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Full Length Research Paper

Physical, chemical and biological changes during the composting of oil palm frond

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An experiment was conducted to evaluate the physiochemical and biological changes that occurred during the composting process of oil palm fronds (OPF) composts. Compost A, B and C were prepared by mixing OPF, chicken manure (CM) and rice bran (RB) at ratio of 40:40:20, 40:30:30 and 40:20:40, respectively. After day 21, the lowest C/N ratio and the highest amount of nitrogen (N), phosphorus (P) and potassium (K) were recorded in compost A with the values of 15.79, 2.33, 2.02 and 1.80, respectively. Compost A was also found to contain the highest number of bacteria throughout the composting process than that of other two composts suggesting that after day 21, OPF compost A was matured enough to be used as soil amendments to agricultural fields.

Key words: Oil palm frond, chicken manure, rice burn, compost.

INTRODUCTION

In Malaysia, oil palm industries generate about 90 million tones of renewable biomass annually, including about 1.3 million tones of oil palm trunks, 2.4 millions tones of oil palm empty fruit bunches and 8 million tones of oil palm frond (OPF) (Alam et al., 2007). The oil palm biomass is lignocellulosic residues which contain 50% cellulose, 25% hemicellulose and 25% lignin in their cell wall (Gu et al., 2000). OPF is a suitable renewable raw material for bioconversion into value added products because it is easily accessible, abundant locally and rich in lignocellulose. In the past, OPF was often used as fuel to generate steam at the palm oil mills (Ma et al., 1993; Hamdan et al., 1998).

However, the air-pollution from OPF burning caused serious environmental concerns and the authorities formulated tight regulatory controls to curb air-pollution from such activities. However, due to escalating labor, transportation and distribution costs of OPF in the field, its proper disposal is becoming more expensive. There is a growing interest in the low and cost attractive solid state bioconversion of OPF into value added products, such as compost (Thambirajah et al., 1995; Umikalsom et al., 1997; Molla et al., 2004; Alam et al., 2005; Bari et al., 2009).

Composting is an environmentally sound technique for recycling of organic wastes. Production of compost at farms, households or industries has been promoted as a means of reducing the volume of organic wastes being dumped in landfills, while simultaneously producing a useful product that enriches garden and agricultural soils. Compost acts as effective surface mulch, increases soil organic matter, improves water-holding capacity, suppresses weeds, and ensures long-term supply of nutrients as the organic material decomposes (Evanylo and Daniels, 1999; Sharma et al., 2011). For these

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Table 1. Percentage of oil palm frond (OPF), chicken manure (CM) and rice bran (RB) in compost A, B and C.

Treatment	OPF (%)	CM (%)	RB (%)
Oil palm frond compost A [Ca]	40	40	20
Oil palm frond compost B [Cb]	40	30	30
Oil palm frond compost C [Cc]	40	20	40

reasons, composting has been advocated as one component of sustainable agriculture (Arrouge et al., 1999; Edwards et al., 2000).

Composting is an interdependent biological processes carried out by a myriad of microorganisms essential for the decomposition of organic matter. Many biological, chemical and physical changes take place during the composting process. Under the influence of microbial interference, many of the organic compounds such carbohydrates, sugars and cellulose undergo biochemical transformations producing heat, water and CO_2 (Colak, 2004; Gajalakshmi and Abbasi, 2008; Kausar el al., 2010). These transformations provide valuable information of the composting process and can be used for controlling mechanisms to achieve optimum composting of lignocellulosic OPF (Stoffella and Kahn, 2001). Therefore, the study was undertaken to determine the physiochemical and biological changes occurred during the composting of OPF.

MATERIALS AND METHODS

Preparation of compost and the composting processes

OPF, chicken manure (CM) and rice bran (RB) were used as composting substrates. The OPF was dried for 3 weeks, and then ground into small particle size of less than 2 cm. The OPF was ground to ensure and accelerate the biodegradation processes.

All the substrates were mixed together according to the treatments (Table 1) and moistened with water. Each of the mixtures was transferred into different composting tank. Holes were made around the tank wall for aeration. Moisture content was maintained around 40-60% throughout the composting period by watering. The composts were stirred twice in a week to ensure the composts have a good aeration. Compost was considered mature when the temperature was close to ambient temperature and its structure became friable and crumbly.

