

original article

Effect of rice bran on the quality of vermicompost produced from food waste

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INTRODUCTION

There is a strong emphasis on sustainable agriculture around the world. This is based on the pillars of quality and yield with minimum environmental damage. However, the widespread use of fertilizers, particularly in developing countries, causes negative effects such as reducing the quality of products, increase the cost of fertilizer, destruction of desirable microorganisms, and irreparable damage to the soil structure.^[1-3] The food waste (FW) contains 70% of organic matter in developing countries, which typically dispose of

into landfills, with high cost and effect on the public health and environment.^[4,5] As well as, rice husk and rice straw with high silica and a nutrients source usually dispose of or burn in the developing countries, which pollute the air, water, soil, and have health harmful effects. Because of these problems, governments and environmental organizations look for new ways to manage and use of these wastes.^[6] Vermicomposting is recognized process to produce a clean

ABSTRACT

Aims: The present study was carried out to evaluate the production of eco-friendly and environmentally bio-fertilizer from a mixture of food waste (FW) and rice bran (RB).

Materials and Methods: The various mixtures of RB and FW (1:1, 1:2, 1:3, and 1:5) were prepared and spread in Diy beds for 20 days. After that, the raw compost was poured in four containers beds contains 100 adult earthworms *Eisenia foetida* for 30 days. Physical and chemical parameters including temperature, humidity, carbon to nitrogen (C/N) ratio, and pH were monitored.

Results: The obtained results showed that at the first of composting process, the temperature was sharply increased and after that dropped and reached to the ambient temperature. The C/N ratio was decreased in studied Diy beds during preparing and vermicompost processes. The averages of C/N ratios in the raw FW and RB at mixing ratios of 1:1, 1:2, 1:3, and 1:5 were 45.35, 38.43, 35.3, and 32.11, respectively. The C/N ratios in the vermicompost were reduced to 20.85, 18.3, 16.86, and 15.16, respectively.

Conclusion: The results of this study showed that composting and vermicomposting process can be used as a potential tool for bio convert rice bran and food waste. However, it is suggested that the rice bran can be amended with food waste to ensure better quality of vermicompost.

Key words: Composting, *Eisenia foetida*, food waste, rice bran, vermicomposting

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fertilizer for sustainable agriculture. Vermicompost is a mesophilic aerobic process, which leads to degradation and stabilization of organic matter by the coactions of earthworms and microorganisms, particularly performance of bacteria and actinomycetes.^[1,7-10] More than 3000 species of earthworms are recognized in the world, where the *Eisenia foetida* have the spatial ability and play an active role in the decomposition and transformation of organic waste into fertilizer that has been proved by research.^[11,12]

Vermicompost has the major advantage compared to conventional compost such as odorless, adjusted pH, low electrical conductivity, and contain high concentrations of elements such as nitrogen, potassium, and phosphorus. Vermicompost is stable and has uniform combination. The level of contamination is less than raw materials and other fertilizers. Production of organic acids during process and presence of micronutrients such as iron, copper, and zinc in the vermicompost make it an effective fertilizer for plants. The organic acids, digestive tract secretions, exudates from the surface of worms, various enzymes, and humic acid have the same effects of plant's hormones that stimulate the growth of them.^[1,13-16] Phenolic substances that produce in vermicompost cause the plant's resistance against the pathogens. Some studies showed that the humic substances in vermicompost are more than it in compost.^[7,17] Vermicomposting, due to the form of granulated excrement of the worm, has a bulk condition that causes to have a less density than usual compost, which makes more porosity of soil and increases the permeability of water in the soil. Because of high humidity retention capacity in the vermicompost, water is available for plants in longer time. Unlike conventional composting, vermicompost is not introduced in thermophilic phase. Instead, earthworms with crush and chop of organic materials, aerated mass through their digestive systems, make the vermicompost a clean fertilizer and relatively free from pathogens, especially the coliforms. Therefore, this fertilizer can be used in indoor applications.^[1,13,18]

