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Composting of dry bean (*Phaseolus vulgaris*) husk: Physicochemical and spectroscopic characterization

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Abstract

Bean husk is one of the waste products generated during bean processing, which are often improperly disposed on farmlands. In order not to be a nuisance and consequently lead to environmental pollution, an environmentally friendly approach of managing this waste material is essential. Composting was chosen as the approach because of the biodegradable nature of the waste material. Thus, in this study bean husk was composted and the changes that took place in the material during the composting process were evaluated. The study was carried out for ten (10) weeks, and the changes in the pH, temperature (°C), moisture content (%), electrical conductivity ($\mu\text{S}/\text{cm}$), total carbon to nitrogen ratio, and the loss in weight (%) were monitored. Fourier transform infrared spectroscopy (FTIR) was also used to study the changes in the waste material during the composting process. The results showed that the pH ranged from 7.03 - 9.40, while the temperature, moisture content, electrical conductivity, carbon to nitrogen (C:N) ratio ranged from 26.33 - 29.70 °C, 25.18 - 31.39 %, 146.70 - 247.86 $\mu\text{S}/\text{cm}$, 35.25 - 74.18 respectively. The loss in weight was from 32.91 - 60.00 %. The FTIR analysis showed the presence of C-O, aromatic C=C, aliphatic C-H stretching vibrations at about 1200-950 cm^{-1} , 1500-1650 cm^{-1} , and 3000-2800 cm^{-1} respectively, which are typical functional groups in lignocellulosic materials like the beans husk.

This study shows that the waste bean husk can be composted, as the results obtained are consistent with previous studies.

Keywords: *Waste material, compost, bean husk, FTIR analysis*

Introduction

Solid waste management is a major problem globally. The sudden shoot up in the quantity of waste material is the main concern of the environmental crisis, which occurs from very swift urbanization and population increase. The density of waste generated in Nigeria ranges from 280-370 kg/m³, and annually about 25 million tons of waste are generated at a rate of 0.44-0.66 Kg/capital/day (Ogwueleka, 2009).

Discharge of wastes which are organic from industries, agriculture and domestic has led to harmful environmental and economic problems. In view of this, organic wastes are being recycled to generate needed organic manure for agricultural goals. Wastes are also treated biologically resulting into nutrient source which are valuable (Coker, 2006; Paraskeva & Diamadopoulos, 2006). Another feasible method of treating this waste is through composting technology (Benifez *et al.*, 1999; Mills, 2006).

Composting is defined as the biological breakdown of organic wastes and its stability carried out aerobically, under situations that permit the growth of thermophilic temperature due to the heat being produced biologically (Dalzell *et al.*, 1987; Sunar *et al.*, 2009). Compost of organic waste differ in quality and their stability depending on their sources, and this further depends on the make-up of raw material used for the production of compost (Ranalli *et al.*, 2001). Generally, there are factors that affect the success of composting either by influencing directly or indirectly the microbial activities. These include the form of raw materials to be composted, its nutrient composition of its nutrient, temperature, moisture content, aeration and alkalinity (Savala, *et al.*, 2003).

The stabilized compost generated should improve the growth of plant and useful for agricultural application as organic fertilizer (Magadi *et al.*, 2003).

In the process of composting, nitrogen and carbon containing compounds are transformed through microbial activities into organic forms which are stable and complex, which chemically looks like soil humic matter (Diacono & Montemurro, 2010; Stan *et al.*, 2009). The order of break down rate for the different parts of a plant are carbohydrates, sugars, proteins and fats break down the fastest, after which hemicelluloses decompose, followed by cellulose and lignin being the final (Mohee, 2007).

Beans (*Phaseolus vulgaris*) is one of the most frequently consumed legume globally, and it is an important legume produced for consumption by humans directly, and its value commercially exceeds that of other legume crops combined (Broughton *et al.*, 2003; Graham & Vance, 2003; Porch *et al.*, 2013). The dried seeds, or “pulses”, of *P. vulgaris* are an important source of dietary protein for millions of people throughout the globe, although it is low in methionine and cysteine they are supplement to diets rich in maize, rice or other cereals which are lacking those amino acids (Broughton *et al.*, 2003). Beans are an essential valuable source of the amino acids like lysine and tryptophan; the minerals iron, zinc and copper; and useful flavonoids phytochemicals, and antioxidants (FAO, 1999).

