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Nutrient recovery from apple pomace waste by vermicomposting technology

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HIGHLIGHTS

- Earthworms were able to convert apple pomace waste into a value added product.
- The addition of straw to apple pomace did not enhance earthworm biomass.
- The resulting vermicomposts were characterized by slightly acidic to neutral pH.
- The total content of nutrients increased during vermicomposting.

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ABSTRACT

The present work was focused on vermicomposting apple pomace waste and its mixtures with straw in volume proportions of 25%, 50%, and 75%. The feasibility was evaluated on the basis of agrochemical properties and earthworm biomass. Vermicomposting was able to reduce the weight and volume of the feedstock by 65% and 85%, respectively. The resulting vermicomposts were characterized by slightly acidic to neutral pH (5.9–6.9), and optimal EC (1.6–4.4 mS/cm) and C:N ratios (13–14). The total content of nutrients increased during vermicomposting for all of the treatments with the following average final values: N = 2.8%, P = 0.85%, K = 2.3%, and Mg = 0.38%. The addition of straw to apple pomace did not enhance earthworm biomass, but did increase the available content of nutrients during vermicomposting. The data reveals that vermicomposting is a suitable technology for the decomposition of apple pomace waste into a value added product.

1. Introduction

Currently, the world produces 70 million metric tons of apples per year, while the countries of the European Union contribute about 15% of this amount (WAPA, 2013). In the Czech Republic apple trees represent the most important fruit species, and in 2012, 80,000 tons of apple juice was produced. Approximately 1.5–2 tons of apples, depending on their types and age, are required to produce 1 ton of juice, so the utilization ranges from 65% to 50%. The solid material which remains after the extraction of juice is called apple pomace. Apple pomace has been used as a feed for herbivorous animals and as a component in fruit tea. However, the market has been changing, and the livestock population has declined. The proportion of apple pomace in fruit teas has decreased due to higher demand from purchasers for components with better aroma and taste. Thus, apple pomace has become bio-waste.

Vermicomposting is one possible solution for handling this feedstock. It is the processes of ingestion, digestion, and absorption of organic waste carried out by earthworms, followed by the excretion of casting through the worm's metabolic system, during which their biological activities enhance the levels of nutrients in the organic waste (Venkatesh and Eevera, 2008). Compared to the feedstock and conventional compost, vermicompost contains increased and more soluble levels of major nutrients and organic matter with improved quality (Sinha et al., 2010).

At this time, there do not appear to be any scientific studies on the vermicomposting of apple pomace waste. Keeping the above facts in mind, the present study was implemented to investigate the feasibility of vermicomposting apple pomace and its mixtures with straw on the basis of agrochemical properties and earthworm biomass.

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2. Methods

2.1. Feedstocks and their pre-composting

Apple pomace obtained from a food-processing company, and shortly chopped wheat straw as a bulking agent to improve structure, enhance aeration, and absorb excess liquids were used in the experiment. For the experiment, dry wheat straw was soaked in water for 1 month to enhance the absorption capacity and thus aid in faster decomposition. Thus, the dry matter content of the straw decreased from 90% to 18%.

2.2. Treatment of bio-waste during the pre-composting process

The composition of the feedstocks (in volume proportion) is given below:

I Apple pomace (50%) + straw (50%).
II Apple pomace (25%) + straw (75%).
III Apple pomace (50%) + straw (50%).
IV Apple pomace (75%) + straw (25%).
V Apple pomace (100%).

All treatments were pre-composted in 70 L capacity laboratory reactors kept in a room at 25 °C for 14 days.

An active aeration device was used to push air through the composted materials from the bottom. The mixtures were batch-wise aerated for 5 min out of each half hour in a volume of 4 L of air min^{-1}. On the basis of their previous experiences, Hanc et al. (2012) found that this aeration level was usually sufficient to achieve the optimal parameters of the composting process.

