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Conversion of Leather Industry Solid Waste to Organic Fertilizer by Vermicomposting: Use for Plant Growth

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ABSTRACT
The generation of leather industry solid waste is a matter of concern for its potential polluting ability. This study assessed vermicomposting of leather industry-generated lime flesh and shaving waste through a mix with cattle dung using Eisenia fetida earthworm, aiming at sustainable reuse in agriculture. The chromium content of shaving waste was optimized to under 2 mg/kg using hydrogen peroxide with potassium carbonate treatment. The lime flesh was treated with hydrochloric acid treatment. Treated shaving waste and lime flesh were mixed with cattle dung in a proportion of 1:1 and 2:1 in different vermicompost fields. After 30 days 40 Eisenia fetida were introduced in each field and vermicomposted for 90 days within a moisture of 50%. The number of earthworms increased in the 1:1 portion of vermicompost. The number of earthworms, pH, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), carbon and nitrogen ratio (C: N), total potassium (TK) and total phosphorus (TP) readings was taken at 0, 30, 60 and 90 days respectively. Composting resulted in a significant reduction of pH, and TOC. A reduction in C: N ratio by approximately nine-fold and an increase in TKN and TP was observed. A slight reduction of TK was also observed. The results indicated that the earthworm Eisenia fetida has been able to convert the lime flesh and shaving waste into nutrient-enriched fertilizer products in the same proportion of waste and cow dung. The vermicompost was applied on the Napier grass plantation and the accumulation of heavy metal effect on plants was investigated for eco-friendly plant growth. The composts and plants' different parts were analysed for heavy metals. It was found to be under the permissible limits recommended by WHO. The vermicompost enhanced the organic matter significantly and nutrients were improved for better crop yield.

KEYWORDS
earthworms, vermicomposting, organic fertilizer, plant development, waste management

INTRODUCTION

The leather processing uses 1000 kg of raw material to obtain only 200 kg of the usable leather finished product. The solid and liquid waste includes about 250 kg of non-tanned solid waste, 200 kg of tanned waste, and 50,000 kg of wastewater effluent. The total raw material processed yields only 20% of finished leather products and more than 60% of solid and liquid waste containing the highly carcinogenic heavy metal chromium [1,2]. According to a comprehensive computation of mass balance and efficiency of leather manufacturing in a conventional process, only about 50% of corium collagen and less than 20% of the chemicals used are retained in the finished leather [3]. The 'zero waste' concept involves the reuse of organic residues produced from agriculture, municipal and industrial waste as a resource rather than the treatment or disposal of the waste [4]. Currently, several studies have been conducted on the 'zero waste' concept through recycling to convert the value added to waste [5].

Biological processes have been widely recognized in converting organic materials into nutrient-rich fertilizers and soil conditioners through composting and or vermicomposting [5]. The earthworms eat the organic residues and transform the nutrient-enriched compost to aid the waste stabilization process that can be used as a substrate for plant growth. This process involves symbiotic interaction between earthworms (e.g., *Eisenia fetida*, *Eudrilus eugeniae* and *Perionyx excavatus*) and microorganisms to produce a stable, homogeneous and humus-like end product known as vermicompost [6]. In general, vermicompost is physically, nutritionally and biochemically improved over traditional compost because the mineralization rate of organic matter is accelerated and a higher degree of humification is obtained [7,8].

Sustainable conversion of the leather industry's solid waste to bio-compost fertilizer is one of the great solutions for tannery yard solid waste management. The potential for recycling should be exploited by ensuring the segregation of waste. It is equally important to the commercialization of waste as by-products and cooperation between tanners to make recycling and re-use options economically feasible [3].

The lime flesh is generated as solid waste from the tanneries. It is one of the low molecular weight-containing proteins that are not properly utilized for constructive applications. Fleshing is 35% on the wet weight of the raw hides with 80% moisture. The lime flesh emanating from tanneries can be subjected to bio methanation, glue manufacture, enzyme, protein, and animal feed production. However, fleshing is a rich source for the production of organic manure that has a very high utility in the agricultural sector. Therefore, fleshing is not commercially feasible for manufacturing glue and gelatine due to the low molecular weight of protein [9].

The splits obtained during the splitting operation are very thin in substance and cannot be utilized. As a solid waste, chrome splits account for 4–6% of total waste. They are collected and used as raw materials in the leather board industry. In most of the chrome waste, the chrome content of Cr_2O_3 is found to be 2.0-2.5% [10].

The chrome shavings are small, thin pieces of leather formed during the shaving operation. It accounts for chrome shaving is almost 10% of the weight of raw material processed [11]. Currently, this waste is collected by feed manufacturers, steam treated and converted into a leather meal. The current purpose of collecting chrome shavings is mainly for utilizing themes of the leather meal. It is hydrolysed similarly to poultry feeds and used as a supplemental protein source for livestock [12].

Few studied the application of vermicompost on plants and its potential use in plant growth. The addition of vermicompost significantly increased shoot biomass by 78% and root biomass by 57%. It was found, that vermicompost increases soil fertility and the growth of the plant. In vermicomposting the active component is involved in the biodegradation and conversion process. The resident microbial community, among fungi, plays a very important role [13,14].

