THE EFFECT OF SAWDUST AS A BULKING AGENT ON THE IN-VESSEL COMPOSTING OF FOOD WASTE IN A MANUALLY-TURNED DRUM

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ABSTRACT
Composting is one approach for recycling organic waste, that mostly consists of kitchen and food residue waste. This can be done at household level by use of in-vessel composters. Sawdust as a bulking agent was used to assess the effect of bulking agent:food waste (BA:FW) ratio on the stabilising process of food waste in an in-vessel composter drum. The drum was turned manually at hourly interval at 2 rpm in 5 minutes. Three BA:FW v/v ratios were studied; 2:1,3:1, and 4:1 using more or less same food waste composition. Temperature, bulk density, moisture, pH and porosity were monitored over a period of 15 days. Temperature generally rose to above 45^{o}c within the first 5 days in all the ratios and started to fall after 10days except for 2:1 ratio that remained high even at the 15th day. The moisture content increased during the process with the highest values occurring in the 2:1ratio. There was an semi-logarithmic relationship between the bulk density and porosity across all BA:FW ratios. The pH increased from the initial value of about 4.5 to between 6 and 7.5. Except for less rapid attainment of thermophilic temperature and sustainability, the 4:1 ratio generally achieved the best composting conditions. This study appears to suggest that well rationed BA:FW mixture may be stabilised rapidly in an in-vessel composter enabling a high turn-over to handle the food waste generated in a household.

Key words: Bulking agent, in-vessel compositing, waste stabilisation

1.0 INTRODUCTION

Large percentage of solid waste produced in households and commercial outlets is biodegradable. Remarkable amounts of these wastes are being generated from households and institutions such as schools, hotels and hospitals. Studies have shown that a large percentage of domestic and commercial municipal waste is putrescible. A study in Montreal(Ville de Montreal, 1991) showed the domestic and commercial waste to have 24% and 27% respectively of putrescible materials. Morin *et al* (2003), also reported food waste materials from Canada to be characterised by a pH of 3.8-5.2, TN% of 3-16%, C/N ratio of 4-20 and C% of 46-50%. In developing cities municipal solid waste‘s organic content ranges between 50-65% (Mayabi and Muli, 2006). Such materials when landfilled are known to produce leachate with both organic and inorganic contaminants, posing danger to groundwater. Organic matter is also bulky hence requires larger space for landfiling. Landfills have also become expensive because of necessary facilities to make them environmentally acceptable, lack of sites due to NIBY syndrome and fear of diminished property value.

Composting is one approach for recycling organic waste that mostly consists of kitchen and food waste residue. This can be done at household level by use of in-vessel composters. One of this is the rotating drum unit (Freeman and Cawthon, 1999). This is rotated by a motor providing agitation, aeration and mixing. Using in-vessel technology, rapid decomposition tends to occur and allow more efficient utilization of the unit (Smith *et al.*, 2006)

In-vessel composting produces stable compost but should achieve this as rapidly as possible. Though the overall goal of a compost process is to produce mature compost, this can take several months(3-6) to achieve and would require very large units to cope with the waste production rate. Compost maturity may not be necessary for field application (Bernal *et al,* 1998). Past studies have demonstrated that appropriate blends of compost components produce better products and reduce the time to achieve compost stability (Donahue, *et al.* 1998).

The goal of the in-vessel drum composting of the food waste is to stabilize the compost as rapidly as possible. Bulking materials such as sawdust, paper, hey, wheat straw, etc are often added to compost feedstock to absorb water, provide porosity and adjust C/N ratio (Sullivan *et al*. 1998).

The objectives of this study was to determine the effect of sawdust (bulking agent) material to food waste ratio(BA:FW) on composting process and changes in physico-chemical characteristics of the compost using a manually turned in-vessel drum composter.