2.3. The vermicomposting process

Vermicomposting of aerobically pre-composted feedstock was conducted in a specially adapted laboratory with controlled conditions (temperature 22 °C, relative humidity 80%, ventilation for 15 min every 12 h). A 12 L batch of material was manually mixed with 3 L of substrate containing a total of 450 earthworms of the genus *Eisenia* (treatments II–V). Earthworms were added not alone but in their original beef manure substrate to reduce their initial stress and improve their adaptability to the new environment. In the case of treatment I (control without earthworms), 3 L of substrate was replaced by 3 L of the original pre-composted materials (apple pomace (50%) + straw (50%)). Even after the earthworms had been sorted out, the remaining substrate was not utilized due to the possible presence of cocoons from which new earthworms could hatch and affect the treatment. The mixture was placed into a plastic bowl with a perforated bottom, equipped with irrigation and temperature measurements. Each treatment was carried out in triplicate. Before sampling, the eventual leachate which was captured in a stainless bowl was returned to the vermicomposted material to achieve a closed loop. A sample of 200 g was collected from each bowl each month during the five month study period. The earthworms were sorted out, and the resulting samples were dried at 40 °C to a constant weight and ground to ensure homogeneity.

2.4. Analytical methods

Measurements of pH and electrical conductivity (EC) were conducted on samples mixed with deionized water (1:10 w/v dry basis). Organic carbon was determined by dichromate oxidation in sulfuric acid solution and total nitrogen by the Kjeldahl method using a Gerhardt analytical system Vapodest-manager device. Total element contents (P, K, and Mg) were determined in the digests obtained by pressurized wet-ashing (HNO_3 + HCl + HF) with microwave heating using an Ethos 1 system (MLS GmbH, Germany). The contents of ammonium nitrogen ($N–NH_4^+$), nitrate nitrogen ($N–NO_3^-$), and the available portions of P, K, and Mg were determined in CAT solution (0.01 mol l^{-1} $CaCl_2$ and 0.002 mol l^{-1} diethylene triamine pentaacetic acid (DTPA)) at the rate of 1:10 (w/v) according to the International BSI Standard EN 1365, 20011. The $N–NH_4^+$ and $N–NO_3^-$ contents in the extracts were measured colorimetrically using the SKALAR SANPLUS SYSTEM®. The element concentrations were determined using inductively coupled plasma optical emission spectrometry (ICP-OES).

3. Results and discussion

3.1. Weight and volume

From a practical point of view, changes of weight and volume during vermicomposting are important for planning the amount of processed feedstock and the final product on a given area or space. Weight loss was fairly even during the process. However, the treatment containing 75% straw showed more rapid weight decline, while the treatment containing apple pomace by itself exhibited a slower decrease in weight. On average for the treatments, the weight of the final vermicompost was one third of the initial feedstock. Hanc and Pliva (2013) found that samples consisting of pre-composted kitchen waste with woodchips and paper lost 20% and 55% of their weight, respectively. In this experiment, the volume decreased from 70% to 80% after one month. In the coming months, the volume decreased slightly. Vermicomposting was able to decrease the initial volume overall by 84–89% depending on the addition of straw.

3.2. Value of pH, EC, and C/N rate

Two weeks of pre-composting caused an increase in pH from 4.0 to 6.7 for the treatment containing only apple pomace, nevertheless this was a lower pH than mixtures with straw (up to 7.2). Higher proportions of apple pomace in the mixtures resulted in lower pH values, probably due to the high contents of organic acids (e.g. malic acid). There was a difference between composting and vermicomposting in terms of pH. The pH value in treatment I slightly but gradually increased. This pattern is typical for the composting of source separated household bio-waste as well (Sundberg and Jonsson, 2008). The pH values of mixtures containing a high proportion of apple pomace (50–100%) increased slightly after 1 month of vermicomposting. The increase in pH could be caused by the degradation and consumption of organic acids by microorganisms. Subsequently, a decrease in pH was observed which was directly proportional with the amount of straw in the treatment. The pH values of the final vermicomposts were lower by 0.6 units when compared with the initial mixtures. These differences increased directly with the proportion of straw. The lowest pH was observed in vermicompost containing 75% straw and 25% apple pomace. A decrease in pH (from 8.6 to 7.3) was found in the study conducted by Suthar (2010) who vermicomposted agro-industrial sludge. The decline in pH may be due to the mineralization of the organic compounds, and thus an increase in the contents of organic and humic acids (Suthar and Singh, 2008; Garg et al., 2006).

The EC fluctuated around 1 mS/cm in treatment I which did not contain earthworms. The EC gradually increased in all of the treatments with earthworms, which could be explained by the release of bonded elements during earthworm digestion (Garg et al., 2006), and the release of minerals during the decomposition of organic matter in the form of cations in the vermicomposts (Tognetti