Physical changes in composting

Changes in temperature

The temperature was measured daily throughout the composting period. The temperature was measured at four different points in the compost pile using a thermometer. The thermometer was dipped into the compost pile approximately 2/3 inches depth for about five minutes before taking the reading.

Moisture content

The moisture content of composts was measured daily at random from different points in the compost piles using a Moisture Content Meter.

Chemical changes in composting

Electrical conductivity (EC)

EC was measured weekly. Ten grams of each type of composts was added to 100 ml of distilled water (1:10 v/v), placed on a shaker for 30 min and left for 24 h. Salinity was determined using an Electrical Conductivity Meter and expressed as dS/m .

Carbon (C), Nitrogen (N), and C: N ratio

For the determination of carbon (C) content, the samples were put into the furnace for 5 h, that is, at 300°C for the first hour and later at 500°C for the remaining 4 h. The samples were then left overnight before the ashes were weighed. The percentage of carbon contents were calculated with the following formula:

$$\%\ \text{Carbon} = \frac{(\text{Sample dry weight}) - (\text{Weight of ash})}{\text{Sample dry weight}} \times 100$$

Nitrogen content was determined using the digestion method. Individual compost was dried for 72 h at 60°C and ground to pass through a 20 mm mesh sieve. 0.25 g of each sample was put into digestion flask with 5 ml of concentrated sulphuric acid (H_2SO_4) and was digested at 200°C for 30 min. Then the temperature was increased to 360°C and maintained for 1 h. 10ml of hydrogen peroxide (H_2O_2) was added until the reaction had completed. Finally, the solution was made up to 100ml with distilled water. Nitrogen was determined using the Autoanalyser (System 4, Chemlab). The percentage of nitrogen content was calculated from the following formula:

$$\%\ \text{Nitrogen} = \frac{(\text{ppm} \times 400 \times \text{dilution})}{10^6} \times 100$$

C/N ratio was determined using the following formula:

$$\text{C/N ratio} = \frac{Total\ carbon}{Total\ nitrogen}$$

Macronutrients

P and K macronutrients and heavy metals in composts and plant tissues were determined using the AQUA-REGIA method. 0.5 g dry weight of finely ground samples were added with 3 ml HCl and 1 ml HNO_3 in 50 ml Kjedahl flask and heated at 110°C in a digestion block until 1 ml of the sample solution was left. Again, 3 ml HCl and 1 ml HNO_3 were added, if the sample colour was not changed to white. After the sample solution had cooled down, 10 ml of 1.2% HNO_3 was added (v/v) and digestion was continued for another 30 min at 80°C. Distilled water was added to cool and to make up the sample solution to a volume of 20 ml, and heated at 80°C for 30 min. After cooling, distilled water was added to maintain the volume at 20 ml. It was then shaken and filtered through Whatman® filter papers no 2. The final solution was used to determine P and K micronutrients by using an Atomic Absorption Spectrophotometer (Perkin Elemer Model 310).