2.0 MATERIALS AND METHODS

The food residue used in this experiment was obtained from the Jomo Kenyatta University of Agriculture and Technology(JKUAT) staff restaurant. Two batches of food waste were collected and used for the experiment. The batches were similar in content with negligible variation in consistency and composition. After

collection the material was mixed with sawdust obtained from the wood workshop
at the university until the desired sawdust (bulking agent):Food waste(BA:FW) ratio on volume /volume basis was achieved. One batch was used to prepare BA:FW ratios of 2:1 and 3:1 while the other batch for 4:1 ratio. The moisture content of the mixture was determined and when found to be between 45-55%, the material was fed to the composter. Otherwise when the moisture was below 40% or above 55%, adjustments were done accordingly before being fed to the composter. The moisture content was determined gravimetrically using about 100g of sub-sample dried in a microwave at 103°c for 24 hrs.

A plastic drum of about 210 litres, with dimensions of 0.92 m in length and 0.56 m in diameter was used as the composter.

Figure1: Suspended composter drum model

The drum was suspended horizontally above the ground by anchoring it to external wooden support stands attached to its ends by a groove (Figure.1).

The drum was reinforced with metallic plates bolted to the drum ends and for supporting the drum against the wooden posts. It was fitted with steel pipe extension on one end to act as a handle for turning. The turning was done on hourly basis at 2 rpm for 5 minutes each time throughout the day and night. The drum model was a horizontal composter similar to the prototype in–vessel mechanical rotating drum described by Haug(1993). The drum was partitioned at the centre into two compartments each 0.46 m in length and with lockable square inlets measuring 15 cm by 15 cm for each chamber. Each compartment could hold a maximum of 0.1m^3 of material.

A grab sample was collected every other day for determination of pH, moisture, porosity and bulk density. Temperature was determined directly using a handheld long steam thermometer inserted at three different locations and the average obtained. The pH was determined in 1/1 volume mixture of the compost material and distilled water using a pH/ion meter and a pH probe. The bulk density and porosity were determined using a 3 litre container with a 3 cm raised cover.

The container was filled with overflowing material, covered and dropped five times from a height of 10 cm to compact the material uniformly (USCC, 1997). More material was added and the same procedure repeated until no more materials could be added. A straight edge was then used to remove excess material above the brim. The bulk density was calculated as the mass of the material divided by the volume of the container. Using the same compacted material, the porosity was determined by slowly adding water into the container ensuring no floatation and air entrapment. This was done over a period of 2 hrs until the water was level with the top of the container. Porosity was obtained by dividing the volume of water added by the volume of the container.

3.0 RESULTS AND DISCUSSION

Figures 2,3 and 4 shows changes in the physico-chemical properties of the composting materials with time for different bulking ratios. All the ratios attained thermophilic temperatures (>45^{o}C)

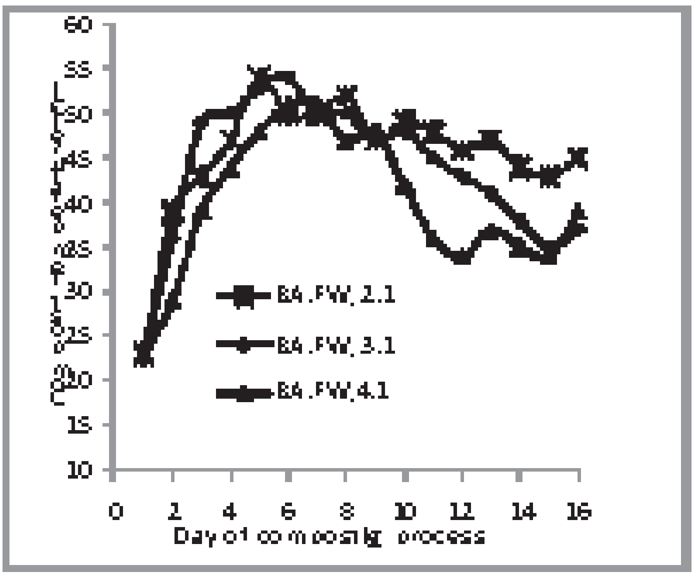

Figure 2: Changes in temperature in three BA:FW ratios.