In recent years, the impact of bran residues on the quality of vermicompost fertilizer was studied in the world. According to Kitturmath *et al.*, rice and wheat bran proved to be good additives for palatable substrates in vermicomposting of cow dung and paddy straw, which supported better growth of earthworms and production of desirable vermicompost.^[19] In study of Jusoh *et al.*, compost production of rice straw was evaluated in the presence and absence of effective microorganisms. The results showed that the amount of nutrients in the compost with effective microorganisms was more than it in compost without effective microorganisms.^[20] The results of the survey conducted by Shak *et al.* showed that rice straw and rice husk have effect on the quality of vermicomposting.^[6]

The aim of this study was to produce vermicompost fertilizer from organic waste foods in combined with rice bran (RB) for

the 1st time. The main purpose of this study was to evaluate the effect of RB on the quality of vermicompost fertilizer from FW.

MATERIALS AND METHODS

Materials

In this study, FWs was provided from the main student kitchen of Isfahan University of Medical Sciences and RB of the rice husk was purchased from Zarin Shahr rice industries in Isfahan province. Vermicompost containers were prepared from Nader Plast Co., and earthworm was purchased from Afra Sabz Co., Iran.

Composting process

In the first step, rice bran: Food waste ratio (RB: FW) was prepared in four level of 1:1, 1:2, 1:3, and 1:5 and overspread in 4 beds for 20 days in condition of the compost process. Moisture was set about 60–70% at the start of the composting process. Water was sprayed on the surface of the bed daily to keep moisture in the optimum value. The parameters of temperature, pH, and carbon to nitrogen (C/N) ratio (organic carbon to total nitrogen [TN]) of each bed were monitored to determine the progress of composting. Temperature and pH were measured and recorded in beds every day, but C/N ratio was measured in raw material every 7 days to the end of the process.

Vermicomposting process

In the second step, the produced compost was spread in four containers with dimensions of 40 cm × 40 cm × 30 cm and some holes in there's sides. Hundred adult earthworms *E. foetida* were added in each container. In this process, the humidity was set around 60–70%. At this point, the pH and temperature were monitored daily, but carbon (C) and nitrogen (N) were analyzed weekly for C/N ratio calculation. All beds (1:1, 1:2, 1:3, and 1:5) were repeated for 3 times. Hence, 12 beds were studied for vermicomposting process. Aeration was done by turning the bed every day manually and vermicompost beds were evaluated for 1 month in the presence of worm in the solid waste laboratory of Isfahan University of Medical Sciences.

Physical and chemical analyses

Physical and chemical tests including temperature, humidity, C/N ratio, and pH were monitored along the compost and vermicompost process. Temperature changes in each bed were recorded by a digital thermometer bar model GM1311. For the measurement of pH, samples were dried in the oven (model SHFD 55 ST) at 103–105°C (24 h) and then mixed with distilled water in 1:10 ratio and were filtered after 10 min. The pH was measured with a pH meter digital model Lutron YK-2001CT. To determine the moisture content of the substrate, the sample weight loss was measured after 24 h at 105°C on the basis of the specific amount of dry matter.^[21]

Gravimetric method was used to measure the organic carbon. In this method, the samples were dried in the oven (24 h at 75°C), after weighting they were heated in an electrical furnace for 2 h at 550°C and weighted again and the amount of volatile solids (VS) and organic carbon were calculated as Equations (1) and (2), respectively.^[22]

$$\%VS = 100 - \%Ash. \tag{1}$$

$$\text{Organic carbon} = \frac{\%VS}{1.8} \tag{2}$$

An automated thermal elemental analyzer (ECS 4010 CHNS-O analyzer) was employed to determine of TN in the compost samples, and C/N ratio was also calculated.

RESULTS

The mean and standard deviations of physical and chemical parameters of raw material substrates are presented in Table 1.

In Table 2, the mean and standard deviation of the physical and chemical parameters for substances are shown at the beginning of the process, after composting, and after vermicompost process. As shown in Table 2, average of C/N decreased in the RB: FW ratio from 1:1 to 1:5 for the raw mixture. These trends also repeated in the final fertilizer from composting and vermicomposting process. This is because of changes in nitrogen content. Nitrogen was increased during the compost and vermicompost process. Also, total organic carbon (TOC) and VS were decreased during the process.