Vermicomposting or bio-composting is one of the viable, simple, and economical processes by which organic solid wastes can be efficiently managed by converting them into organic manure/soil conditioners. Earthworms or anaerobic biodegradation can be used for solid waste management, organic matter stabilization, soil detoxification, and vermicompost production. The research aimed to convert the leather industry's solid waste into valuable organic fertilizer through vermicomposting. The Eisenia fetida was used as a vermicomposting agent. Several studies on vermicomposting or biodegradation including food, agriculture, etc. have been conducted. However, to the best of our knowledge, there is no published report on the leather industry's shaving and fleshing waste conversion to fertilizer through vermicomposting.

EXPERIMENTAL

Materials Collection

Limed animal fleshing (ANFL) and Chrome shaving waste were collected from tanneries situated in Hemayetpur, Dhaka, Bangladesh. Cow Dung was collected from local firms. Earthworm *Eisenia fetida* was collected from Haluaghat, Mymensing, Bangladesh. The raw ANFL was kept at less than 4 °C in a refrigerator and the shaving dust was kept in an airtight place. The Napier Grass cuttings were collected from Porshuram, Feni, Bangladesh, and tubs were prepared from water bottles. The cuttings were kept in a warm and humid place to start germination.

Chemicals

All chemicals (E. Mark Germany) of analytical grade were used in the experiment. The hydrochloric acid, Potassium carbonate, sulfuric acid (98% concentrate), Hydrogen Peroxide, ferrous sulphate, orthophosphoric acid (90% concentrate), potassium iodide, ferrous sulphate, sodium thiosulphate, 0.1 N standard volumetric solutions, and the starch indicator were used in experiment and testing.

Equipment

The pH of the solution was investigated by using a pH meter (HANNA Instruments). Grinding of fleshing and shaving waste was carried out by an electric grinding machine and ground to 1-2 mm size. All required shaking was performed by a shaking machine (SK-L330-Pro, DLAB). A soil nutrient detector

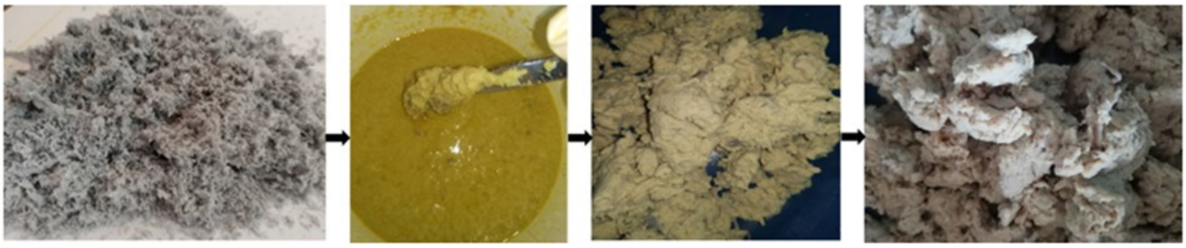
(Shandong Hengmei Electronic Technology Co., Ltd, HM-GT 3) was used to investigate the nutrient of the vermicompost fertilizer. An Atomic Absorption spectrometer (PerkinElmer, PinAAcle 900H) was utilized to analyse the heavy metal on the vermicompost and plant after digesting the sample with concentrated HNO_3: concentrated $HClO_4$, 4:1, v/v). Digestion protocols were as follows: vermicompost, soil and vegetable samples were dried in an oven and taken one gram of the sample and sieved for fine particles. The 0.5 g of sieved sample was mixed with 10 ml of HNO_3 (70%) and maintained at 80 °C for 1 hour, and 100 °C for 2 hours respectively with aided reflux apparatus and fume hood. The 5 ml of $HClO_4$ was added and heated for 2 hours at 150 °C. The digested solution was then diluted into deionized water and 25 mL was filtered and put in a vial bottle, ready to test AAS. The Fourier-transform infrared (FT-IR) spectra of treated waste and composted organic fertilizer were obtained in the frequency range 4000–500 cm^{-1} on a Bruker (Alpha II) FT-IR spectrometer equipped with spectrum software. Thermogravimetric analysis (TG) was performed, using a Thermogravimetric analyser (PerkinElmer, TGA 8000) apparatus recording TG. TG was carried out in the temperature range from 50 to 700 °C under a nitrogen atmosphere at a heating rate of 10 °C/min.

Experimental Methods

Cattle dung, Raw ANFL and Chrome shaving waste were the main materials for this experiment. Collected Cattle dung was dried in the sun for 10 days and dried cattle dung was kept for further operations. Dried cattle dung was ground and kept in a dry place for further use.

Treatment of Limed Flesh

Raw limed flesh was collected from the commercial tannery processing industry. Fleshing was washed in plentiful water to eliminate the adhered dirt and capillary-deposited lime. The washed fleshing was treated with 10 ml in the 1-litre hydrochloric acid solution for about 4–6 hours to remove sulphide and calcium salts, followed by chopping them into small pieces. The pieces were washed thoroughly in tap water and finally dried and ground by an electric grinding machine. The ground powder was stored at 4 °C until the start of the experiments.



a) b) c) d)

Figure 1. The flow chart of chrome leaching treatment. a) Chrome shaving waste, b) Treating with potassium carbonate and hydrogen peroxide, c) Shaving waste after the second treatment, d) Treated shaving (collagen) waste

Treatment of chrome shaving

It is necessary to perform Chromium removal without destroying the protein required for the usage of shaving dust as a raw material for vermicomposting. The removal flowchart is shown in Figure 1. In detail, shaving waste was obtained from the tannery and mechanically ground to 1-2mm size. About 1 kg of shaving dust was taken and divided into 3 equal parts. Part-1 of shaving dust was mixed and submersed in freshly prepared 1.5 Litre of 10% solution of potassium carbonate with 60 ml of 30% hydrogen peroxide leaching solution. Then washed for 40-45 minutes at 25 °C with occasional stirring in 3-5 minute intervals. After washing was finished, the leaching solution was separated from the leather protein using a filtration cloth. The separated solution was reused in the same procedure adding 60 ml of 30% hydrogen peroxide for the part-2 and washing in the same way. The separated exhausted leaching solution was then acidified with pH-6 with 38% sulfuric acid. The solution can be used in chrome tanning baths.