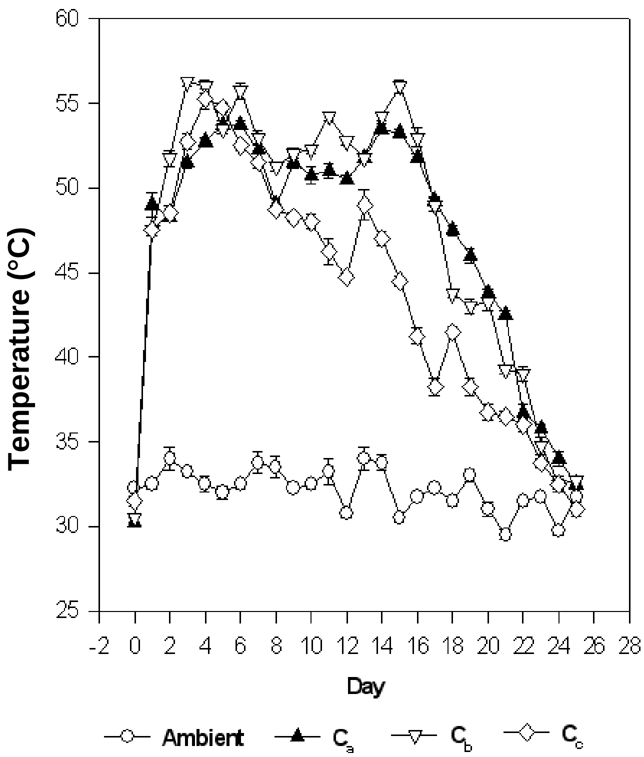

Figure 1. Changes in temperature (°C) during composting processes. C_a = Oil palm frond compost A, C_b= Oil palm frond compost B, C_c = Oil palm frond compost C and ⌶ = Standard deviation.

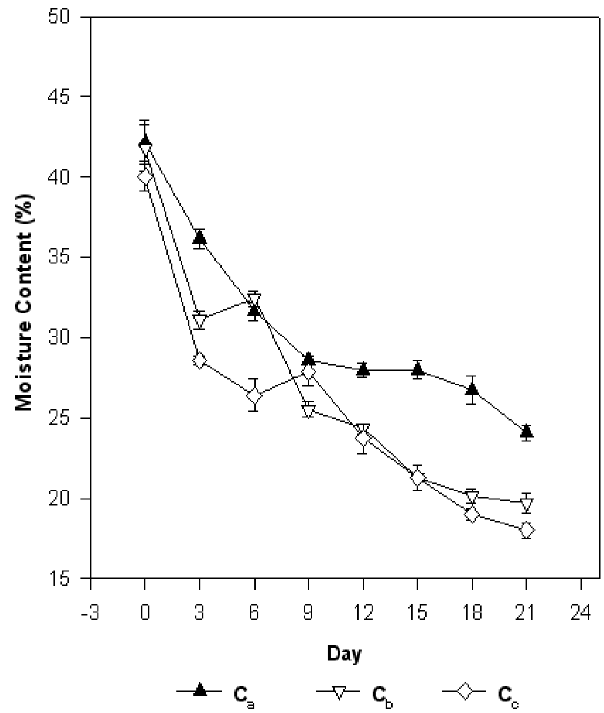

Figure 2. Changes of Moisture Content during Composting Processes. C_a = Oil palm frond compost A, C_b= Oil palm frond compost B, C_c = Oil palm frond compost C and ⌶ = Standard deviation.

Biological changes in composting

Bacterial count

Microbial count was done weekly during the composting period. Serial dilutions on Nutrient Agar (NA) were performed to determine the dynamic of bacterial population in compost samples. 10 g of compost sample was suspended in 90 ml of sterilized distilled water and placed in a mechanical shaker for 30 min. Serial dilutions were prepared and 1ml aliquot (10^{-4}, 10^{-5} and 10^{-6}) was pipetted onto each petri dish with NA for determining the total bacterial population. All plates were incubated for 2 days at room temperature (28°C) in the dark. Bacterial population was expressed as cfu/g dry weight compost.

Statistical analysis

All the experiments were conducted using completely randomized design (CRD) with four replications. Results were subjected to analysis of variance (ANOVA) and tested for significance by Least Significance Different (LSD) using PC-SAS version 9.0 (SAS Institute, Cary, NC).

RESULTS

Changes in temperature

Figure 1 shows the changes in temperature during the composting processes of OPF for a period of 25 days. The initial temperature was 30°C. During the first week of composting, the temperature shows an increase especially compost C_b that reached a maximum temperature of 56°C on day 3. Meanwhile compost C_a and C_c reached maximum temperature 56 and 55°C, respectively, at day 6 and 4, respectively. At the end of the composting processes, the temperatures of all treatments reached to a minimum level of 31°C.

Moisture content (MC)

The moisture content of OPF composts is shown in Figure 2. Figure showed that at the end of the composting process, OPF compost A [C_a] had the highest moisture content (24%) followed by OPF compost B [C_b] (20%) and C [C_c] (19%).