Bean husk is formed or gotten from the removal of beans outer layers, leaving only the seeds; this process is called husking. Seeds are removed from the husks and the remaining husks are then used for different purposes such as a supplemental fiber for ruminants, animal feed and can as well be converted into compost. After harvesting or processing, the bean husk is discarded and ultimately causes environmental pollution. However, this can be managed to reduce pollution and its effects on humans via composting. The compost produced can be used by farmers as organic fertilizer and soil conditioners. The aim of this study is therefore to evaluate the possibility of composting waste beans husk. This was achieved by monitoring the changes in pH, temperature, moisture content, electrical conductivity, loss in weight, and total carbon to nitrogen ratio during the composting process, as well as the spectroscopic (FTIR) analysis of the raw material and the resulting compost.

Materials and Methods

Materials

The waste material (bean husk) was purchased from Ipata market, Ilorin, Kwara State, Nigeria. Materials such as plastics, glasses and other objects present in the waste material were removed before it was composted.

Methods

Composting process

The composting process was aerobic and in vessel and it was carried out for ten weeks according to the method of Elaigwu *et al.* (2016). Briefly, 50 g of the beans husk was weighed into each of thirty already weighed 250 mL conical flasks and 50 mL distilled water was added to each flask. They were then left on a workbench for composting. Triplicate sampling was carried out on a weekly basis for ten weeks, and their mean and standard deviation were calculated.

Determination of the physico-chemical parameters

The temperature of the compost was tracked during the composting process with the use of a sterile thermometer. 1% (w/w) of compost in distilled water was prepared and the electrical conductivity and pH of compost solution was measured using a well calibrated conductivity meter (HANNA) and pH meter (HANNA) respectively. 1:10 (w/w).

The moisture content was determined using the method of Trautmann, 1992. The weight of compost was taken on each sampling day. The sampled compost was thereafter oven-dried at 80 °C until constant weight was obtained and the sample was reweighed. The amount of moisture content was calculated from the difference in the weight of the compost before and after drying.

The nitrogen content of the sample was determined using Kjeldahl method, which involves three steps namely digestion, distillation and titration. Briefly, 1 g of the sample (compost) was placed into a digestion flask, and 10 mL concentrated sulphuric acid and 1 g of CuSO₄-TiO₂ catalyst were added. The sample was then heated for 4 h in a fume cupboard. After the digestion, the sample was allowed to cool down and 50 mL of distilled water was added. It was then transferred to a Kjeldahl

distillation apparatus, and sodium hydroxide was added to make the solution alkaline. The ammonia produced in the process was transferred into a receiver containing 20 mL of 0.05N sulphuric acid and was further titrated with 0.05N NaOH using the Kolthoff indicator. The total nitrogen was calculated using the following equation:

$$\% N = \frac{S - L \times 70.035}{W}$$

Where N = % Nitrogen content, S = amount of 0.05N sulphuric acid in the receiver, L = amount of 0.05N sodium hydroxide used, and W- weight of sample in grams (AOAC, 1990).

The carbon content of compost was determined by wet oxidation using Walkley-Black method. The carbon-nitrogen ratio was calculated using the result derived from carbon and nitrogen contents.

The FTIR spectra were obtained for a wave number range of 3500–400 cm^{-1} with spectrum BX (Perkin Elner, England) FTIR spectrometer. The samples were prepared for analyses by mixing 100 mg of KBr (spectrometry grade) with approximately 2.0 mg of the sample material and then compressing the mixture to pellets.