Part-1, part-2 and part-3 are then put together and washed with freshly prepared leaching solution using the same way as described above. Then, the exchange with collagen pressed out and rinsing with water was repeated two more times in the same way until the chrome content was brought to 2mg/kg. The filtered solution was stored in a vessel. After that, a 10% solution of ferrous sulphate was added to the used rinsing water until a pH of 7 is reached. Then the collagen was separated by a filter cloth.

EXPERIMENTAL DESIGN OF VERMICOMPOST

Five plastic bowls of 10 L capacity were taken for vermicomposting experiment. The details of feed composition in different vermicompost fields are as follows: field no. 1: 1000 g of dried cow dung was taken as a reference; field no.2: 500 g of cow dung + 500 g of treated fleshed waste; field no.3: 500 g of cow dung + 500 g of treated shaving waste; field no. 4: 300 g of cow dung + 700 g of treated fleshed waste; field no. 5: 300 g of cow dung + 700 g of treated shaving waste. The mixer was homogeneously mixed properly and sprayed water to maintain moisture above 70%. Then the mixture was turned manually every day and kept for 30 days with maintaining proper moisture and regular stirring of mixtures in dark. Each field was covered with jute cloth for protection from light. Samples from five mixtures were systematically collected in zip poly bags to determine different nutrient parameters like TOC, TKN, TK, and TP (stage 1). After 30 days, when the bedding reached a suitable pH, earthworms were introduced to the mixtures. The number of earthworms released was 40 for every bowl field and same time samples from every field were collected (stage 2). After 30 days, samples were collected for the third time (stage 3) simultaneously. Cocoons were checked and counted in the mixtures. To ensure proper breeding and bedding, mixtures were transported to earthen pots. Proper care was taken for the next 30 days and then samples were collected (stage 4). After 90 days, (stage 5) vermicompost was sieved and the number of worms was counted. Then the sieved compost was dried and weighed separately.

EXPERIMENTAL DESIGN ON PLANT GROWTH

The resultant vermicompost was applied to Napier Grass growth. The shoot (stem) development, leaves area increase, dying rate of leaves, root branching, and root area increase were observed. The observation was carried out for 45 days and then the leaf, stem, and root were tested for the presence of any harmful heavy metals.

RESULTS AND DISCUSSION

The limed fleshing (ANFL) is obtained by employing fleshing machines in tanneries, which are potentially alkaline-denatured. It is not financially feasible to use the same fleshing to make the glue due to the low molecular weight of protein. However, fleshing has a high percentage of sodium sulphide which are unsuitable for making glue. Generally, fleshing is disposed of through a landfill. The disposal of this fleshing is currently a major issue. Fleshing can be pre-boiled to separate the fat from the other ingredients before being used to make tallow. The method for obtaining tallow then proceeds to green fleshing. The quality of the tallow is sufficient for cosmetic purposes, even though the acidity index generally is greater than the index of the tallow obtained from green fleshing [10]. Most fleshing wastes are disposed to land openly risking public health. For that reason, a green solution to this problem should be found and vermicomposting is a sustainable approach. Treated lime fleshing contains 78-80% moister, ash 8.3%, and total nitrogen 15.2% which are suitable for vermicomposting [15].

Chrome shaving dust was washed with a solution of Potassium Carbonate and Hydrogen Peroxide to remove dangerous chromium from it. To convert the chrome shaving to collagen the following reaction might occur:

$$Cr_2O_3 + K_2CO_3 + O_2 \rightarrow K_2CrO_4 + CO_2 \quad (1)$$

The chromium present in chrome shaving dust is in the chromium (III) state and is considered harmless. Under uncontrollable conditions, however, it can conceivably be oxidized to mutagenic chromium (VI). The chromium content in shaving waste before and after treatment was determined by Atomic Absorption Spectrometer. It was found that untreated shaving waste was 148.37 mg/kg and treated 1.95 mg/kg respectively. However, in the five-time washing stage (Potassium Carbonate and Hydrogen Peroxide) chrome content was determined by AAS and found at 30.45, 26.45, 7.40, 5.25 and 1.95 mg/L respectively. The chromium content was under the limit of quantification which was much needed for the study. Excess chromium was removed with a solution as K_2CrO_4 which is more basic and removed by washing.

The higher number of worms indicates that the vermicompost is beneficial for the worms and that nutrition is adequate in the compost. The number of worms is expected to rise to some good margin within the time frame. After 30 days the release of earthworms exhibited different patterns of cocoon production with varying percentages of substrates in the feed mixtures. The cocoon production was found at 319, 310, 308, 65, and 52 in the field-1 (Control), field-2, field-3, field-4 and field-5 respectively. Whereas the number of earthworms released was 40 for every field. The cocoon production in vermicompost fields nos. 2 and 3; was statistically significant with each other with control field-1. If the ratio of cow dung and solid waste is 1:1 cocoon production is statistically significant. The lesser cocoon in field-4 and 5 (cow dung and waste ratio 1:2) exhibits an increase in waste concentration, decreasing the cocoon production in the feed mixture. It was concluded from the results that waste with a cow dung ratio of 1:1 served as a good feed for earthworms. In the five vermicompost fields, the survival rate of earthworms was confirmed by the presence of lethal, which confirmed the leather industry's treated waste is favourable for the normal growth of the earthworms, except for the ratio of 1:2.

a) b) c)

Figure 2. Dried vermicompost fertilizer a) Only cow dung b) Fleshing waste c) Treated Shaving dust

Figure 2 showed the sieved and dried vermicompost after 90 days of composting. It was found control cow dung was 574 gm, treated fleshing (fleshing + cow dung) 426 gm, and treated shaving (shaving dust + cow dung) 446 gm respectively after dried sieved.

