± 0.09*	59.34	8.41 ± 0.03	17.12± 0.03*	50.88

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, BD = Buffalo Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

GD+BP (1:1) and GD alone, respectively. It has been reported earlier that the values of TKN significantly increased by 35% during vermicomposting of tomato fruits (Manual *et al*., 2010; Fernandez-Gomez, 2010). TKN increased in the final product after the processing of earthworms may be due to the mineralization and addition of various by-products or assimilatory product through the earthworms (Chauhan and Singh, 2012). It was reported that mineralization of C- rich matters and action of N-fixing bacteria present in the feed mixture may also results in the increase of nitrogen content (Plaza *et al*., 2008). As significant portion of worm is protein so degradation of dead worms can also be a reason for increasing the TKN content (Atiyeh *et al*., 2000). In comparison to initial waste mixture nitrogen content was increased 2.16 fold during the vermicomposting process using kitchen waste, rotting foliage and cow dung (Mousavi *et al*., 2017).

One of the highly accepted indicators of compost maturation is C/N ratio which represents the mineralization and stabilization of organic wastes during the process of vermicomposting (Cardenas and Wang, 1980). The C/N ratio declined in all the combinations of buffalo and goat dung with kitchen wastes after the processing of earthworm *Eutyphoeus waltoni* (Tables 3, 7; Figs. 3, 7). This decline of C/N ratio is caused due to loss of carbon which is accompanied by addition of nitrogen through the earthworms during the process (Suthar, 2007; Kaur *et al*., 2010; Singh *et al*., 2010). In all the combinations of buffalo dung with kitchen wastes the C/N ratio decreased from (62.22-81.38) to (11.33-13.69). After the processing of earthworm *Eutyphoeus waltoni* the maximum decrease of the C/N ratio was 83.18% which was observed in BD alone and minimum decrease of C/N ratio was 79.86% which was observed in the combination of BD+BP (1:1). Among all the combinations of goat dung with kitchen wastes the maximum decrease of C/N ratio was 72.52% which was observed in GD alone and minimum decrease of 68.14% was observed in the combination of GD+VW (1:1). Many studies have reported that C/N ratio declined sharply during the process of vermicomposting (Vig *et al*., 2011; Malafaia *et al*., 2015). During vermicomposting, earthworms promote acceleration in humification which results in the decrease of C/N ratio (Suthar, 2006; Dores Silva *et al*., 2011; Vig *et al.*, 2011).

TK content in all the feed mixtures of buffalo and goat dung with kitchen wastes has been shown in Tables 3, 7 and Figures 3, 7. Significant increase of TK content was observed in all the combinations of feed mixtures after the processing of *Eutyphoeus waltoni*. Among all the combinations of buffalo dung and kitchen wastes maximum increase of TK was observed in the combination of BD+BP (2:1) i.e. 14.90% (6.07 ± 0.01 to 7.14 ± 0.02) and minimum increase of TK was observed in the combination of BD+VW (2:1) i.e. 5.43% (6.97 ± 0.01 to 7.37 ± 0.01). Between all the combinations of goat dung with kitchen wastes maximum increase of TK was observed in GD+BP (2:1) i.e. 20.81% (6.32 ± 0.04 to 7.98 ± 0.01) and minimum increase was observed in GD alone i.e. 10.62% (6.23 ± 0.03 to 6.97 ± 0.01). It was also reported by Suthar (2007) that TK increased in the vermibeds after 150 days.

Total available phosphorus is significantly higher in all the composted feed mixtures of buffalo dung and goat dung with kitchen wastes than the initial feed mixtures. Total available phosphorus content increased from 14.38% to 25.01% in the combination of buffalo dung and kitchen wastes and 8.50% to 13.67% in the combination of goat dung with kitchen wastes (Tables 4, 8; Figs. 4, 8). Among all the combinations of buffalo dung and kitchen wastes the maximum increase of TAP was observed in the combination of BD+BP (2:1) i.e. 25.01% (5.43 ± 0.01 to 7.24 ± 0.02) and minimum increase of TAP was observed in the combination of BD+BP+VW (1:1:1) i.e. 14.38% (7.21 ± 0.01 to 8.42 ± 0.02). In all the combinations of goat dung and kitchen wastes maximum increase of TAP was observed in the combination of GD+BP+VW (1:1:1) i.e. 13.67% (6.32 ± 0.01 to 7.32 ± 0.00) and minimum increase

Table 3: Concentration of C:N ratio and TK in initial feed mixtures and final vermicompost of buffalo dung mixed with kitchen wastes in different combinations