Results and Discussion

pH

The change in pH during the composting period is shown in Fig. 1. The pH ranged from 7.5-9.4 during the composting period, which falls within the range previously reported (Bord na Mona, 2003; De Bertoldi *et al.*, 1983). At the beginning of the composting process the pH was neutral. However, at the later part of the composting process, the pH became alkaline. This trend could be due to the decomposition of nitrogen containing organic matter during the composting process, which led to the accumulation of ammonia that dissolved in the water fraction forming an alkaline solution (Rynk, 1992; Tumuhairwe *et al.*, 2009).

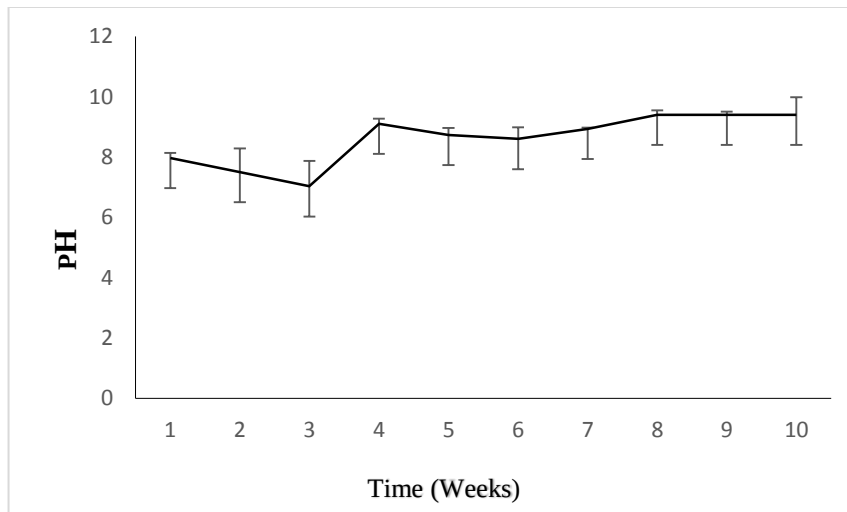


Fig. 1: Change in pH during the composting process

Temperature

The change in temperature during the composting process is presented in Fig. 2. Temperature is an important factor to consider for composting efficiency (Finsten *et al.*, 1986). The increase in temperature at the early stage of the composting is due to high microbial activity which results in rapid break down of the readily available organic matter and nitrogenous compounds by microorganisms (Raut *et al.*, 2006). This phase is known as the thermophilic phase.

As the organic matter become stabilized, the microbial activities and the organic matter decomposition rate decreased, lead to a decrease in temperature as seen in the later part of the composting process (Raut *et al.*, 2009). This phase is known as the maturation phase.

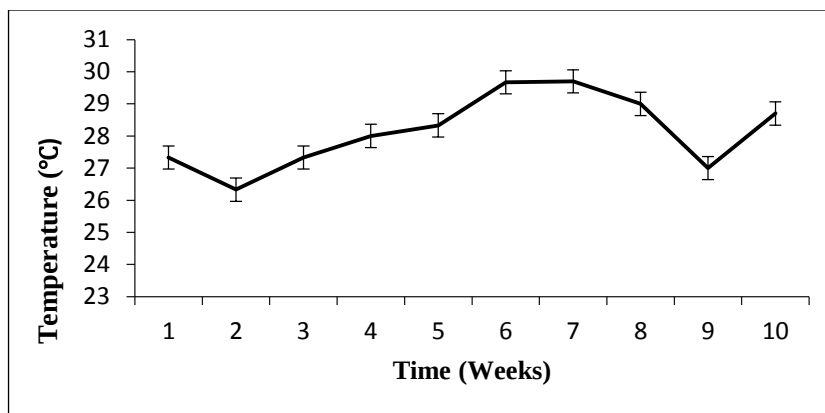


Fig. 2: Change in temperature during the composting process

Loss in weight

Fig. 3 shows the percentage loss in weight during the composting process. The % loss in weight was found to range from 33% to 62%. Higher percentage was obtained at the end of composting. As the composting process progresses, the activities of the microorganism increases, which breaks down the organic matters, leading to increased loss in weight (Shilev, 2007). The increased weight loss was rapid during the early stage of the composting and became almost constant at the later stage of composting due to maturation and decrease in microbial activity.