In vermicomposting specific species of earthworms are employed to speed up the conversion of the organic waste and create a higher-quality final product. It uses worms and microbes. Vermicompost is created when earthworms consume organic waste, process it through their digestive system, and then release it in the form of granules (cocoons). The earthworm castings include more nutrients that are readily available to plants because of the chemical secretions that help break down soil and organic material [15].

Nitrogenous substances create ammonia gas which increases the pH of the mixture and makes the bedding unsuitable for the earthworms. Earthworms are very sensitive to pH. Out of their suitable pH range, they are dead. For this reason, the regular stirring of the mixture is important so that gaseous substances can come out from the mixture. The moisture content of castings ranges between 32 and 66% and the pH of around 7 was always maintained.

In general, the pH of a worm's bed tends to drop over time. If the worm-food sources are alkaline the effect is a moderating one tending to be neutral or slightly alkaline shown in Figure 3. The results were reproducible within 3–7% error limits. Worms can survive in a pH range of 5 to 9 [17]. Most experts feel that the worms prefer a pH of 7 or slightly higher.

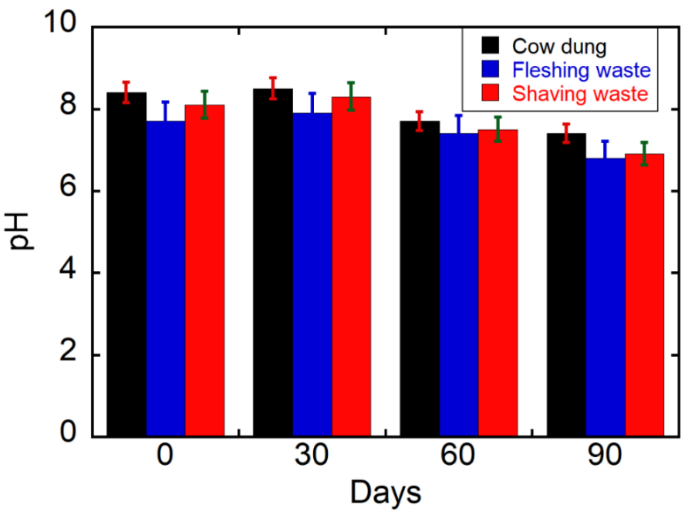


Figure 3. Dried vermicompost fertilizer pH through the composting (vertical bar on the lines shows the error bar for three experimental data)

The pH can be adjusted upwards by adding calcium carbonate. In the rare case where they need to be adjusted downwards, peat moss can be introduced into the mix. pH conditions between 6.5 and 8.6 are suitable for the cultivation of earthworms. However, a decrease in pH was observed over time in all waste (Figure 3), which could have occurred with the dissolution in water of the ammonia resulting from the microbiological metabolism of bacteria present in the substrates or the excrements of the earthworms, as suggested Edward [17].

Data from three vermicompost were taken after 0 and 90 days and the parameters were TOC, TKN, TK, TP, and C/N. All samples were analysed in triplicate and the results were averaged. The results were reproducible within 3–5% error limits. The three vermicompost specimens were also tested for the presence of heavy metals (Cr, Pb, Fe, Ni, and Cu) before the plantation of grass. After plantation, various plant parts of the Napier Grass were tested for any possible uptake of heavy metals from the fertilizers and compared with the minimum standard set by WHO. At the same time, data for growth and other visual observations were collected.

Table 1 shows the Total Organic Carbon (TOC), Total Kjeldahl Nitrogen (TKN), Total Pottasium (TK), Total Phosphorus (TP), and carbon-nitrogen ratio (C/N) analysed nutrient data from 0- and 90-day vermicomposting. The TOC parameter shows organic carbon significant decline, which is in congruence with the other studies' vermicomposting [18,19]. There are two main reasons why TOC decreases after the vermicomposting process: the mineralization of the organic matter (a process that happens when earthworms and microorganisms work together), and the annelids' diet, as they use some of the carbon in their diet to build their biomass. A drop in TOC at the end of the vermicomposting procedure indicates that the original material degraded. However, after the vermicomposting procedure, C/N (one of the most common indices of compost maturation) significantly decreased in all treatments. These findings confirm those of other studies that also showed the acceleration in humidification promoted by earthworms during vermicomposting results in a decrease in the C/N ratio [20]. These findings are related to the decrease in TOC and increase in N concentrations observed after vermicomposting.