Combinations	C:N ratio			TK (g/kg)		
	IFM	VC	% decrease	IFM	VC	% increase
BD	81.44 ± 0.30	14.65 ± 0.02*	82.02	4.97±0.01	5.46 ± 0.01*	8.98
BD+VW (1:1)	62.64 ± 0.14	11.33 ± 0.03*	81.92	7.62 ± 0.03	8.55 ± 0.00*	10.88
BD+VW (2:1)	68.21 ± 0.23	12.65 ± 0.02*	81.46	6.97 ± 0.01	7.37 ± 0.01*	5.43
BD+BP (1:1)	66.33 ± 0.18	13.36 ± 0.02*	79.86	7.14 ± 0.02	8.25 ± 0.01*	13.46
BD+BP (2:1)	72.52 ± 0.33	13.08 ± 0.01*	81.97	6.07 ± 0.01	7.14 ± 0.02*	14.90
BD+BP+VW (1:1:1)	62.26 ± 0.26	12.43 ± 0.02*	80.04	7.42 ± 0.01	8.32 ± 0.01*	10.82

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, BD = Buffalo Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

Table 4: Concentration of TAP and TCa in initial feed mixtures and final vermicompost of buffalo dung mixed with kitchen wastes in different combinations

Combinations	TAP (g/kg)			TCa (g/kg)		
	IFM	VC	% Increase	IFM	VC	% increase
BD	4.95 ± 0.01	5.92 ± 0.01*	16.39	1.80 ± 0.12	2.39 ± 0.16*	24.69
BD+VW (1:1)	7.33 ± 0.02	8.81 ± 0.01*	16.80	3.30 ± 0.14	3.56 ± 0.08*	7.31
BD+VW (2:1)	6.21 ± 0.01	7.93 ± 0.02*	21.69	3.11 ± 0.20	3.28 ± 0.09*	5.19
BD+BP (1:1)	6.92 ± 0.01	8.34 ± 0.02*	17.03	2.80 ± 0.17	3.36 ± 0.11*	16.67
BD+BP (2:1)	5.43 ± 0.01	7.24 ± 0.02*	25.01	2.38 ± 0.03	3.20 ± 0.16*	25.63
BD+BP+VW (1:1:1)	7.21 ± 0.01	8.42 ± 0.02*	14.38	3.15 ± 0.16	3.58 ± 0.14*	12.02

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, BD = Buffalo Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

Table 5: Concentration of pH and EC in initial feed mixtures and final vermicompost of goat dung mixed with kitchen wastes in different combinations

Combinations	pH			EC (ds/m)		
	IFM	VC	% decrease	IFM	VC	% decrease
GD	7.70 ± 0.03	7.20 ± 0.06*	6.5	2.15 ± 0.01	1.38 ± 0.01*	35.82
GD+VW (1:1)	8.45 ± 0.07	6.90 ± 0.03*	18.35	2.65 ± 0.01	1.29 ± 0.02*	51.33
GD+VW (2:1)	7.80 ± 0.02	7.03 ± 0.04*	9.88	2.48 ± 0.01	1.18 ± 0.01*	52.42
GD+BP (1:1)	7.30 ± 0.03	6.82 ± 0.06*	6.58	2.37 ± 0.02	1.20 ± 0.02*	49.37
GD+BP (2:1)	7.59 ± 0.03	7.10 ± 0.10*	6.46	2.33 ± 0.00	1.16 ± 0.01*	50.22
GD+BP+VW (1:1:1)	7.11 ± 0.10	6.80 ± 0.05*	4.37	2.26 ± 0.01	1.19 ± 0.10*	47.35

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, GD = Goat Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

Table 6: Concentration of TOC and TKN in initial feed mixtures and final vermicompost of goat dung mixed with kitchen wastes in different combinations

Combinations	TOC (g/kg)			TKN (g/kg)		
	IFM	VC	% decrease	IFM	VC	% increase
GD	441.33 ± 0.07	182.86 ± 0.11*	58.57	5.62 ± 0.01	8.47 ± 0.01*	33.65
GD+VW (1:1)	548.39 ± 0.47	269.85 ± 0.63*	50.80	8.63 ± 0.93	13.32 ± 0.01*	35.22
GD+VW (2:1)	535.57 ± 0.08	253.41 ± 0.09*	52.69	8.32 ± 0.07	12.57 ± 0.03*	33.82
GD+BP (1:1)	527.00 ± 0.07	255.43 ± 0.07*	51.54	7.90 ± 0.08	12.62 ± 0.02*	37.41
GD+BP (2:1)	514.68 ± 0.07	243.05 ± 0.05*	52.78	7.42 ± 0.01	11.79 ± 0.04*	37.07
GD+BP+VW (1:1:1)	525.97 ± 0.08	247.86 ± 0.07*	52.88	7.99 ± 0.02	12.32 ± 0.03*	35.15

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, GD = Goat Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

Table 7: Concentration of C:N ratio and TK in initial feed mixtures and final vermicompost of goat dung mixed with kitchen wastes in different combinations