Changes in physicochemical parameters such as temperature, pH, C/N ratio, and TN during the 50 days process of fertilizer

making for different proportions of RB and FW are shown in Figures 1 and 2.

As shown in Figure 1, pH was decreased during the 1st day of composting process in all 4 treatment beds and the bed condition had a tendency to acidic properties. However, after 10 days, pH was gone for alkaline phase and remained in alkaline conditions to the end of the process [Figure 1]. Results showed that the trends of temperature was increased at the start of the process and dropped after a few days to ambient temperature and remained to the end of vermicompost [Figure 2]. The C/N ratio decreased in all treatment beds during vermicompost and compost [Figure 3], as well as nitrogen was increased during the process [Figure 4].

Figure 5 presents the trend change of temperature and C/N ratio during composting and vermicomposting process.

DISCUSSION

The composting process involves the accelerated degradation of organic matter by microbial activity. Intensive decomposition produces heat which is reflected by a rapid increase in temperature. The compost material in our study was energy-rich, so the temperature level observed was higher.

The pH of composts was significantly different than initial pH. The pH of all the feed combinations decreased from alkaline (7.52–7.78) to slightly acidic (6.31–6.54) condition. The shifting in pH could be attributed to the production of carbon dioxide, ammonia, nitrate, and organic acid by microbial decomposition of organic matter during the

Table 1: Physicochemical properties of the rice bran and food waste

Parameters	TOC (%)	TN (%)	C/N ratio	pH	Moisture content (%)
FW	37 ± 1.7	1.2 ± 0.07	30.5 ± 0.85	7.75 ± 0.04	50 ± 1.4
RB	35.67 ± 2.94	0.55 ± 0.05	64.85 ± 0.74	7.4 ± 0.06	9.6 ± 1.8

RB: Rice bran, FW: Food waste, TOC: Total organic carbon, TN: Total nitrogen, C/N: Carbon to nitrogen

Table 2: Physical and chemical parameters of raw mixtures, compost, and vermicompost

Raw materials ratio	TOC (%)	TN (%)	C/N ratio	VS (%)	pH
1RB: 1FW					
Initial	35.44 ± 1.59	0.75 ± 0.08	47.35 ± 0.45	59.38 ± 2.44	7.52 ± 0.02
Composting	27.18 ± 2.14	0.9 ± 0.04	30.06 ± 0.87	45.12 ± 3.29	7.54 ± 0.07
Vermicompost	17.3 ± 1.2	0.95 ± 0.05	17.85 ± 0.66	28.47 ± 2.54	7.49 ± 0.04
1RB: 2FW					
Initial	35 ± 2.84	0.88 ± 0.05	38.43 ± 0.23	58.77 ± 1.84	7.63 ± 0.12
Composting	28 ± 3.2	0.99 ± 0.03	28.69 ± 0.95	47.52 ± 4.92	7.73 ± 0.04
Vermicompost	22.99 ± 2.01	1.35 ± 0.09	16.3 ± 1.12	37.9 ± 3.09	7.58 ± 0.09
1RB: 3FW					
Initial	35.8 ± 1.32	0.98 ± 0.04	35.31 ± 0.47	59.09 ± 2.03	7.66 ± 0.03
Composting	30.87 ± 1.24	1.06 ± 0.11	28.06 ± 0.5	50.42 ± 1.9	7.72 ± 0.07
Vermicompost	25.47 ± 1.75	1.49 ± 0.07	17.04 ± 1.24	42.12 ± 2.69	7.78 ± 0.14
1RB: 5FW					
Initial	36.63 ± 2.64	0.97 ± 0.07	36.11 ± 0.73	60.66 ± 4.06	7.76 ± 0.05
Composting	35.4 ± 1.82	1.25 ± 0.02	27.33 ± 0.68	58.4 ± 2.8	7.5 ± 0.08
Vermicompost	30.13 ± 0.94	1.62 ± 0.08	18.16 ± 0.46	50.13 ± 1.44	7.82 ± 0.09