Table 1. Nutrient parameter (%) (mean ± SD) analysis of 0- and 90-day vermicomposting (n = 3)

Parameter (weight in %)	Days	Cow dung (%)	Fleshing waste (%)	Shaving waste (%)
TOC	0	21.85±0.508	55.12±2.82	45.11±1.62
	90	12.47±0.06	16.3±0.912	17.27±0.523
TKN	0	0.95±0.05	0.81±0.0321	0.71±0.008
	90	1.45±0.076	1.99±0.042	1.73±0.032
TK	0	0.319±0.015	0.168±0.003	0.468±0.002
	90	0.539±0.032	0.275±0.008	0.281±0.002
TP	0	0.124±0.021	0.275±0.007	0.127±0.002
	90	0.556±0.0424	0.604±0.0142	0.849±0.032
C/N	0	23.65	68.04	63.54
	90	8.6	8.19	9.98

Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4+) in the chemical analysis of soil, water, and wastewater. A significant increase in nitrogen concentration occurred at the end of the experiment in all treatments and those composed of tanning waste of the fleshing and shaving types. At the end of the trial, N concentrations significantly increased in all treatments, particularly those containing fleshing and shaving tanning waste. A linear rise in N concentration was seen as the doses of primary waste and lime were increased in the cattle dung. Even though these statistics do not match with some reports [19], they are consistent with other research that used vermicomposting on substrates other than tanning sludge [18]. The mass reduction during vermicomposting is associated with an increase in nitrogen (N) due to the nitrogenation of the earthworms' by-products and the release of carbon through their metabolic processes [19]. Given that 65–75% of earthworms' bodies are made up of proteins, these substances may originate from excrement, urine (as ammonia and urea), mucus proteins, and the tissues of dead earthworms [19,20]. The higher K concentration observed at the end of the experiment is related to a decrease in volume resulting from the vermicomposting process. These data differ from those studies in which a decrease in K was observed at the end of the vermicomposting process of tanning sludge mixed with cattle dung [18]. This decrease could be related to K consumption by the earthworms [19]. It is important to note that in all treatments, K concentrations were much higher at the end of the trial than they has been at the beginning. This decline could be attributed to the earthworms' consumption of K. However, it might be the high K concentration found at the end of our study is connected to a volume reduction brought on by the vermicomposting procedure.

In the treatments where an increase in P concentration was observed at the end of the experiment, this was probably a consequence of the reduction in volume resulting from the vermicomposting process. A significant decrease in the C/N ratio (which is one of the most traditional indicators of the maturation of a compost) after the vermicomposting process in all treatments was observed. These results are related to the decrease in TOC and increase in N concentrations observed after vermicomposting which corroborates with the results of different studies that also demonstrated that the acceleration in humidification promoted by earthworms during vermicomposting causes a decrease in the C/N ratio [19,20]. In the treatments where an increase in P concentration was observed at the end of the experiment, this was probably a consequence of the reduction in volume resulting from the vermicomposting process. A limiting factor of our study was that the initial and final volumes of the substrates were not measured. However, it was observed that the compost volume of the pots containing tanning sludge of the liming type was smaller at the end of the experiment.

Figure 4 shows the comparison percentage of vermicomposting nutrients. TOC found in the prepared vermicompost was higher than the normal vermicompost and farmyard manure for both fleshing wastes and treated shaving dust. The cow dung is below normal and farmyard vermicompost. TKN, TK, and TP were lower than normal vermicompost for both three composts. The C/N was higher than normal vermicompost in the prepared composts. The normal and farmyard comparison was done with a UNIDO publication [21].

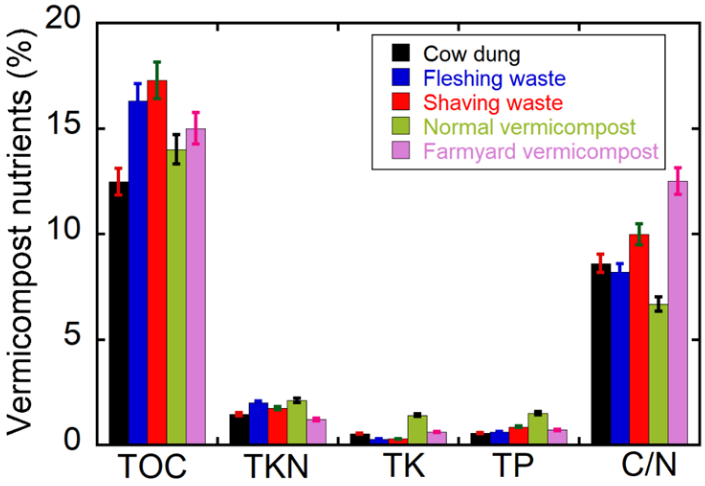


Figure 4. Nutrient comparisons of vermicomposting (vertical bar on the lines shows the error bar for three experimental data)

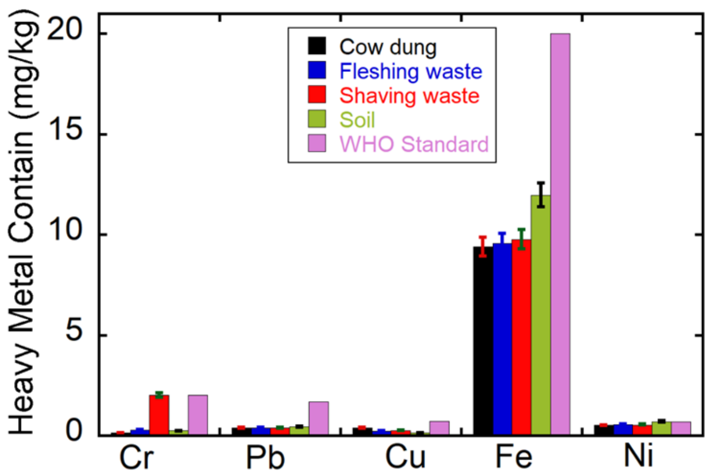


Figure 5. Comparisons of heavy metal in vermicompost (vertical bar on the lines shows the error bar for three experimental data)

The number of worms is expected to rise. Initially, the number of earthworms released was 40 for every bowl. Finally, it was found 319, 52, and 65 in cow dung, fleshing waste and shaving waste vermicompost respectively. More number of worms indicates that the vermicompost is beneficial for the worms and that nutrition is adequate in the compost.