Combinations	C:N ratio			TK (g/kg)		
	IFM	VC	% decrease	IFM	VC	% increase
GD	78.52 ± 0.37	21.58 ± 0.02*	72.52	6.23 ± 0.03	6.97 ± 0.01*	10.62
GD+VW (1:1)	63.54 ± 0.59	20.25 ± 0.03*	68.14	7.24 ± 0.04	8.64 ± 0.02*	16.21
GD+VW (2:1)	64.02 ± 0.69	20.14 ± 0.05*	68.55	6.72 ± 0.02	8.32 ± 0.01*	19.24
GD+BP (1:1)	67.39 ± 0.72	20.24 ± 0.03*	69.97	6.84 ± 0.01	8.19 ± 0.02*	16.49
GD+BP (2:1)	69.90 ± 0.61	20.60 ± 0.07*	70.53	6.32 ± 0.04	7.98± 0.01*	20.81
GD+BP+VW (1:1:1)	66.13 ± 0.44	20.11 ± 0.05*	69.60	7.19 ± 0.02	8.41± 0.01*	14.51

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, GD = Goat Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

Table 8: Concentration of TAP and TCa in initial feed mixtures and final vermicompost of goat dung mixed with kitchen wastes in different combinations

Combinations	TAP (g/kg)			TCa (g/kg)		
	IFM	VC	% increase	IFM	VC	% increase
GD	4.22 ± 0.37	4.82 ± 0.01*	12.45	2.58 ± 0.03	3.38 ± 0.06*	23.67
GD+VW (1:1)	6.55 ± 0.59	7.43 ± 0.00*	11.85	3.28 ± 0.06	4.18 ± 0.03*	21.54
GD+VW (2:1)	5.82 ± 0.69	6.36 ± 0.00*	8.50	2.88 ± 0.05	3.78 ± 0.07*	23.81
GD+BP (1:1)	6.21 ± 0.72	7.16 ± 0.01*	13.27	2.68 ± 0.03	3.18 ± 0.04*	15.73
GD+BP (2:1)	5.47 ± 0.61	6.11 ± 0.01*	10.48	2.38 ± 0.04	2.88 ± 0.05*	17.37
GD+BP+VW (1:1:1)	6.32 ± 0.44	7.32 ± 0.00*	13.67	3.03 ± 0.06	3.68 ± 0.03*	17.67

Each value is the mean ± SE of six replicates. IFM = Initial Feed Material, VC = Vermicompost, GD = Goat Dung, BP = Banana peel, VW = Vegetable Waste. *Significant ($P < 0.05$) between before and after vermicomposting in 30.0x30.0x10.0 cm^3 area of vermicompost bed.

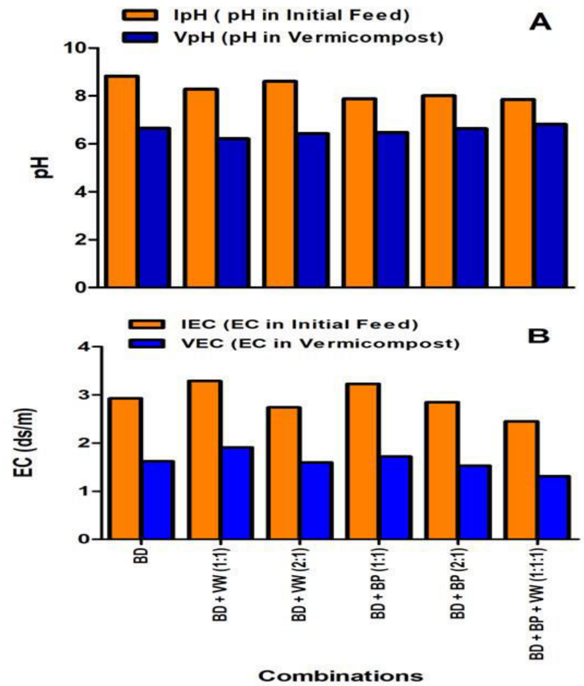

Fig. 1: Concentration of pH (A) and EC (B) in initial feed material and the vermicompost of different combinations of buffalo dung with kitchen wastes by *Eutyphoeus waltoni.* IpH= pH in initial feed material, VpH= pH in vermicompost, IEC= electrical conductivity in initial feed material, VEC= electrical conductivity in vermicompost, BD= buffalo dung, VW= vegetable waste, BP= banana peel.