RB: Rice bran, FW: Food waste, TOC: Total organic carbon, TN: Total nitrogen, C/N: Carbon to nitrogen, VS: Volatile solids

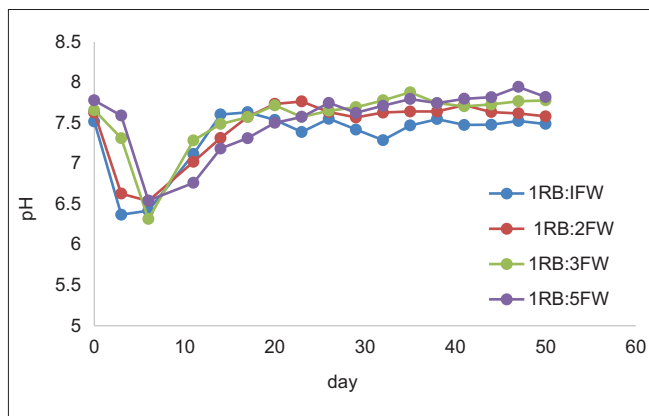


Figure 1: Changes in pH during the composting and vermicomposting

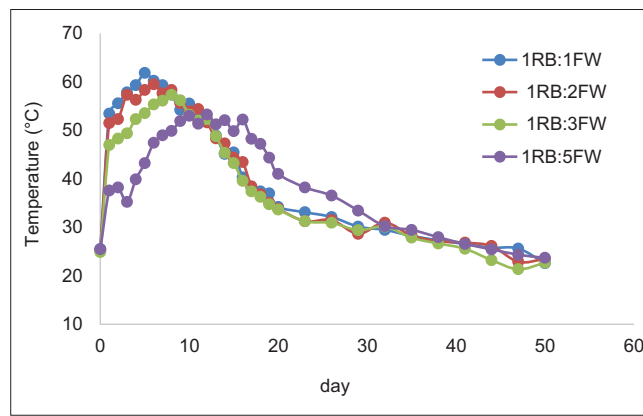


Figure 2: Changes in temperature during the composting and vermicomposting

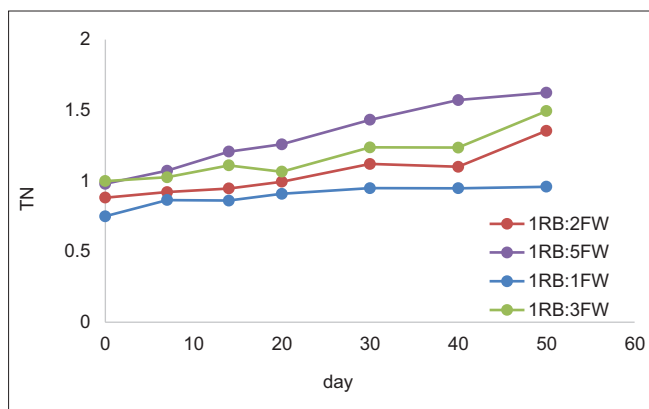


Figure 3: Changes in total nitrogen during the composting and vermicomposting

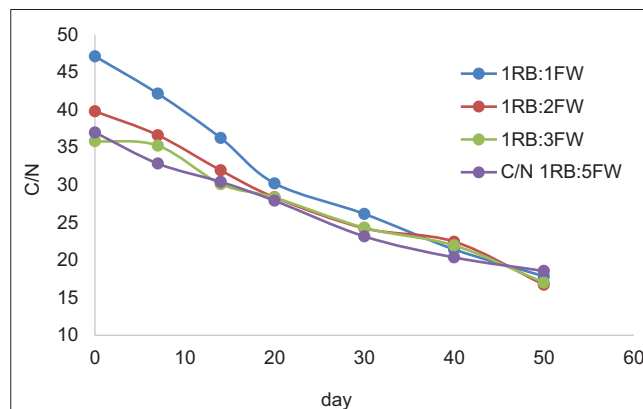


Figure 4: Changes in carbon to nitrogen ratio during the composting and vermicomposting

composting process. Figure 1 shows that the greater amount of RB in raw mixture turns the composting process to acidic conditions. The pH had most reduction in 4 days for the ratio of 1RB:1FW while in the ratio of 1RB:5FW, it was occurred in 8 days.