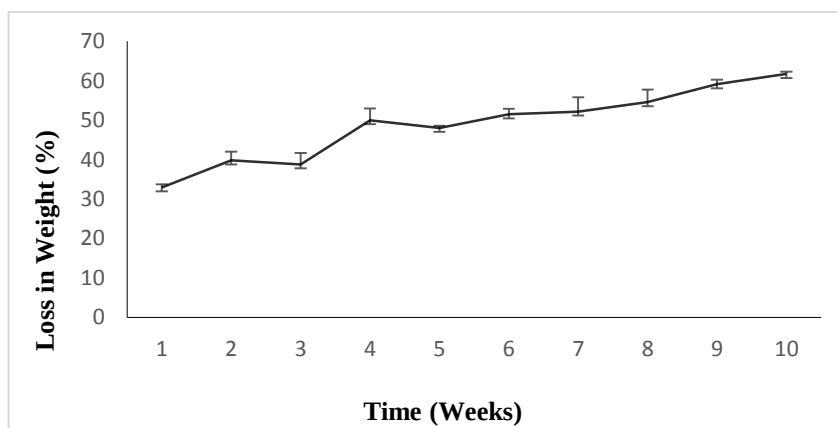


Fig. 3: Change in loss in weight during the composting process

Moisture content

The change in moisture content during the composting process is shown in Fig. 4. The moisture content during the compost process in this study ranged from 25.78% to 31.39% within six weeks and became almost constant afterwards. The increase during the first six weeks was due to high microbial activity during this period that led to high decomposition of the feedstock (Tiquia & Tam, 2000). After this period the decomposition of the feedstock was low, resulting in stable moisture content observed (Miller & Finstein, 1985).

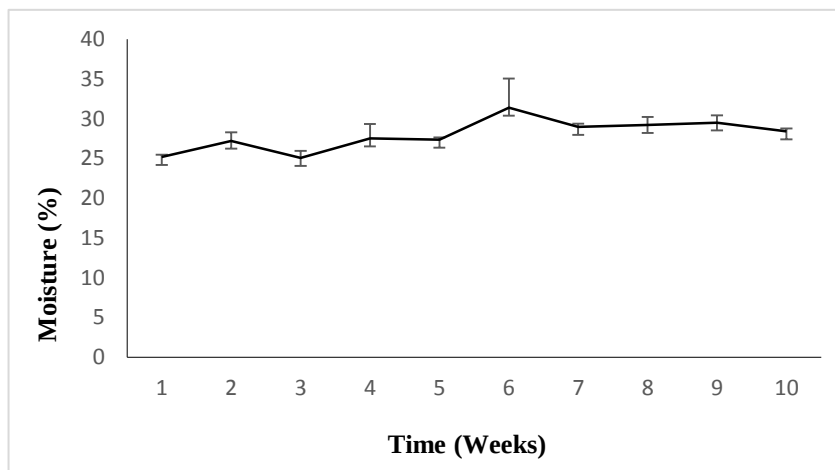


Fig. 4: Change in moisture content during the composting process

Electrical conductivity (EC)

The change in electrical conductivity during the composting period is shown in Fig. 5. Electrical conductivity is regarded as desirable physical parameter for compost maturity (Tai & He, 2007). Electrical conductivity is a measure of the soluble salt content which can greatly affect plant growth. It is an important parameter in evaluating the suitability and safety of compost for agricultural purposes, because high salt concentration in the composted residue causes phytotoxicity problems (He *et al.*, 1995).

The EC during composting process varies between 146.7 to 247.86 $\mu\text{S}/\text{cm}$ with week one having the highest EC (247.8 $\mu\text{S}/\text{cm}$) due to the high concentration of water soluble salt derived from the compost feedstock

(He *et al.*, 1995). It reduced afterward, which could be due to little volatilization of ammonia or precipitation of mineral salts (Kumar *et al.*, 2006). It increased again and remained almost stable which could be caused by the release of large quantity of mineral salts and greater concentration effect of mass loss (Kalemawala *et al.*, 2012; Kumar *et al.*, 2010).