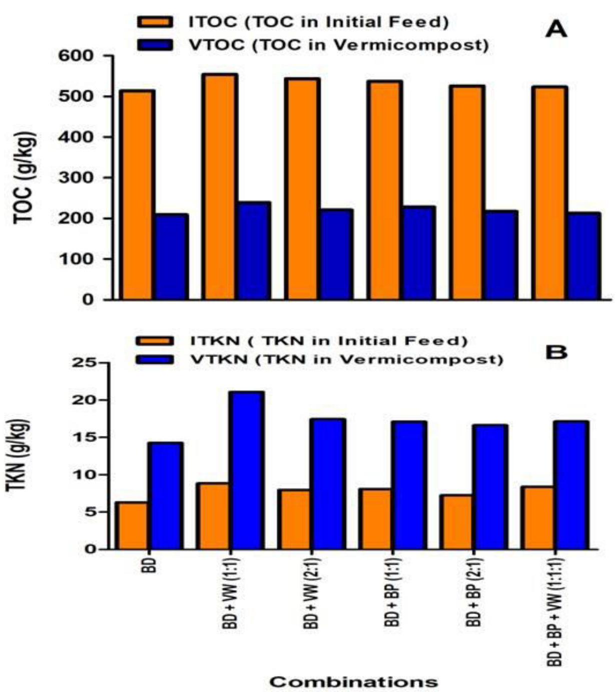

Fig. 2: Concentration of TOC (A) and TKN (B) in initial feed material and the vermicompost of different combinations of buffalo dung with kitchen wastes by *Eutyphoeus waltoni.* ITOC= total organic carbon in initial feed material, VTOC= total organic carbon in vermicompost, ITKN= total kjeldahl nitrogen in initial feed material, VTKN= total kjeldahl nitrogen in vermicompost, BD= buffalo dung, VW= vegetable waste, BP= banana peel.

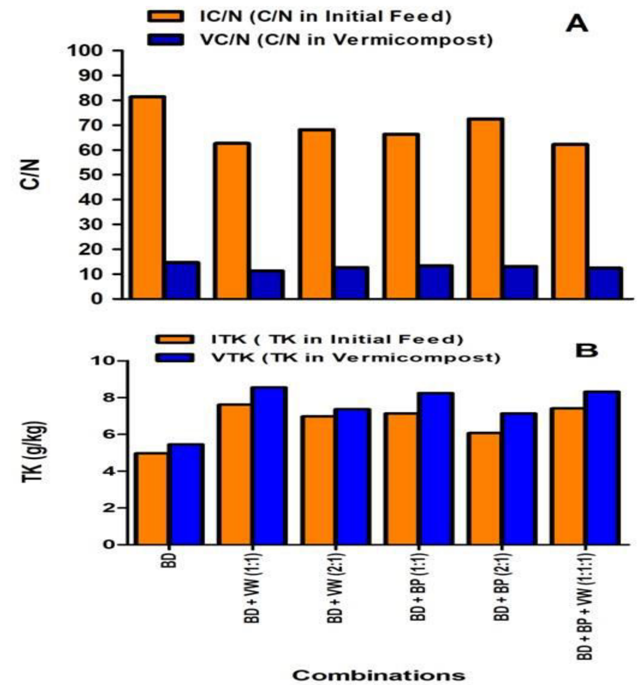

Fig. 3: Concentration of C/N ratio (A) and TK (B) in initial feed material and the vermicompost of different combinations of buffalo dung with kitchen wastes by *Eutyphoeus waltoni.* IC/N= carbon to nitrogen ratio in initial feed material, VC/N= carbon to nitrogen ratio in vermicompost, ITK= total potassium in initial feed material, VTK= total potassium in vermicompost, BD= buffalo dung, VW= vegetable waste, BP= banana peel.

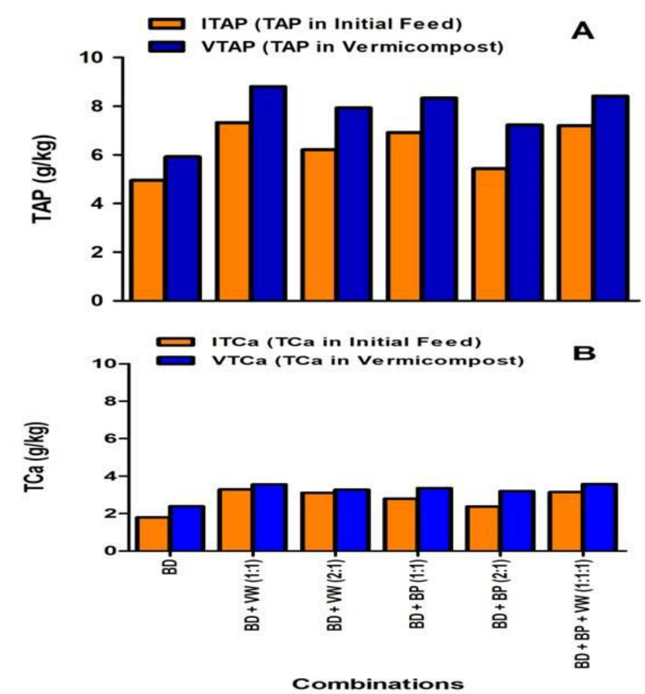

Fig. 4: Concentration of TAP (A) and ITCa (B) in initial feed material and the vermicompost of different combinations of buffalo dung with kitchen wastes by *Eutyphoeus waltoni.* ITAP= total available phosphorus in initial feed material, VTAP= total available phosphorus in vermicompost, ITCa= total calcium in initial feed material, VTCa= total calcium in vermicompost, BD= buffalo dung, VW= vegetable waste, BP= banana peel.

