BRIEF REPORT

Composting treatment of fur waste originating from tannery
[version 1; peer review: 1 approved, 1 approved with reservations]

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Abstract

The tanning industry generates effluents with a high contaminant load represented in a considerable amount of liquid, solid, and gaseous waste. Solid waste, such as residual hair, fat, and meat, are dumped directly in landfills, triggering serious environmental problems. The objective of this research was to compost this waste, previously desulfurized, in a mixture with remnants from pruning as a bulking agent. This low-cost strategy may reduce the total amount of waste.

A composting pile was created using residual hair and pruning remnants in a proportion of 3:1 (w/w) and then an inoculum was added. The waste degrading process ran for 141 days, followed by a maturation period of 64 days. Throughout the process, the temperature, moisture, pH, and electrical conductivity (EC) were monitored. The highest temperature reached was 69.7°C, which secured good disinfection. The EC was 0.27 dS/cm, having lower values than Spanish regulations, possibly due to the salt removal over the irrigation periods. The organic matter content decreased continuously, to reach an endpoint of 42%; this result agrees with the high organic matter content of the tannery waste and the pruning remnants. Germination index was 43.55%, which indicates the presence of phytotoxic substances. As compared to the initial value (10.73%) there was partial degrading of these substances. The challenge is to improve this parameter by identifying new mixtures and adding efficient microorganisms that help to degrade phytotoxic substances.

Keywords
compost, tanning, waste
Introduction

Modern society has to address a broad suite of sustainability challenges in urban and rural areas. The tanning process converts the skins of bovine animals, sheep, and pigs into leather, ready to be used for various purposes. Tannery operations are divided into four processes: riverbank, tanning, post-tanning, and finishing. From an environmental standpoint (cleaner production), the first two processes are important for the volume and pollutant load of effluents, while the last two account for the amount of solid wastes and solvent emissions generated in different operations that yield finished leather. Of the total weight of the skins entering the tannery, 60% is eliminated. In Tungurahua province, Ecuador, it is estimated that out of the 920,000 cattle headcount, 500,000 skins are treated in tanneries yearly.

This study proposes, through a desulfurization process, to reduce the sulfide concentration in these residues, and then take advantage of their nutrients (organic matter and nitrogen) to carry out a composting process. As a result, a stabilized product, compost, will be obtained. In order to improve the C/N ratio, the pellet residues will be mixed with pruning remnants. Specifically, this study addresses the following objectives: (i) characterize the fur waste, (ii) build and test a desulfurization system for the fur waste, (iii) identify the appropriate percentage of fur and pruning remnants, (iv) establish the appropriate composting system, and (v) determine the quality of the compost.

Methods

A total of 576 kg of fur residues was obtained from the tannery “EL ALCE leathers” located in Guano canton, Chimborazo province.

Desulfurization consisted of catalytic oxidation of sulfide containing residues with compressed air and magnesium sulfate (ALMACEN EL AGRO, Riobamba-Ecuador), 0.4 g/kg of pellet of fur. Sulfur determination was carried out according to APHA 4500-S2F protocol. Duration of the operation was 5 h in accordance with the protocol. With this process, the removal of sulfur was accomplished by converting it into sulfuric acid and reducing sulfur dioxide emissions.

Physical-chemical analysis enabled the evaluation of chemical oxygen demand (COD) and sulfide concentration in fur residues (meat, grease, and hair) and of fur water. We determined COD according to APHA 5220 D protocol.

Previously desulfurized fur residues were dried and crushed (to a size ranging from 1 cm to 5 cm) and mixed with crushed pruning remnants according to CCIA 2013. pH and electrical conductivity were measured for solid/water ratio of 1:10 (w/w) at each turning using glass electrode (Model Seven2Go Advanced Single-Channel Portable pH Meter, Mettler, Toledo). Potassium was determined according to the method described in Navarro et al. Humidity was measured gravimetrically in an oven at 105 °C for two hours to constant weight. Phosphorus was determined by spectrophotometer (UV5, Mettler Toledo, USA) at 440 nm according to AOAC 958.02/960.02 protocol. Total nitrogen was determined according to AOAC 955.04 protocol.