Before the plantation of Napier Grass, the heavy metal Cr, Pb, Cu, Fe, and Ni were determined by AAS of three resultant vermicompost and normal soil.

The comparison chart shown in Figure 5, indicates that the concentration of chromium found in vermicompost as prepared from chrome shaving dust is similar to the standard limit sets by WHO [22]. In the others fleshing and cow dung vermicompost, the heavy metals are found below the permissible limits set by WHO.

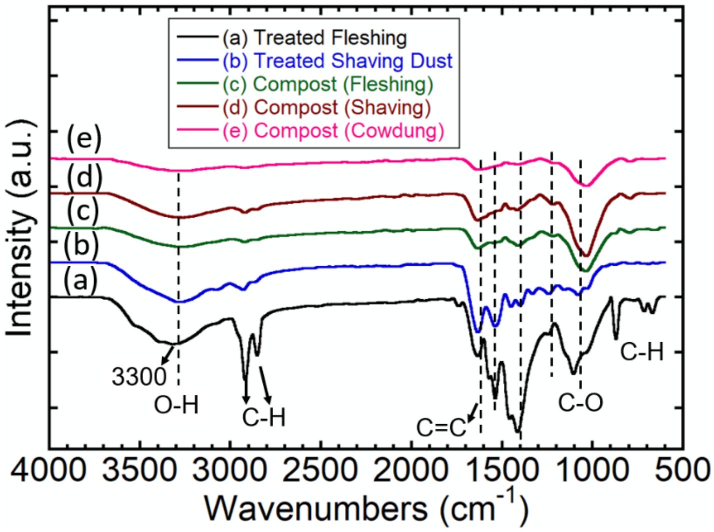


Figure 6. FTIR spectra of (a) Treated Fleshing (b) Treated shaving dust (c) Fleshing compost (d) Shaving Compost and (e) Cowdung compost after 90 days

The FTIR spectra were recorded in the spectral region of 4000–500 cm^{-1} and their frequency assignment was discussed. The FTIR spectra were studied to measure wavelength and intensity which have characteristics of specific types of molecular vibration and stretching that help to identify functional groups of samples on the surface as shown in Figure 6. An intense broad band centred between 3300 and 3500 cm^{-1} indicates a strong hydrogen band of OH− stretch in a carboxylic group which strongly appeared in treated fleshing and shaving dust. A symmetric band at 2925 and 2854 cm^{-1} occurred due to aliphatic C–H group stretching of fatty acids. The highly intense peak of treated waste and compost at 1600 cm^{-1} can be ascribed to the C=C skeletal vibration of compost carbon. In addition, the spectra band from 1070 cm^{-1} can be ascribed to the presence of oxygen moieties, C=O carbonyl groups. Peaks at 2921, 2849 and 700 cm^{-1} have confirmed the presence of C-H (Alkanes) groups in treated waste and compost. Furthermore, Amide bands (I and II) also appeared in the frequency range 1540 and 1230 cm^{-1}, these are originating from amide groups. The above-indicated stretching frequencies are the evidence for the presence of protein, polysaccharides, lipids and fatty acids.

The composting shows a relatively decreasing peak intensity of the aliphatic region at 2925 and 2850 cm^{-1} and of polysaccharides at 1090 cm^{-1}. These results were the evidence for degradation and condensation reactions of organic compounds present in compost mixtures [23]. These aliphatic methylene groups were eliminated during the composting period [24]. On other hand, deformations of peaks were found at 1100 cm^{-1}. A strong reduction in the intensity of the bands of lignin at 1400 cm^{-1}, cellulose at 1420 cm^{-1} and hemicellulose at 1460 cm^{-1} in the final compost. Amide II and III peaks were disappearances in the IR spectrum of compost. This result was closely related to the observations recorded by Ravindran and Sekaran [25]. During composting, the protein containing intrinsic hydrogen bonding structure was disrupted and structures were broken up, at the time those carbonyls and amides were easily consumed. A Sharp nitrate band at peak 1384 cm^{-1} occurs on the final day of composting, indicating stable, reproducible and well-composted or maturity of manure. These results would confirm the complete mineralization of polypeptides, polysaccharides, aliphatic methyl groups and lignin.