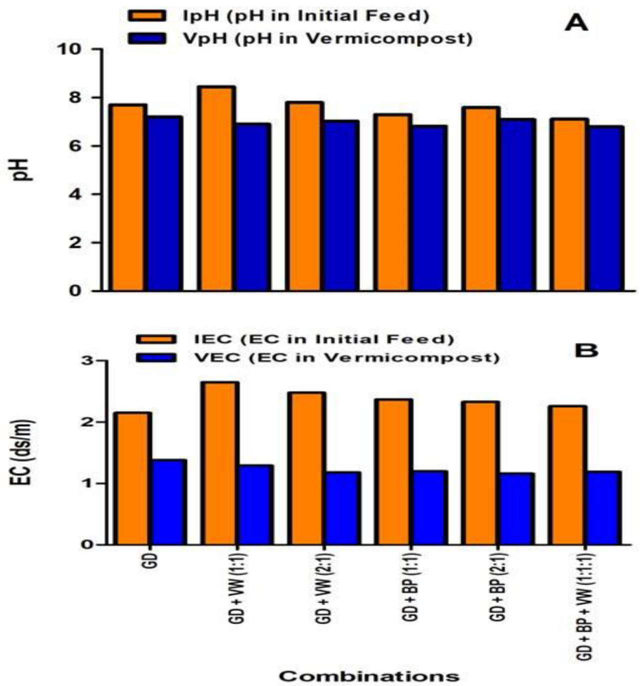

Fig. 5: Concentration of pH (A) and EC (B) in initial feed material and the vermicompost of different combinations of goat dung with kitchen wastes by *Eutyphoeus waltoni.* IpH= pH in initial feed material, VpH= pH in vermicompost, IEC= electrical conductivity in initial feed material, VEC= electrical conductivity in vermicompost, GD= goat dung, VW= vegetable Waste, BP= banana peel.

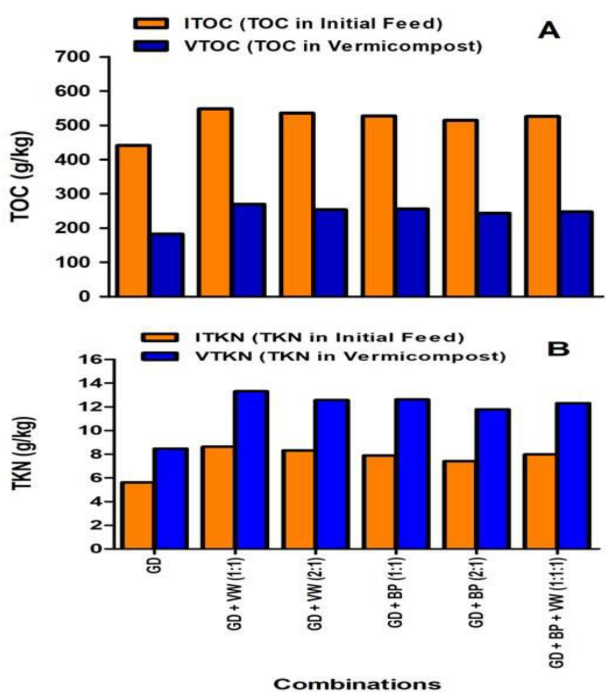

Fig. 6: Concentration of TOC (A) and TKN (B) in initial feed material and the vermicompost of different combinations of goat dung with kitchen wastes by *Eutyphoeus waltoni.* ITOC= total organic carbon in initial feed material, VTOC= total organic carbon in vermicompost, ITKN= total kjeldahl nitrogen in initial feed material, VTKN= total kjeldahl nitrogen in vermicompost, GD= goat dung, VW= vegetable waste, BP= banana peel.