Electrical conductivity (EC)

The EC value was significantly different in between different treatments (Figure 3). Initially, compost C (C_c) had the lowest EC value of 1.52 dS/m whereas compost A (C_a) registered the highest EC with the value of 2.02 dS/m. At the end of composting period, compost A reached the highest EC value of 2.98 dS/m.

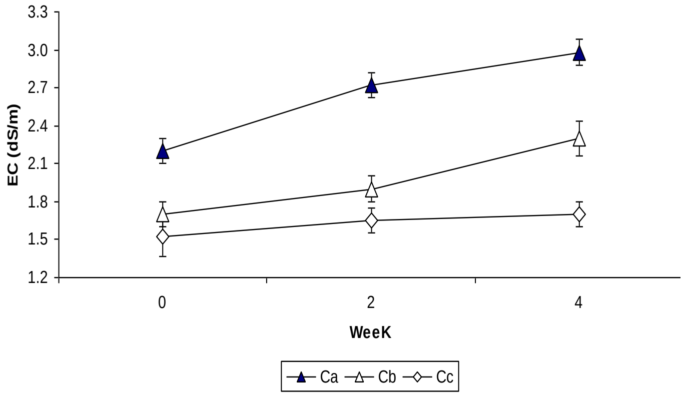

Figure 3. Changes of Salinity (dS/m) During Composting Processes. C_a = Oil palm frond compost A, C_b= Oil palm frond compost B, C_c = Oil palm frond compost C and ⌶ = Standard deviation.

Table 2. Changes of C: N Ratio of OPF composts during composting processes.

Treatment	Days of composting			
	Initial	7	14	21
C_a	29.83 b	20.14 b	16.51 c	15.79 b
C_b	30.76 b	22.17 b	20.63 b	20.54 a
C_c	42.14 a	27.03 a	23.98 a	21.34 a

Means with the same letter within a column are not significantly different using LSD at P<0.05.
C_a = Oil Palm Frond Compost A, C_b = Oil Palm Frond Compost B and C_c = Oil Palm Frond Compost C.

C: N Ratio

The changes in C/N ratio for all treatments during the composting of OPF composts are presented in Table 2. The table showed that at the end of composting the highest C: N ratio was obtained from OPF compost C [C_c] with a value of 21.34, while OPF compost A [C_a] and B [C_b] had values of 15.79 and 20.54 respectively.

Macronutrients

Figure 4 (A, B, and C) shows that there was a significance difference (P<0.05) in N, P and K levels between the three composts. It shows that compost A (C_a) contains high percentage of nitrogen (N), phosphorus (P) and potassium (K) as compared to the other two composts.

Bacterial count

Table 3 shows the microbial count during the composting

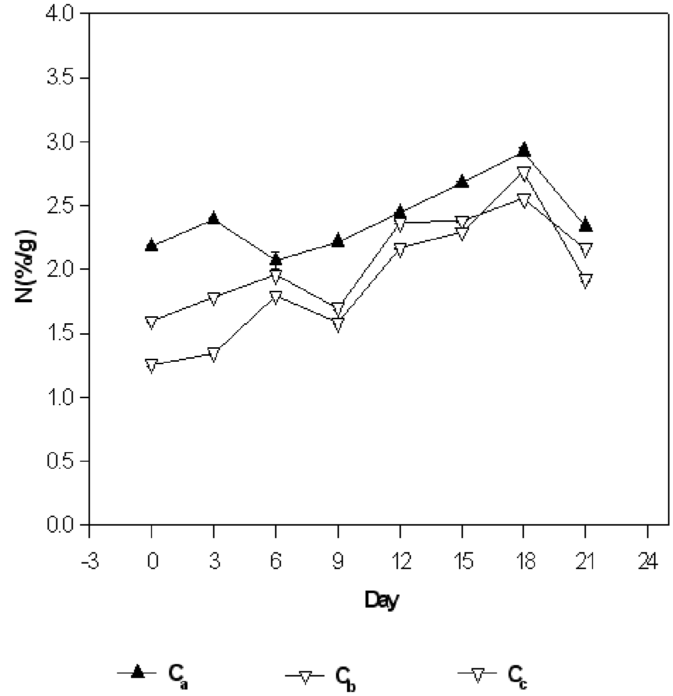

Figure 4A. Nitrogen Analysis during composting processes (%/g dry weight). C_a = Oil palm frond compost A, C_b= Oil palm frond compost B, C_c = Oil palm frond compost C and ⌶ = Standard deviation.