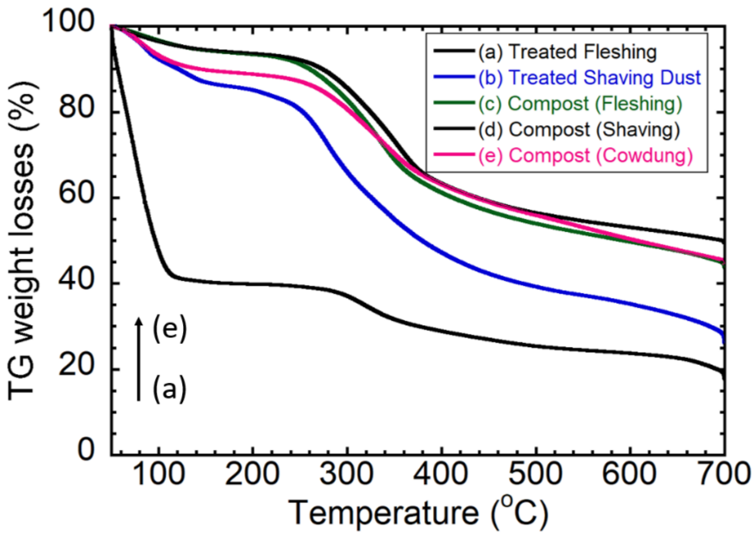


Figure 7. Thermal gravimetric analysis (TGA) of initial (a) Treated fleshing (b) Treated shaving dust and compost (c) Fleshing compost (d) Shaving Compost and (e) Cowdung compost after 90 days

TGA profiles for the initially treated waste and final stages of compost are shown in Figure 7. A weight loss represents the dehydration reaction observed in the temperature range of 50–100 °C treated with initial fleshing and weight sharply losses 60% and finally 80% at 700 °C. The decomposition process occurred in treated shaving waste and compost samples in the range of 200 and 700 °C. The initially treated shaving sample showed a weight loss of 65% dry matter, while it was only 45% in the final compost sample in the temperature range of 200-700 °C. The weight losses at this temperature are attributed to the combustion of carbohydrates and the thermal degradation of aromatic structures. The results support the evidence for the destruction of carbohydrates in mature compost manure. Immature compost was characterized by high carbohydrate components which tend to disappear in the stabilized compost. Weight losses occurring at 310 °C can be associated with the thermal degradation of proteins and also the thermal degradation of cellulose catalysed by sodium and potassium [26].

The four tubs were filled with vermicompost and tagged as soil (S), treated shaving dust (TSD), cow dung (CD), and Fleshing (F). The first tub was filled with 1 kg of sandy loam soil as a reference. The second tub was filled with 0.5 kg of soil and 0.5 kg of shaving dust vermicompost (1:1 proportion). The third tub was filled with 0.5 kg soil and 0.5 kg cow dung vermicompost (1:1 proportion). The fourth tub was filled with 0.5 kg soil and 0.5 kg fleshing vermicompost (1:1 proportion). The soil and compost were mixed evenly before filling the tubs. Two healthy Napier Grass cuttings were planted in each tub, in such a way that at least one knot is under the soil and one is above the soil. Adequate water was sprayed and the tubs were placed in the same condition of light and air available for each tub. When the cuttings seemed to be spirited, then one cutting was removed from every tub, and observation was carried out on one cutting.

The cuttings were watered every day in the morning and the afternoon and observed for 45 days. The observations were carried out in two stages. In the first stage, the leaves were measured for 30 days with a gap between each observation of at least 2/3 days. Then the plants were cut. After further germination, the second stage started and the leaves were measured for 15 days in the same way. The growth rate was found fastest in cow dung and faster in Shaving dust as shown in table 2.

Table 2. Measurement of leaf area increment (mean±SE) of 30- and 45-day vermicompost

Day	Shaving Dust (cm)	Fleshing Waste (cm)	Cow Dung (cm)	Soil (cm)
30 (1st stage cutting)	39.5±1.185	37.0±1.125	41.0±1.23	37.0±1.126
45 (2nd stage cutting)	35.5±1.025	18.5±0.37	20.0±0.6	16.5±0.51

A linear increase in leaf area was observed in the Napier grass which was cultivated using shaving dust compost. But in the end, cow dung provided better nutrition and so the increasing rate of leaves of the latter one sailed the former one. The growth rate of plants in the fleshing waste was lower than in shaving dust. The deficiency of nitrogen in the fleshing waste can be the reason for lower growth as nitrogen plays a significant role in plant growth.

The rate of death was found higher in the soil and lower in the cow dung compost. This is because the soil nutrition was not available which was necessary for the plant. As the composts were treated specially to make them able to provide nutrition, the plants live longer. The other reason can be the limitation in choosing healthy cuttings. Also, root development was found higher in cow dung for the same reason. So, the prepared composts were more suitable for plant growth than soil singly.

High levels of heavy metals are released into the surface and groundwater, soils, and the biosphere by human activities such as industrial production, industrial pollution, mining, transportation, and agriculture. The possibility of food contamination through soil root contact makes the buildup of heavy metals in crop plants extremely concerning. Despite not being necessary for plant growth, heavy metals such as Cr, Cd, Pb, and Ni are easily absorbed and accumulated by plants in poisonous forms. Vegetables cultivated in heavy metal-contaminated soil and irrigated with wastewater may pose a risk to both human health and wildlife. Metal bioavailability to plants is significantly influenced by the number of heavy metals in the soil solution.