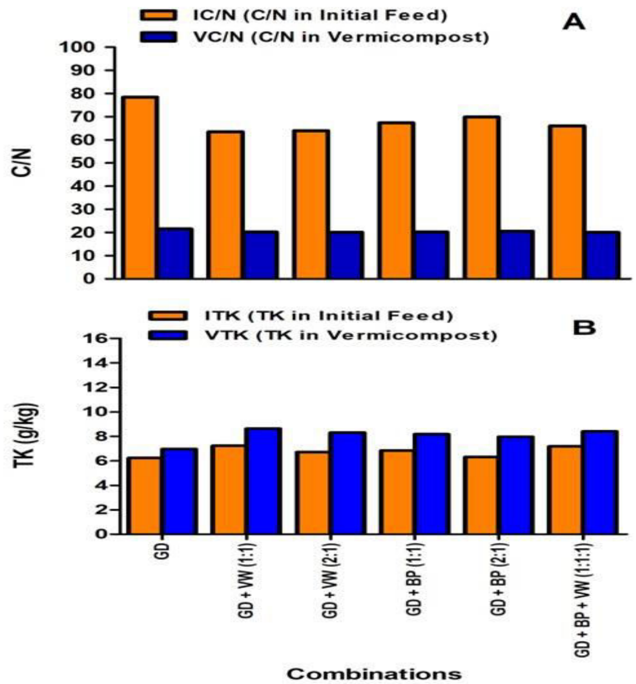

Fig. 7: Concentration of C/N ratio (A) and TK (B) in initial feed material and the vermicompost of different combinations of goat dung with kitchen wastes by *Eutyphoeus waltoni.* IC/N= carbon to nitrogen ratio in initial feed material, VC/N= carbon to nitrogen ratio in vermicompost, ITK= total potassium in initial feed material, VTK= total potassium in vermicompost, GD= goat dung, VW= vegetable waste, BP= banana peel.

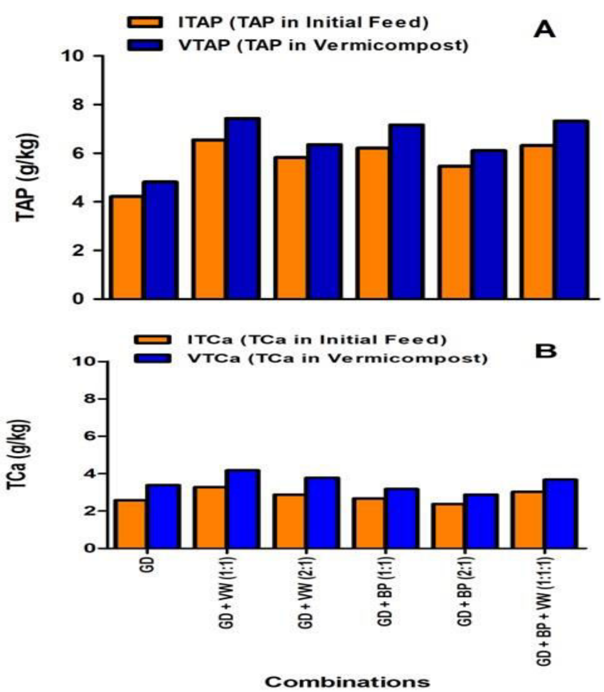

Fig. 8: Concentration of TAP (A) and ITCa (B) in initial feed material and the vermicompost of different combinations of goat dung with kitchen wastes by *Eutyphoeus waltoni.* ITAP= total available phosphorus in initial feed material, VTAP= total available phosphorus in vermicompost, ITCa= total calcium in initial feed material, VTCa= total calcium in vermicompost, GD= goat dung, VW= vegetable waste, BP= banana peel.

was observed in the combination of GD+VW (2:1) i.e. 8.50% (5.82 ± 0.01 to 6.36 ± 0.00). Increase in TAP is associated to the quality of feed materials, processing time and worms according to previous researchers (Hartenstein and Hartenstein, 1981; Ndegwa *et al*., 2000). Suthar (2007) reported that total phosphorus content increased significantly in the final composted mixture, this may occur due to phosphorus mineralization during the process. It has also been reported that earthworm passes feed material through its gut which can be a reason for adding some amount of P to worm excretion which in turns increase the available phosphorus for plants (Lee, 1985). During the decomposition of organic matter micro-organisms produce acid, which solubilize insoluble phosphorus which later increased the phosphorus content in the composted mixture by earthworms (Pramanik *et al*., 2007). An increase of 25% in phosphorus content of paper waste sludge after the activity of earthworms has been reported (Satchell and Martin, 1984).

Total calcium is significantly higher in all the final composted mixture compared to the initial feed mixture of buffalo dung and goat dung with kitchen wastes (Tables 4, 8; Figs. 4, 8). Maximum increase of 25.63% of calcium was observed in BD+BP (2:1) (2.38 ± 0.03 to 3.20 ± 0.16) and increase of 23.81% of calcium was observed in GD+VW (2:1) (2.88 ± 0.05 to 3.78 ± 0.07). Minimum increase of 5.19% of calcium was observed in BP+VW (2:1) (3.11 ± 0.20 to 3.28 ± 0.09) and 17.37% in GD+BP (2:1) (2.38 ± 0.03 to 2.88 ± 0.05). Increase of total calcium in the final composted mixture by earthworms was also observed by Garg *et al*. (2006). It has been reported that the metabolism of calcium in the gut of earthworms was primarily responsible to increase the inorganic calcium in worm cast (Hartenstein and Hartenstein, 1981).