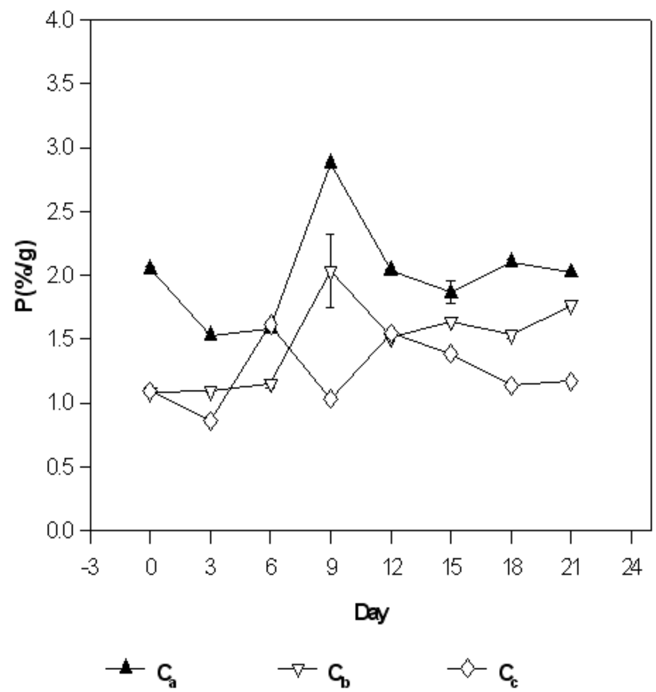

Figure 4B. Phosphorus analysis during composting processes (%/g dry weight). C_a = Oil palm frond compost A, C_b= Oil palm frond compost B, C_c = Oil palm frond compost C and ⌶ = Standard deviation.

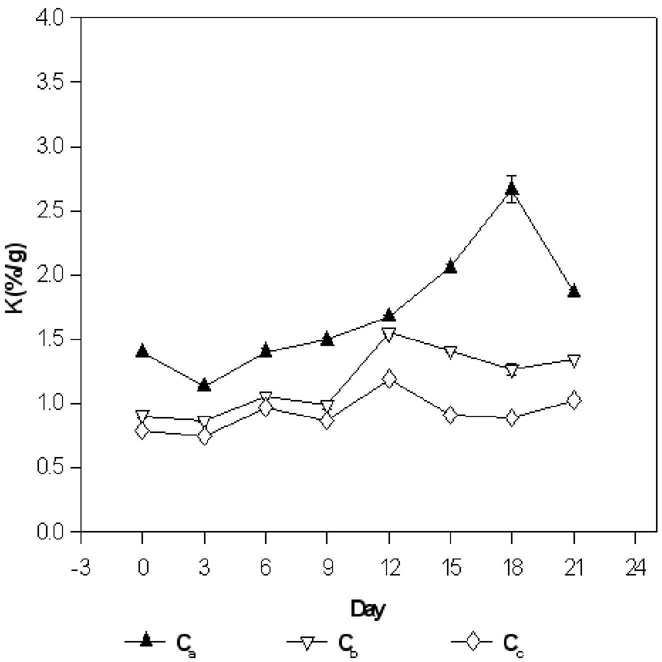

Figure 4C. Potassium Analysis during Composting Processes (%/g dry weight). C_a = Oil palm frond compost A, C_b= Oil palm frond compost B, C_c = Oil palm frond compost C and ⌶ = Standard deviation.

Table 3. Bacterial population in oil palm frond composts during composting processes.

Treatment	Days of composting			
	Initial	14	21	28
C_a	8.31 a	8.75 a	8.64 a	8.48 a
C_b	8.09 b	8.21 b	8.21 b	8.18 b
C_c	8.04 b	8.20 b	8.19 b	8.13 b

Means with the same letter within a column are not significantly different using LSD at P<0.05.
`C_a = Oil Palm Frond Compost A, C_b= Oil Palm Frond Compost B, C_c = Oil Palm Frond Compost C and ⌶ = Standard deviation.

processes of oil OPF compost. OPF compost A [C_a] showed significantly higher microbial count than composts B [C_b] and C [C_c] throughout the composting process. At the end of the composting processes (week 4), the OPF compost A [C_a] gave microbial count of 8.48 cfu/g dry wt whereas those were 8.18 and 8.13 cfu/g dry wt for treatments B [C_b] and C [C_c], respectively.