Table 3. Heavy Metal analysis in plants body after 30 days 1st stage cutting of one sample

Vermicompost	Sample	Cr (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Ni (mg/kg)
Soil (S)	Leaves	0.033	0.411	0.039	2.528	0.358
	Stem	0.046	0.456	0.063	2.871	0.412
	Root	0.046	0.456	0.029	2.802	0.401
Treated shaving dust (TSD)	Leaves	0.067	0.064	0.078	2.201	0.507
	Stem	0.110	0.181	0.058	1.829	0.508
	Root	0.260	0.335	0.065	1.850	0.510
Cow dung (CD)	Leaves	0.035	0.322	0.047	2.517	0.417
	Stem	0.045	0.318	0.091	2.850	0.588
	Root	0.041	0.382	0.095	2.701	0.501
Fleshing (F)	Leaves	0.024	0.337	0.106	2.498	0.439
	Stem	0.036	0.327	0.168	2.504	0.494
	Root	0.049	0.401	0.170	2.302	0.321
WHO-FAO Standard		1.3	2.0	10.0	20.0	10.0

The plants which were grown using vermicompost prepared from tannery wastage can also bio-accumulate heavy metals from used soil or fertilizers which can be bio-transferred to animals or humans. Therefore, the samples were analysed separately for their root, stem and leave using AAS after 30 days (1st stage cutting) and 45 days (2nd stage cutting) respectively. The concentration of heavy metals reduced significantly in the second stage than in the first stage. The concentrations of heavy metals in soil, fertilizer, and plant body are also compared with WHO standards are shown in table 3.
The permissible limit of chromium for soil and plants is 1.30 mg/kg recommended by WHO [22]. The intake of chromium from soil or fertilizer to the plant body proved negligible. In the root, stem, or leaves of the plant Napier grass, the concentration of chromium was found far below the permissible

limit and ranges from 0.26 mg/kg to 0.011 mg/kg. The intake rate decreases with the lifetime of the compost.

The permissible limit of lead for soil and plants is 1.7 mg/kg recommended by WHO [22]. In the composts and soil, the concentration of lead was below the permissible limit which ranges from 0.452 mg/kg to 0.367 mg/kg. In the leaves, roots, and stems of Napier grass, the concentration of lead was recorded far below the permissible limit for shaving dust, fleshing waste, and cow dung compost as well as for soil. The concentration ranges from 0.456 mg/kg to 0.051 mg/kg.

The permissible limit of copper for soil and plants is 10 mg/kg or 0.72 mg/L recommended by WHO [22]. The concentration of copper was found below the limit in the soil and composts which were between 0.385 mg/kg and 0.147 mg/kg. The accumulation of copper in the body of Napier grass was negligible and ranged between 0.039 mg/kg and 0.168 mg/kg.

The permissible limit of nickel sets by WHO is 10 mg/kg for soil and plants [22]. In the composts and soil concentration was below the limit and ranges from 0.707 mg/kg to 0.516 mg/kg. In the plant's body parts, the concentration was found between 0.508 mg/kg to 0.358 mg/kg.

The standard limit of iron for soil is 20 mg/kg; for plants, 4 mg/kg is recommended by WHO. The concentration is found below the permissible limit in the composts and soil. The uptake of iron from soil to the plant bodies was small and ranges below the permissible limit according to WHO.

Heavy metals over their standard values are hazardous to human, plant, and animal life, hence this issue needs to be addressed. A study was conducted to evaluate the quantities of heavy metals in used soil, fertilizer, and grown plants.

The amount of industrial solid waste is increasing and is a significant contributor to the global waste issue. Waste management and waste treatment techniques are crucial for this reason. Hazardous waste is handled more precisely than other types of waste because it could seriously harm the environment. The majority of hazardous waste is managed following national legislative regulations, just like municipal waste. For issues like operating permits for the handling, storing, or disposal of hazardous waste, requirements are established. Waste can be treated or disposed of using a variety of methods, including (i) recycling waste, (ii) treatment, (iii) storage and (iv) disposal procedures. The vast majority of by-products from numerous industrial processes that were formerly regarded as waste are now seen as "new raw materials." According to their composition, the solid wastes generated by various sectors are divided into several categories. Even though different treatment techniques are used following legal requirements, disposal costs are still rising. Out of all the possible waste types, fleshing and shaving were chosen for this study which can be further added.

CONCLUSION

The main goal of this research was to utilize tannery waste through vermicomposting and apply it to Napier Grass growth to study the effects of the composts on plant growth. Also, it was important to assess the concentration of some toxic heavy metals in the prepared composts, soil and the plant's body (root, leaves, and stem). It can be concluded that decreasing in TOC and C/N ratio, as well as increases in TKN, TK, and TP, are indicators of good organic fertilizer. Decreasing TK in shaving dust compost will be a topic of further improvement. The comparison data chart shows that the studied vermicompost has properties almost similar to typical vermicompost as well as bacterial compost. The composts were analysed for the presence of heavy metals (Cr, Pb, Cu, Ni, and Fe) and the metal concentration was found below the permissible limits recommended by WHO. The growth rate of plants was also satisfactory and plants were not affected by any disease. The plants' body parts (leaves, stems, and roots) for different composts and soils were analysed separately for any accumulation of heavy metals. The results have shown that the concentration of heavy metals in each sample was below the standard limits recommended by WHO. Therefore, the study revealed all the properties of standard vermicompost and shows positive effects on plant growth without any toxic metal contamination in the plants' body parts. The manufactured vermicompost can be used as a bio-compost fertilizer or as a substitute for expensive inorganic fertilizers.

Author Contributions

Conceptualization – Abdulla-Al-Mamun M, and Hossain N; methodology – Abdulla-Al-Mamun M, Hossain N; formal analysis – Abdulla-Al-Mamun M, Hossain N, Hossain M I; investigation – Hossain N, Hossain M I, Sultana R; resources – Abdulla-Al-Mamun M, Hossain N, Hossain M I, Sultana R; writing-original draft preparation – Abdulla-Al-Mamun M, Hossain N, Hossain M I, Sultana R; writing-review and editing – Abdulla-Al-Mamun M; visualization – Hossain N, Hossain M I, Sultana R; supervision – Abdulla-Al-Mamun M. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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