The changes of pH during the compost phase were more it changes in vermicompost [Table 2]. The pH of mixtures waste was neutral at the beginning but slightly acidic during compost. Initially, pH values in the different ratio of FW to RB were ranged from 7.52 to 7.78 and in final compost, the range was received from 7.54 to 7.73. The maximum decrease in pH was reported in composting for 1RB:3FW ratio and minimum was in 1RB:5FW ratio. Several studies have reported similar results during composting of different wastes.^[23,24] The decrease in pH had been related to organic materials and formation of intermediate chemical products such as ammonium ions and humic acids during the composting process.^[23] Pramanik reported that the decomposition of organic matter led to the formation of ammonium ions and humic acids. The presence of carboxylic and Phenolic groups in humic acids caused lowering of pH and ammonium ions increased the pH of the system.^[25]

The temperature has long been considered as an important parameter in monitoring the composting process and determining compost quality. Temperature is also strongly correlated with microbial activity and in relation to composting stages and is used to describe the suitable conditions for the proliferation of different microbial groups, i.e., mesophiles and thermophiles.^[26] The composting stages based on temperature, mesophilic, thermophilic, curing, and ambient temperatures are clearly displayed for the composting experiment as shown in Figure 2. Temperature was received to thermophilic phase after a day in 1RB:1FW and 1RB:2FW ratio while it happens on the 12 days for the ratio of 1RB:5FW. According to Figure 2, the greater amount of RB had more effect on change of temperatures, as well as the peak of temperature are higher (1RB:1FW 4 days 63.36°C, 1RB:2FW 5 days 61.7°C, 1RB:3FW 8 days 57.18°C, and 1RB:5FW 12-day 53.5°C). The temperature in all treatments reached ambient temperature after 50 days. The longest thermophilic phase in the aerated static composts is a result of the C/N balance within the feedstock and larger volume of material used. The Canadian Council of Ministers for the Environment guidelines declared that temperature should be 55°C for 3 days in compost process for pathogen reduction. The temperature profiles from

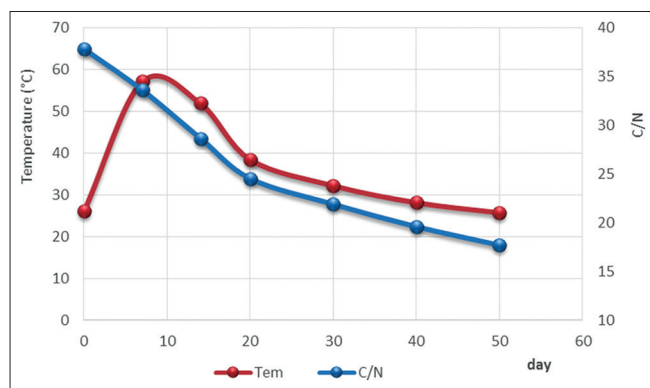


Figure 5: Trends of temperature and carbon to nitrogen ratio during composting and vermicomposting process

four treatments composting showed that there was a highly degradable substrate in beds, which is further enhanced by the high surface area of the RB. The addition of RB may help achieve and sustain temperature in the thermophilic phase for a longer period, enhancing the degradation and stabilization. Several other studies had shown that the temperature increased at the start of process and decreased again after the decomposition of waste. The increasing of temperature was due to the activity of microorganisms in the presence of high organic matter.^[26-28] Figure 5 shows that the temperature increased in the early days of the composting process, due to microbial activity, degradation, and decomposition of organic matter and organic acids produced. As shown in Figure 5, decomposition of organic matter in early days was high due to microbial activity, which C/N ratio was reduced.