but was achieved quickest in the 3:1 ratio (Figure. 2). Achieving higher temperatures in a shorter period of time indicates high rate of biodegradation and therefore a shorter retention time required to reach compost stability. This would allow more efficient use of the in-vessel technology (Smith *et al.,* 2006). Bulking ratio 4:1 did not maintain sustained thermophilic temperatures as compared to the other ratios. This is important in composting in order to sanitise the compost. Figure 2 also shows that the bulking ratio 2:1 remained thermophilic even after 15 days suggesting that a BA:FW ratio that is too low may increase the time required for compost stabilization. The temperature trend indicates that the compost material utilising bulking agent ratios of 3:1 and 4:1 approached stabilisation within 15 day period. Temperature reduction is indicative of compost stabilisation (Bernal *et al.,* 1998). It would appear that the bulking ratio in the range of 3:1 and 4:1 can suitably be applied.

The pH increased from low values of about 4.5 to an optimum value of 6.5-7.5 (Figure. 3) suitable for microbial activity for composting. The pH increase was attained simultaneously with thermophilic temperature. The 4:1 and 3:1 ratios had a rapid increase in pH as compared to the 2:1 ratio. This is in agreement with the study by Smith *et al.,*(2006).

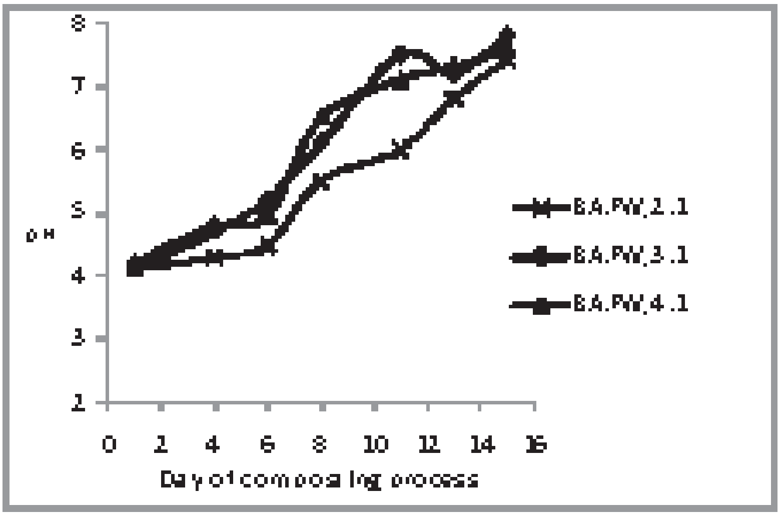

Figure 3: Change in pH in the BA:FW ratios

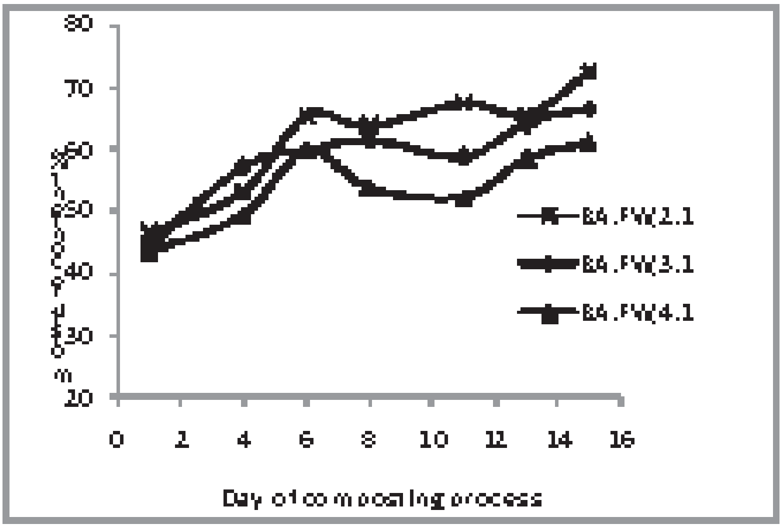

Figure 4: Change in moisture content % in the BA:FW ratios

The moisture content variations shown in Figure 4 indicate the importance of the bulking agent materials. The moisture content was higher than optimum(40-55%) after the start of the process in all the ratios. But the moisture increase was much higher in lower bulking agent ratio. This is expected since as the bulk material increases in volume, more material is available for moisture absorption. The increase in moisture content with time appears to suggest that leachate production due to biodegradation was not adequately absorbed by the bulking material. The lowest moisture was recorded in the 4:1 ratio, but still much higher than composting optimum value of 40-55% that suggested poor water absorption capacity of the bulking agent. A study on different bulking materials by Adhikari *et al.*(2007), showed large variation in characteristics such as water absorption capacity, dry matter and carbon content from the materials ranging from sawdust(wood shaving), hey, cardboard paper and paper. This underscores the need for pilot study for various recipe of food waste residue and available bulking agent materials to determine the appropriate match of BA type and the waste recipe.