In order to accelerate the composting process, an inoculum was prepared with a mixture of mature compost (2.5 lb.), chicken residue (2.5 lb.), pork slurry (10 L), and molasses (2.5 L) coming from collection center of the Escuela Superior Politécnica de Chimborazo. With the conditioned waste, a 2.5 m × 2.5 m × 1.5 m pile was assembled. Three parts of fur were used for one part of pruning remnants; the homogeneous mixture was placed into a 100-liter tank for fermentation for 24 hours.

In the initial and final samples (after 2 months of maturing), in addition to the parameters listed above, germination index (GI) were determined according to Moreno and Moral 2011, using radish seeds (Raphanus sativus) (supplier: El Agro Riobamba-Ecuador) to establish the maturity of the obtained compost; briefly: GI is calculated from the ratio of germinated seeds and the root length of radish seeds in an aqueous compost solution.

Results and discussion

Sulfides were reduced by 23.7% (Table 1). This percentage could increase by extending the duration of the desulfurization process.

The waste degradation process lasted for 141 days, followed by a maturity of 64 days. The stack showed a reduction in volume, size, and odor, indicative of the decomposition of the materials used, including residual hair, as previously observed by Numpaque and Viteri. One important parameter to highlight is the rapid increase in temperature, reaching maximum values of 69.7°C (Figure 1), which ensured a good disinfection process.

The moisture content varied from 45 to 65%, which is considered as optimal. We found slightly alkaline medium, with an average final pH 7.94. The amount of organic matter

| Parameter | Initial values (mg/L) | Final values (mg/L) | Method |
|-----------|-----------------------|---------------------|--------|
| COD       | 9800                  | 3370                | APHA 5220 D |
| Sulfur    | 4936                  | 3767                | APHA 4500- S2F |
decreased to 42%, and this data is consistent with the Spanish Standard Royal Decree 506/2013 on fertilizer products. Contents of total N (3.62%), P (0.31%), and K (0.39%) of the matured compost were higher than those obtained in composting processes of waste materials with wastewater from the tannery industry, which present values of 1.36%, 0.001%, and 0.23%, respectively. Reported electrical conductivity (EC) values of 0.27 dS/cm were below the Spanish Standard; this is possibly due to the salts washing off over irrigation periods. It is preferable for the compost to have low EC values, since the presence of salts in high concentrations inhibits plant growth.

To establish the maturity of the compost, the GI value was determined using Radish seeds (Raphanus sativus). In the final compost, GI was 43.55%, a value that indicates the presence of phytotoxic substances. Nevertheless, if we start from the assumption that GI of the pile at zero time has been 10.73%, a clear decrease of these substances is evident. The increase in GI is an indication of the degree of maturity of the compost.

**Conclusions**

The quantity and type of nutrients in this compost allowed the rapid growth of microorganisms, while recording thermophilic temperatures close to 70°C, which guaranteed an adequate hygiene of the product. Based on the contents of organic matter, in accordance with the Spanish Standard Royal Decree 506/2013, it was assessed that the obtained compost belonged to Group 6. Organic amendments, No. 2, Annex 4 ‘Waste of Leather Industries, of the Skin and Textile’, indicates that with

![Figure 1. Temperature variables. Orange: average temperature (°C) in the compost. Blue: average temperature (°C) of environment.](image1.png)

![Figure 2. Organic matter % in the compost.](image2.png)
an adequate control of the composting process, parameters of an acceptable product can be obtained, in relation to the pollutant load. Considering that the initial germination index was 10.73% and the final 43.55%, it can be concluded that there was a partial elimination of phytotoxic substances. The challenge is to improve this parameter by looking for new mixtures and inoculating efficient microorganisms that allow these substances to be degraded. At present, the compost obtained could be used in restoration projects of deteriorated and soils poor in organic matter, or as cover material for sanitary landfills.