TOC content was lesser in all the compost beds than initial TOC [Table 2]. Maximum decrease in TOC was recorded in 1RB:1FW (100%) followed by 1RB:2FW (77%), 1RB:3FW (60%), and 1RB:5FW (23%). The combined action of earthworms and microorganisms may be responsible for TOC loss from the initial feed waste in the form of CO₂. Similar observations had been reported during the compost process of sugar industry waste.^[23] Sharma reported 20–45% reduction in TOC as CO₂ during composting of municipal or industrial wastes.^[29]

TN content in the all compost fertilizer was higher than that of initial waste mixture. The initial TN content of the waste mixtures was in the range of 0.75–0.98% [Table 2]. Whereas the TN content of compost was in the range of 0.9–1.25%. Results as shown in Figure 3 show that the greatest increasing in TN was achieved in the ratio of 1RB:5FW (28%) and the lowest was for 1RB:3FW (7%). Kaushik and Garg had reported 2.0–3.2 fold increase in TN during composting of textile mill sludge mixed with cow dung and wheat straw.^[30] Plaza *et al.* reported that the nitrogen content of compost increase due to mineralization of C-rich materials and possibly due to the action of N-fixing bacteria. Decreases in pH may be another important factor in nitrogen retention by compost which otherwise may be lost as ammonia at

higher pH values.^[31] Addition of nitrogen in the form of mucus, nitrogenous excretory substances, growth stimulating hormones, and enzymes from earthworms was also been reported.^[32,33]

The C/N ratio reflects the spectra of changing in carbon and nitrogen concentration of the waste during composting process.^[34] The loss of CO₂ through microbial respiration and the simultaneous addition of nitrogen by worms in the form of mucus and nitrogenous excretory material perhaps lowered the C/N ratio in the final products. In the present study, C/N ratio decreased sharply in the final product after 20 days of composting process. The C/N ratio of the RB and FW in initial process was ranged from 35.84 to 47.42 [Table 2] which was reduced up to 27.1–30.12 in compost after 20 days. Final C/N ratios of compost were reduced in the range of 16.72 (1RB:2FW) to 18.54 (1RB:5FW), depicting the overall decrease of 100–160% after 50 days of worm's activity from the initial values at start phase. The present findings showed conformity with the previous worker that reports up to 85.2% reduction in C/N value in the compost.^[35] The C/N ratio <20 indicates the improved quality of the compost and compost.^[36]

The earthworms in the vermicomposting process modify the physical, biological, and chemical properties of the waste materials. The final vermicompost was pleasantly earthy in odor, granular, nutrient-rich, much darker in color, and more homogeneous than initial materials after 30 days by *E. foetida* earthworm activity. The decomposition of organic matter in vermicompost depends on several factors such as nature of feed substrate, aeration, moisture, temperature, and earthworm species that used in the process. Hence, they effect on final fertilizer characteristics such as pH, electrical conductivity, TOC, TN, total availability of phosphorus, total potassium, and metal content.

Adequate moisture is one of the most important requirements of earthworms during vermicomposting. The growth rate of earthworms has been related to the moisture level in the vermicomposting system. An optimum moisture ranged between 50% and 80% has been considered for efficient vermicomposting; however, up to 90% of moisture level has also been considered efficient for vermicomposting process.^[37] According to Reinecke and Venter, the optimum moisture content for *E. foetida* is 70%.^[38] Neuhauser *et al.* considered 70–80% moisture content is optimum for *E. foetida* in cow manure, and in the other study reported *E. foetida* development and reproduction at 82% of moisture content level.^[39] They require moisture in the range of 60–70%. The feedstock should not be too wet, otherwise it may create anaerobic conditions which may be fatal to earthworms.^[17] The moisture of feed mixtures used in the present study was in the suggested range.

Temperature measurements were recorded on a daily basis from the start of the experiment at three different locations

of the vermicompost beds, respectively, until near ambient temperature values were reached. The average temperature profile for 1RB:1FW, 1RB:2FW, 1RB:3FW, and 1RB:5FW for each vermicomposting mixes are presented in Figure 2. The average starting temperatures of the vermicomposting process were in the range of 24.0–41.02°C.