Conclusion

This study clearly revealed the changes in the physico-chemical properties of buffalo and goat dung mixed with kitchen wastes in different ratios after the processing of earthworm *Eutyphoeus waltoni.* The result indicated that dung which is used alone and the dung which are mixed with kitchen wastes in different ratios had different effect on the process because of different physico-chemical properties. Experimental data provide a sound basis that this technology of using earthworms is suitable for the conversion of kitchen wastes and animal dung into organic fertilizers. This will not only reduce the load of synthetic fertilizers but will also act as a soil conditioner and a source of plant nutrients in agriculture.

Acknowledgements

The authors are highly thankful to the Head, Department of Zoology, D.D.U. Gorakhpur University, Gorakhpur, India for providing necessary laboratory facilities.

References

Aira M, Monroy F. and Dominguez J. (2007) Earthworms strongly modify microbial biomass and activity triggering enzymatic activities during vermicomposting independently of the application rates of pig slurry. Sci Total Environ. 385(1): 252-261.

Atiyeh RM, Arancon N, Edwards CA and Metzger JD. (2000) Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes, Bioresource Technol. 75(3): 175-180.

Bremner JM and Mulvaney RG. (1982) Nitrogen total. In: Method of soil analysis, (eds.) Miller R.H., Keeney D.R., Page A.L., Miller R.H. and Keeney D.R., American Society Agronomy, Madison, pp. 575-624.

Cardenas RR and Wang LK. (1980) Composting process. Solid waste processing and resource recovery. Springer, pp. 269-327.

Cestonaro T, de Mendonca Costa MS, de Mendonca Costa LA, Pereira DC, Rozatti M.A and Martins MF. (2017) Addition of cattle manure to sheep bedding allows vermicomposting process and improves vermicompost quality. Waste Manag. 61: 165-170.

Chauhan HK and Singh K. (2012) Effect of binary combinations of buffalo, cow and goat dung with different agro wastes on reproduction and development of earthworm *Eisenia fetida* (Haplotoxida: Lumbricidae). World J Zool. 7: 23-29.

Chavan RG, Alandikar NP, Bansode RD, Thakur AA, Totad KC and Lamkane SL. (2017) Management of kitchen waste by using vermicomposting method, Int J Innov

Sci Res Technol. 2(6): 28-29.

Dores-Silva PR, Landgraf MD and Rezende MO. (2011) Chemical monitoring of vermicomposting from domestic sewage sludge. Quím Nova 34(6): 956-961.

Elvira C, Goicoechea M, Sampedro L, Mato S and Nogales R. (1996) Bioconversion of solid paper-pulp mill sludge by earthworms. Bioresource Technol. 57(2): 173-177.

Febriyantiningrum K, Nurfitria N and Rahmawati A. (2018) Study of potential of Pasar Baru Tuban's vagetable waste as liquid organic fertilizer. National Seminar on Community Research and Development.

Fernandez-Gomez MJ, Nogales R, Insam H, Romero E and Goberna M. (2010) Continuous-feeding vermicomposting as a recycling management method to revalue tomato-fruit wastes from greenhouse crops. Waste Manag. 30(12): 2461-2468.

Garg P, Gupta A and Satya S. (2006) Vermicomposting of different types of wasts using *Eisenia fetida:* A comparative study. Bioresource Technol. 97:391-395.

Garg V and Gupta R. (2011) Optimization of cow dung spiked pre-consumer processing vegetable waste for vermicomposting using *Eisenia fetida.* Ecotoxicol Environ Safe. 74(1): 19-24.

Garg VK, Chand S, Chillar A and Yadav A. (2005) Growth and reproduction of *Eisenia fetida* in animal wastes during vermicomposting. Appl Ecol Environ Res. 3(2): 51-59.

Garg VK, Suthar S and Yadav A. (2012) Management of food industry waste employing vermicomposting technology. Bioresource Technol. 126: 437-443.

Gunadi B, Blount C and Edwards CA. (2002) The growth and fecundity of *Eisenia fetida* (Savigny) in cattle solids precomposted for different periods. Pedobiologia 46: 15-23.

Gupta PK. (2005) Vermicomposting for sustainable agriculture. Bharat Printing Press, Jodhpur, pp.11-14.

Hait S and Tare V. (2011) Vermistabilization of primary sewage sludge. Bioresource Technol. 102(3): 2812-2820.

Hartenstein R and Hartenstein F. (1981) Physicochemical changes effected in activated sludge by the earthworm *Eisenia fetida.* J Environ Quality 10(3): 377-381.

Kaur A, Singh J, Vig AP, Dhaliwal SS and Rup PJ. (2010) Cocomposting with and without *Eisenia fetida* for conversion of toxic paper mill sludge to a soil conditioner. Bioresource Technol. 101(21): 8192-8198.

Kaviraj and Sharma S. (2003) Municipal solid waste management through vermicomposting employing excotic and local species of earthworms. Bioresource Technol. 90: 169-73.

Lee KE. (1985) Earthworms: their ecology and relationships with soils and land use, Academic Press Inc., London, UK.

Lee S, Hosaka A and Tase N. (2012) Influence of animal waste disposal pits on groundwater quality. J Groundwater Hydrology 51: 3-14.