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**Data availability**

**Underlying data**

Figshare: *Average Pile temperature*, https://doi.org/10.6084/m9.figshare.11753187.v1

Figshare: *Physical Chemica, Seeds*, https://doi.org/10.6084/m9.figshare.11755182.v1

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).
Open Peer Review

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The manuscript deals with a very relevant problem. However, the introduction needs elaboration. In the last decade, several works on "composting and vermicomposting" of tannery waste have been reported. Researchers have worked extensively. Therefore, more research citations are needed. The work needs to highlight the novelty of the work as compared to all other works done with tannery wastes.

The study design needs to address a few more parameters in order to be inclusive. Results section needs elaboration. How the compost treatments affecting the growth parameters of radish seeds require proper data or figures to corroborate the findings. Microbial growth also needs to be presented with some quantitative or qualitative assessments. Distinction between beneficial or pathogenic can be the first step. Or, authors can just analyse NFB and PSB population growth following in-vitro methods.

Desulphurization can only be a part of the physicochemical analysis.

Fur industry tannery waste also contains a high amount of Cr-salt / Na ions in the chemical spill. That needs to be verified and compared among the treatment combinations.

The manuscript does not mention statistical analysis. For better understanding and acceptability among the readers, the authors can perform some basic statistical analysis of the data provided, report the t-test or variability among the treatment combinations. A time dependent study can be more comprehensive with proper statistical data. It can be improved using SPSS/ Prism/R.

The source data underlying the results seems reproducible.

With the current results, I think it supports the conclusion. However, as mentioned earlier, addition of some physicochemical parameters will provide the reader a better visibility.
Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Environmental Biotechnology, Bioremediation, Waste management

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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Imre Vágó
Institute of Agricultural Chemistry and Soil Science, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen, Debrecen, Hungary

I read with great interest the article entitled “Composting treatment of fur waste originating from tannery” written by César Puente, Janneth Jara-Samaniego, Alexander Guapulema, and Diego Burbano-Salas in which:
1. authors draw attention on the importance of process industrial waste coming from tanneries;
2. a 141 days (waste degradation) + 64 days (maturing) long compost experiment is described. The study was carried out with the purpose of discuss a low-cost strategy to decompose
tanning industrial waste.

I have found that the paper contains interesting and up-to-date information on the topic about waste management. In that sense, I find that the research finds well within the scope of the journal, and adds new information. However, there are a series of limitations that make me recommend some minor revisions of this manuscript.

**Major concerns:**

- **Introduction should be expanded.**

- The study proposes a comparison between the results obtained at different time points in the composting process, namely: COD, sulfur, Organic matter %. It should be mentioned that only Organic matter was monitored from the mentioned parameters. COD and sulfur values shown at the beginning and at the end of compost process only. It would be more fortunate to compare these parameters. If only at two time points - these parameters (COD and sulfur) were measured, then Organic matter values should be selected at same time points for comparison purposes, if enough data available for further statistical tests.

- Authors concluded that “...Considering that the initial germination index was 10.73% and the final 43.55%, it can be concluded that there was a partial elimination of phytotoxic substances. The challenge is to improve this parameter by looking for new mixtures and inoculating efficient microorganisms that allow these substances to be degraded.” What missing are the authors’ recommendations regarding how to improve germination index according to the observations discussed in the study. Please specify which exact parameters must to be “improved” e.g. in pH value, N ?! etc. in order to improve the germination index.

**Is the work clearly and accurately presented and does it cite the current literature?**
Yes

**Is the study design appropriate and is the work technically sound?**
Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**
Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**
Partly

**Are all the source data underlying the results available to ensure full reproducibility?**
Yes

**Are the conclusions drawn adequately supported by the results?**
Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Alternative (and also traditional) plant nutrition methods, parameters
influencing the effectivity of plant nutrients on different soil types, plant cultures, water supply. Effects of different plant nutrients on the quantity and quality of plant products, furthermore on the chemical and some microbial parameters of soils. Effects of global warming and changing distribution of precipitation on the methods of sustainable plant nutrition.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.