Worms can survive in a pH range of 5–9.^[18] However, the range of 7.5–8.0 is considered to be the optimum condition for worm's activity. The pH of waste materials significantly influences the vermicomposting process. The variation of the mean pH in each of the vermicomposting beds monitored over a period of 30 days is shown in Figure 1. Initially, the pH of the feed material was 7.54, 7.73, 7.7, and 7.5 for 1RB:1FW, 1RB:2FW, 1RB:3FW, and 1RB:5FW, respectively. The initial pH values depend on the composition of the ingredients and clearly indicated that the feed material used in the vermicomposting process was slightly alkaline with a pH above 7 for all mixes. After the inoculation of worms on day 20, the pH increased to alkaline values for the vermicompost samples of 1RB:1FW, 1RB:2FW, 1RB:3FW, and 1RB:5FW thereafter leading to a final mean value of 7.49 for 1RB:1FW, 7.58 for 1RB:2FW, 7.78 for 1RB:3FW, and 7.82 for 1RB:5FW. Little variations of pH were observed for vermicompost and the results obtained in this study agree with the observations made by Francou *et al.*^[40] Khwairakpam and Bhargava reported a decrease in pH during the vermicomposting of sewage sludge. The pH change of different waste mixtures can be attributed to differences in physicochemical characteristics of wastes that used in the process. Initially, all feed mixtures had acidic to alkaline pH, but the final pH of the vermicompost was almost neutral.^[41] These results therefore showed that the pH for all mixes (varying from 7.52 to 7.78) of the vermicomposting materials was well within the normal range (6.5–8.0) for optimum microbial activity and suitable for earthworms (pH range of 5.5–8.5).^[42] In comparison with the pH value of Mauritius standards, which is in the range of 5.5–8.0, the final results on day of 50 were well within the range.^[43] However, since the pH results obtained throughout the experiments were within an acceptable pH range of 6.0–7.5 for the development of bacteria, 5.5–8.0 for fungi, and 5.0–9.0 for the action of actinomycetes, it can be concluded that at any point, the pH in the vermicomposting mixes was not a limiting factor during the experiments.^[44]

The data for the change of TOC with vermicomposting process (30 days) are presented in Table 2. The initial average TOC content in vermicompost beds were 45.75%, 47%, 50.28%, and 58.55% for 1RB:1FW, 1RB:2FW, 1RB:3FW, and 1RB:5FW, respectively. The set of data illustrated from Table 2 indicated that there was an overall decreasing trend in the TOC (28.5% for 1RB:1FW, 37.75% for 1RB:2FW, 42.35% for 1RB:3FW, and 50.21% for 1RB:5FW) throughout the vermicomposting processes as similarly reported by Wang *et al.*^[45] In this study, although there was randomness in

the variation of TOC for all mixes, the ratio of 1RB:1FW demonstrated the most significant and rapid decrease in the TOC, signifying the highest biological degradation of organic matter. It was also possible that the FW mix contained organic matter which was more easily degradable by the microbiological fauna present than in the other three mixes. Stability is related to TOC whereby a higher decrease in TOC means a more stable product indicating that degradation of waste is dependent on earthworm activity.^[46] However, all the three mixes could be said to have undergone sufficient microbial degradation. Inoculation of earthworms in the decomposing of organic waste material promotes biochemical degradation, and their activity also promoted the colonization of decomposer communities of the waste system, this is due to biological stable as well as chemical environmental conditions. Dominguez and Edwards reported that earthworm fragments and homogenizes the ingested material through muscular action of their foregut and also adds mucus and enzymes to ingested material and thereby increasing the surface area for microbial action while microorganisms perform the biochemical degradation of waste material providing some extracellular enzymes within the worm's gut. This combined action between earthworms and microorganisms bring about carbon loss from the substrates in the form of CO₂.^[47]

TN content in the all vermicompost fertilizer was higher than initial waste mixture. In the first vermicompost process, TN content of the waste mixtures was in the range of 0.9–1.25% [Table 2]. Whereas the TN content of vermicompost was in the range of 0.95–1.62%. Results of Figure 3 show that the greatest increasing in TN was achieved in the ratio of 1RB:3FW (40%) and the lowest was for 1RB:1FW (5%). The present study indicated an increase in TN [Figure 3] of the final products. On an average 300% increase was observed in the TN content of vermicompost. This increase was attributed to the relative increase in nitrogen on loss of dry matter as CO₂, water loss during mineralization, N addition through feedstock substitution and in the form of mucus, excretory substances from the earthworm which were not initially present in the feedstocks.^[48] Significant differences in TN were also observed among the treatments [Figure 3] with the maximum of 1.62% recorded for 1RB:5FW followed by 1RB:3FW (1.49%), 1RB:2FW (1.35%), and 1RB:1FW (0.95%). This was due to difference in C/N ratio of feedstock mixture, the initial TN content of the feedstock, and the extent of decomposition.