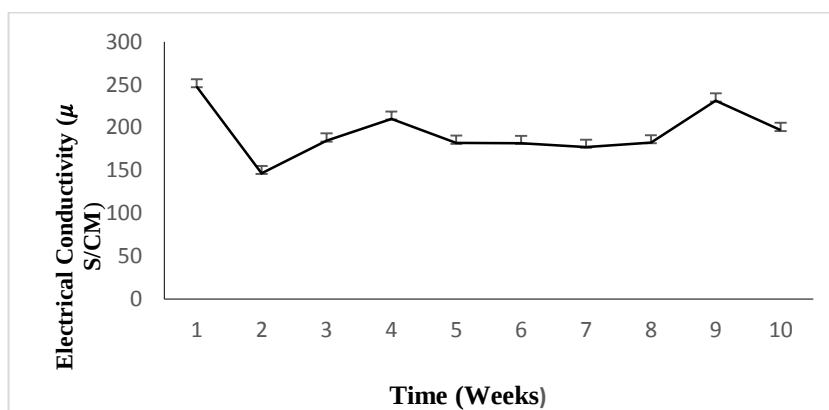


Fig. 5: Change in electrical conductivity during composting process

Carbon-nitrogen ratio (C/N)

C/N ratio is one of the most important parameters that determine the extent of composting and degree of compost maturity (Bernal *et al.*, 1998). The C: N ratio during the composting process is shown in Fig. 6

The C: N ratio of the compost ranged between 35:1 and 74:1. The C/N ratio of the compost increased within the first seven weeks attaining a C/N ratio of 74:1. The possible reason for the C/N ratio to increase in the intermediate stage of the composting period could be due to higher mineralization of nitrogen than carbon, while the decrease afterward could be due to mineralization of organic matter by microorganisms (Bernal *et al.*, 1998). The biologically degradable organic matter is converted into volatile CO₂ and H₂O which is removed from the compost. Thus, the total N content increases resulting in a decrease in C/N toward the end of composting (Day *et al.*, 1998; Vuorinen & Saharinen, 1997).

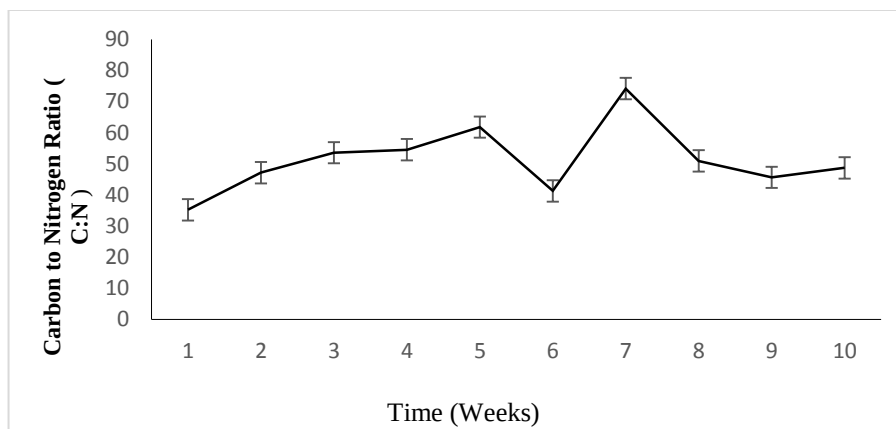


Fig. 6: Change in C: N during composting process

FTIR Analysis

For brevity, the FTIR analysis of raw bean husk and those composted for 5 and 10 weeks is shown in Fig. 7.