Malafaia G, da Costa Estrela D, Guimaraes AT, de Araujo FG, Leandro WM and de Lima Rodrigues AS. (2015) Vermicomposting of different types of tanning sludge (liming and primary) mixed with cattle dung. Ecological Engineering 85: 301-306.

Mousavi SA, Faraji M and Janjani H. (2017) Recycling of three different types of rural wastes employing vermicomposting technology by *Eisenia fetida* at low temperature. Global NEST J. 19(4): 601-606.

Nath G and Singh K. (2009) Utilization of vermiwash potential on summer vegetable crops. J Central European Agricult. 10(4): 417-426.

Ndegwa PM, Thompson SA and Das KC. (2000) Effects of stocking density and feeding rate on vermicomposting of biosolids. Bioresource Technol. 71(1): 5-12.

Nelson DW and Sommers LE. (1982) Total organic carbon and organic matter. In: Method of Soil Analysis, (eds.) Page A.L., Miller R.H. and Keeney D.R., American Society Agronomy, Medison, pp. 539-579.

Perez-Godinez EA, Lagunes-Zarate J, Corona-Hernandez J and Barajas-Aceves M. (2017) Growth and reproductive potential of Eisenia foetida (Sav) on various zoo animal dungs after two methods of pre-composting followed by vermicomposting. Waste Manag. 64: 67-78.

Plaza C, Nogales R, Senesi N, Benitez E and Polo A. (2008) Organic matter humification by vermicomposting of cattle manure alone and mixed with two-phase olive pomace. Bioresource Technol. 99(11): 5085-5089.

Prakash S and Verma AK. (2022) Anthropogenic activities and biodiversity threats. Int J Biol Innov. 4(1): 94-103.

Pramanik P, Ghosh GK, Ghosal PK and Banik P. (2007) Changes in organic- C, N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming and microbial inoculants. Bioresource Technol. 98(13): 2485-2494.

Satchell J and Martin K. (1984) Phosphatase activity in earthworm faeces. Soil Biol Biochem. 16(2): 191-194.

Scotti R, Bonanomi G, Scelza R, Zoina A and Rao MA. (2015) Organic amendments as sustainable tool to recovery fertility in intensive agricultural systems. J Soil Sci Plant Nutrition 15(2): 333-352.

Sharma S. (2003) Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. Bioresource Technol. 90(2): 169-173.

Short JCP, Frederickson J and Morris RM. (1999) Evaluation of traditional windrow composting and vermicomposting for the stabilization of waste paper sludge (WPS). Pedobiologia 43: 735-743.

Singh J, Kaur A, Vig AP and Rup PJ. (2010) Role of *Eisenia fetida* in rapid recycling of nutrients from biosludge of beverage industry. Ecotoxicol Environ Safe. 73(3): 430-435.

Singh K. and Fatima N. (2022). Vermifiltration as a viable and sustainable wastewater treatment process: A novel biofilter technology. Int J Biol Innov. 4(1): 213-220.

Singh K and Singh V. (2015) Toxic effect of herbicide 2, 4-D on the earthworm *Eutyphoeus waltoni* Michaelsen. Environ Process. 2: 251-260.

Sudkolai ST and Nourbakhsh F. (2017) Urease activity as an index for assessing the maturity of cow manure and wheat residue vermicomposts. Waste Manag. 64: 63-66.

Suthar S. (2006) Potential utilization of guar gum industrial waste in vermicompost production. Bioresource Technol. 97(18): 2474-2477.

Suthar S. (2007) Composting potential of *Perionyx sansibaricus* (Perrier) in different waste material. Bioresource Technol. 98: 1231-1237.

Suthar S. (2009) Vermicomposting of vegetable-market solid waste using *Eisenia fetida*: Impact of bulking material on earhworm growth and decomposition rate. Ecological Engineering 35(5): 914-920.

Suthar S and Singh S. (2008) Feasibility of vermicomposting in biostabilization of sludge from a distillery industry. Sci Total Environ. 394: 237-243.

Verma AK and Prakash S. (2020) E-wastes and their impact on environment and public health. Int J Appl Res. 6(9): 164-168.

Vig AP, Singh J, Wani SH and Dhaliwal SS. (2011) Vermicomposting of tannery sludge mixed with cattle dung into valuable manure using earthworm *Eisenia fetida* (Savigny). Bioresource Technol. 102(17): 7941-7945.

Wani K and Rao R. (2013) Bioconversion of garden waste, kitchen waste and cow dung into value-added products using earthworm *Eisenia fetida.* Saudi J Biol Sci. 20(2): 149-154.

Yadav A and Garg VK. (2010) Bioconversion of food industry sludge into value-added product (vermicompost) using epigeic earthworm *Eisenia fetida*. World Rev Sci Technol Sustainable Develop. 7(3): 225-238.