The C/N ratio plays a critical role in cell synthesis, growth, and metabolism of earthworms. For proper nutrition, carbon and nitrogen should be present as substrates in appropriate and correct ratio. C/N ratio is one of the most important indicators of waste stabilization, which is widely used in the index for compost maturation. The C/N ratio as a function of time is an essential indicator widely used for the assessment of the effectiveness of a vermicomposting

process and reflects the organic waste mineralization and stabilization during decomposition of organic matter. The variation in the C/N ratio with time in different beds during vermicomposting is shown in Figure 4. In the present study and as evident from Figure 4, C/N ratio was significantly reduced from 30.12 to 17.84 for 1RB:1FW, 28.35 to 16.72 for 1RB:2FW, 28 to 17 for 1RB:3FW, and 27.1 to 18.54 for 1RB:5FW that indicating a high degree of stabilization in all the feed mixtures. The value of C/N ratios depicted an overall decrease of 29.4–37.6% in all the waste mixtures after 30 days of earthworm activity after the precomposting process. Gupta and Garg showed a decrease of 58–85% in the C/N ratio in the vermicomposting of primary sewage sludge using *E. foetida* and Paul *et al.* observed a reduction of the C/N ratio of up to 37.13% in the vermicomposting of municipal solid waste with *Perionyx ceylanensis*.^[35,49] This hardly corresponded with the values of this study. The significant decrease in the level of the C/N ratio of the substrate could be attributed to carbon loss through CO₂ produced in the process of microbial respiration and addition of nitrogen by inoculated *Eudrilus eugeniae* in the form of mucus, enzymes and nitrogenous excrements as similarly reported by Suthar.^[50] Gupta and Garg stated that vermicomposting processes involved in a sharp decrease in C/N ratio and the similar pattern of C/N ratio correlated with the earlier study.^[35,51] According to the Mauritius Standards, a C/N ratio in the range of 15–25 indicates an advanced degree of the stabilization of organic matter and reveals a satisfactory degree of maturity of organic wastes. Thus, in this research, a high degree of organic matter stabilization was achieved in all the beds.^[39] This concluded the role of *E. eugeniae* in much more rapid decomposition and rates of mineralization of organic matter. Nair *et al.* stated that C/N ratio is the parameter to determine the degree of maturity of compost and to define its agronomic quality.^[52] However, according to Morais and Queda, C/N ratio <20 is indicative of an acceptable maturity while ratio ≤15 is being favored for the use of composts in agronomy.^[53] The greater decrease in the C/N ratio in the cow dung added vermicomposting treatment may be due to more increase in earthworm population that results rapid decrease in organic carbon and simultaneous increase in nitrogen.^[54] The vermicomposts obtained in this study showed that the C/N ratio was within the preferable limit.

CONCLUSIONS

The study showed that the greater amount of RB in beds turns out higher temperatures in composting process, which is the safer removal of microorganisms, especially pathogens and parasites. The amount of TN (increase), C/N (decrease), TOC (decrease), and pH (alkaline) in all the final fertilizer was in standard level and desirable. Integrated approach of composting and vermicomposting processes provides better results by combining both

processes. From the data generated in the present investigation, it is evident that vermicomposting can endorse to be an effective and sustainable technique to reduce the quantity of FW that needs to be sent to the landfill. The results of this study showed that composting and vermicomposting processes can be used as a potential tool for bioconvert RB and FW. However, it is suggested that RB can be amended with FW to ensure better quality of vermicompost.

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Conflicts of interest

There are no conflicts of interest.

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