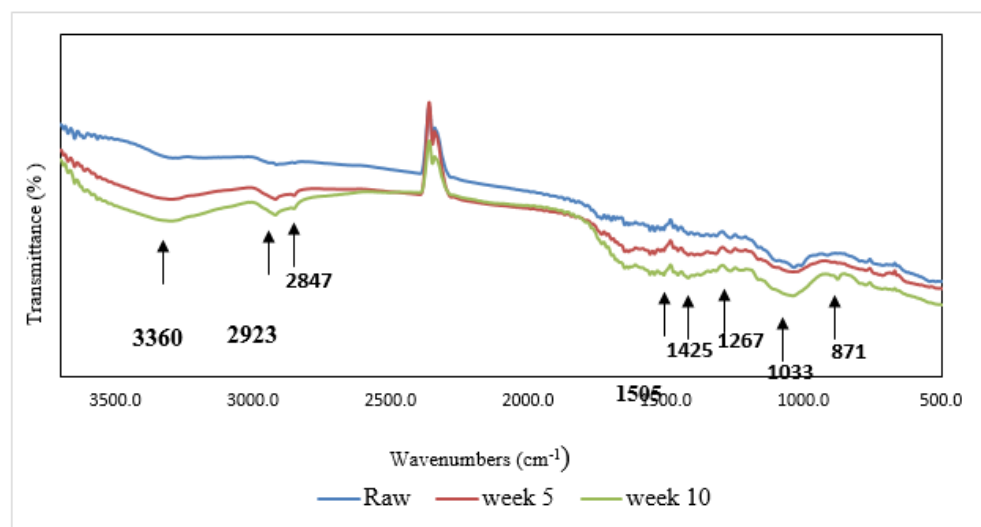


Fig. 7: FTIR spectra of raw bean husk and those composted for 5 and 10 weeks

The spectra show a broad band in the region 3500-3000 cm⁻¹ which represent the O-H stretching of bonded and non- bonded hydroxyl groups

(Higashikawa *et al.*, 2014; Provenciano *et al.*, 2014; Smidt *et al.*, 2011) and this is also associated with phenolic OH and with phenol, alcohol and carboxyl groups (Quaqouidi *et al.*, 2014). The OH band increases with composting time. This could be as a result of the humification process as the composting process increases, leading to increase in relative intensity of this band showing that the compost has a better water retention capacity (Tejado *et al.*, 2007).

The small and weak bands at $3000\text{-}2800\text{ cm}^{-1}$ show the presence of aliphatic C-H stretching (Huang *et al.*, 2006; Provenzano *et al.*, 2014; Quaqouidi *et al.*, 2014). And these bands correspond to the asymmetric and symmetric C-H stretching of methyl and methylene groups (Fel *et al.*, 2014; Smidt *et al.*, 2011). The intensity of bands at $2923\text{ \& }2847\text{ cm}^{-1}$ have been shown to increase during the composting process (Quaqouidi *et al.*, 2014; Smidt *et al.*, 2011). These aliphatic methylene bands indicate the presence of recalcitrant biomolecules such as long chain fatty acids and waxes in mature compost (Quaqouidi *et al.*, 2014; Smidt *et al.*, 2011).

The presence of aromatic groups was indicated by the peak at about $1650\text{-}1500\text{ cm}^{-1}$. This band indicates the C=C vibration of lignin and lignocellulosic material (Carballo *et al.*, 2008; Quaqouidi *et al.*, 2014; Smidt *et al.*, 2011), while the band at about $1200\text{-}950\text{ cm}^{-1}$ is attributed to aromatic carbon and C-O stretching (Huang *et al.*, 2006; Provenciano *et al.*, 2014). The band at 1267 cm^{-1} decreases with composting time.

1033 cm^{-1} is attributed to C-O stretching of polysaccharides; 871 cm^{-1} (Calcite) which increases with composting time. Also the increase of the peak at 871 cm^{-1} suggests a concentration effect of inorganic structures.

The FTIR spectra indicate the presence of aliphatic, aromatic and carboxylic functional groups as well as lignin.

Conclusion

In-vessel composting of bean husk waste was carried out on a laboratory scale as a way of managing the waste material. The physicochemical and spectroscopic characterizations carried out clearly indicated that the biodegradation of bean husk waste yielded enriched composts. The results obtained in this study are consistent with other previous studies, which shows that the bean husk waste composted well. This study further shows

that composting of bean husk can be an efficient way to convert waste into an added value product, which can be used for agricultural, as well as environmental remediation purposes.

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