DISCUSSION

The OPF composts evaluated in this study varied in all measured physical, chemical and biological traits. Among the three OPF composts, compost A, showed satisfactory performance during composting.

The change in temperature among the three composts was found to be not significantly different. However, compost B was found to have the highest temperature than the other two composts. All the composts had been found to maintain the same trend, that is, increased since 2nd day and reached a peak value at the 3rd day to 16th day and started to decrease and reached the ambient temperature at day 25th after initiation. The changes in temperature seem to be related with the microbial population, which increased in number at the 2nd and 3rd week after initiation. It indicated that the temperature was caused by heat energy released from metabolic oxidation of bacteria. For the EC value, compost A was found to have the highest value, that is, 2.24 dS/m at the beginning and 2.98 dS/m at the end of the composting process, followed by the EC values of composts B and C respectively. All three composts have relatively low EC value, that is, less than 3.0 dS/m. This means that the composts were suitable for plant growth and development. According to Gullino and Garibaldi (1994) an EC value of 5.0 dS/m in soilless culture could cause dehydration and death of plant. Compost A was found to have the highest moisture content than compost B and C, with moisture contents of 24.07, 19.70 and 18.00%, respectively. The amount of the moisture content also seems to be related with the percentage of CM composition in compost formula, or with the amount of RB in the compost substrates. Moisture content of the compost indicates the capacity of the composts to hold water. Therefore, compost A had the highest water holding capacity as compared with composts B and C. The moisture content of compost C is closest to the minimum moisture content that is essential for bacterial activity (Miller, 1989) and prevents the odour formation (Golueke, 1989). At the end of the composting process, all the three composts A, B and C, were found to possess desirable value of C:N ratio between 16 to 21 (Nakasaki et al., 1992). Compost A, from initiation to 21st day, was found to have the lowest value of C: N ratio compared with compost B and C, respectively, with C: N ratio of 29.83 at the initiation period and decrease to 15.79 at the end of composting process (21st day), while compost B was not significantly different with compost C. These results were in accordance with the proportion of RB and CM in the composting substrates. The results indicate that the amounts of CM correspond to the value of N, and RB corresponds to the value of C in the OPF compost.

This might be due to the low percentage of C and the high percentage of N in chicken manure compared with rice bran and OPF. Among the three composts, compost A was found to contain the highest nitrogen (N), phosphorus (P) and potassium (K) as compared with compost B and C respectively. The amount of the macronutrients seem to be in accordance with the proportion of CM and RB composition in the composting substrates as CM contains higher amount of macronutrients than those of RB. At the end of the composting process the amounts of macronutrients were higher than those at the initial period. These high values might have been due to the reduction of organic content during the composting process (decomposition) (Chabbey, 1993). An increment of bacteria population was found to achieve peak value at the 2nd week, and then subsequently decreases at the 3rd and 4th week after composting initiation. Generally, compost A was found to contain the highest number of bacteria throughout the experiment as compared with the two other composts B and C. The number of bacteria in composts B and C did not show a significant different. However, compost B was found to contain a higher number of bacteria as compare to compost C. The number of bacteria seems to be in accordance with the percentage of CM composition in the compost formula, where the highest amount of CM was in compost A (40%) as compared with compost B (30%) and compost C (20%). In contrast, the number of bacteria decreased when the amount of rice bran was increased, where the lowest number of RB was in compost A (20%) as compared with compost B (30%) and compost C (40%). The results of all parameters show that composition of chicken manure (CM) is an essential element in the composting process of OPF compost. This substrate provides the sources of bacteria, macronutrients N, P and K, improves electrical conductivity, and improves water holding capacity and moisture content, while rice bran (RB) was also essential to provide C, reduce electrical conductivity, water holding capacity and moisture content.

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