Data for bulk density (ρ_b) and porosity (n) across all the BA:FW ratios showed some correlation. Figure 5 gives the plot of porosity against bulk density and the results had a relationship of the form; $n = -k_o \ln \rho_b + C$, where $-k_o$ is the slope and C the intercept on ρ_b- axis of a linear relationship in a n-plot.

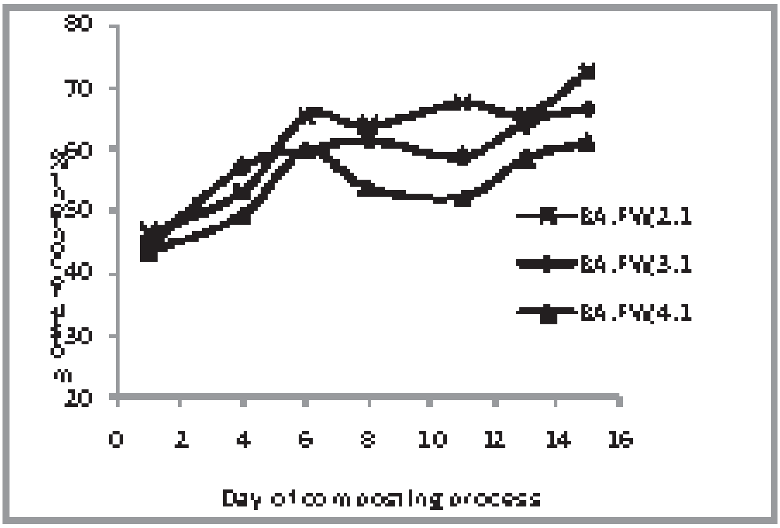

Figure 5: Compost porosity as a function of bulk density

If the porosity is assumed to be the air-filled void, the observation shows that the air flow movement decreases with bulk density. This is consistent with the work of Poulsen and Moldrup(2007) that showed air permeability to decrease with bulk density of compost. However, unlike the n-ρ_b relationship at constant gravimetric water content that followed an exponential function in their work, the above results indicate a semi-logarithmic relationship where gravimetric water content was not constant. This relationship can be applied to an estimated density of the food waste: bulking agent blend for an assumed porosity in a pilot study.

4.0 CONCLUSIONS

The entire bulking agent: Food waste blends tested reached thermophilic temperatures during the 15 day composting period. The temperature increase and eventual decrease during the 15 day period indicated the material had stabilised, particularly the 3:1 and 4:1 ratio blends. The 4:1 ratio had consistently better results although the 3:1 ratio attained the thermophilic temperatures faster and sustained longer than others.

The process achieved optimum range of pH within a few days of operation. The moisture content increased with lower bulking ratio suggesting a low water absorption capacity of the bulking material.

The porosity-bulk density relationship was shown to be semi-logarithmic across the BA:FW ratios and the developed expression can be used to estimate the initial bulk density for a suggested porosity.

5.0 RECOMMENDATION

Further work is required in order to establish the frequency and rate of turning for optimum stabilised biomass characteristics and shortened retention time. A more detailed study of the 3:1 and 4:1 ratios taking into account rate and frequency of turning the drum is necessary to establish optimum conditions for in-vessel composing of food waste residue. Studies with other locally available bulking materials such as paper should also be done for comparison.

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