

Evaluation of Maturation and Stability Some Indexes of Mixed Palm Oil Biowaste Composting Process and Poultry Litter

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Abstract: The efficiency of palm oil biowastes (mostly frond and the empty fruit bunch (EFB) composting, with using poultry litter was investigated in this study. The objectives of this study is to evaluate composting maturation parameters by varying mixing ratio of poultry litter (PL) in palm oil biowaste (POB) to determine the most suitable ratio of the mixing. The experiments were carried out using bin composting method for 11 weeks. Three different mixing ratios of 3:1, 1:1 and 1:3, ~40% moisture content which, were turned daily manually constructed the operational conditions of composting in this study. During composting process, different parameters were measured such as temperature, pH, EC, moisture, N, C and C/N ratio. In all treatments, temperature was between 27 to 58°C, pH ranging between 6.4 to 7.7 and EC was recorded between 2.7 to 5.4 mS.m-1. Results indicate that TOC, TKN and C/N ratio decreased. These monitored parameters were in desired range as mature compost however 1:3 ratio of POB and PL had the lowest C/N ratio, TOC and the highest value of TKN, 18, 27% and 1.48%, respectively.

Key words: Compost • Empty fruit bunch • Palm oil fronds • Poultry litter • C/N ratio

INTRODUCTION

Palm oil production and aviculture are two important agricultural industries, which generate huge amount of organic wastes. In the world's vegetable oil market, palm oil is one of the most important sources. It is one the most productive oil manufacturing plant in the world, which produce annually about 10 to 35 tonnes of 'fresh fruit bunch (FFB) per hectare. This industry generates many types of by products such as the mesocarp fiber, shell, empty fruit bunch (EFB), palm oil frond (POF) which in general are known as palm oil biowastes (POB) [1-2]. According to Mohammed *et al.* (2011) the world total residue of palm oil industry is 184 million tones and about 53 million tons of these biowaste are generated from palm oil industry every year in Malaysia by an increasing rate of 5% per annum [3].

Nowadays, there are a lot of poultry farms in the world which produce considerable amounts of poultry litter per day that is a surcharge to the environment [4]. Poultry litter is a blend of excreta, feed, feathers and a bedding material, which is removed by poultry houses in farm [5-6]. Managing this huge quantity of waste is important to protect the environment and reduce the amount of these wastes. These materials have a potential to be used as fertilizer. Yet these wastes to be used as organic fertilizer require primary treatment. This is to reduce the emission of greenhouse gases in atmosphere, decreasing the production of pathogens, improving the handling and storage properties of these kinds of waste [4, 7]. As reported by many researchers, composting is an efficient alternative way to reduce the residue of organic wastes [8-10].

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In this regard, composting is known as an environmental friendly, economic method in organic waste management for conversion of biowaste for production of more useful material. Composting could be described as an aerobic biological process in which organic wastes are transformed to simpler, more stable and soil-like compounds leading to reduction of the volume of the wastes by microorganism's activities. The mature compost is used as an organic fertilizer with positive effects on soil and environment. It causes in an increase in the amount of agricultural production due to the high amount of nutrition content, moisture-holding as well as improving the aeration and soil structure [7, 9, 11-12]. Therefore composting of bio-waste from palm oil and aviculture industries is a useful way to manage them. The quality of the compost is mainly a result of the feedstock and the condition of composting. The use of PL for composting POB as low cost source for compost has not been explored yet. This study investigates the effect of PL in composting of POB in different concentrations for different compost properties. Stability and maturation indexes of compost have also been discussed.

MATERIALS AND METHODS

Collection of Samples: The poultry litter were collected from a poultry farm in Ladang Byram, Nibong Tebal, Pulau Pinang, Malaysia. The EFB was collected from United Oil Palm Industries Sdn Bhd. in Nibong Tebal, Malaysia. The fronds were collected from USM, Engineering Campus, Nibong Tebal, Malaysia.

Composting Process: The palm oil biowastes (fronds, EFB) were chopped and shredded to small pieces, 6 to 10 cm and eventually mixed with poultry litter by varying ratios, i.e. 1:0, 3:1, 1:1 and 1:3. Table 1 shows the distribution of POB and PL. For each composition, 3 set of samples were made under exact same conditions and the average of the results for each parameter is reported to ensure the accuracy of the data.

The mixed materials were packed in plastic containers with 10³ L capacity with holes in bottom and around to provide aeration and drain of the leachate produced during composting. Moisture was measured every 12 hours and adjusted to be between 40 to 65% to assure the best microbial activity [13]. If the moisture exceeded the range by turning and aeration, the moisture was reduced. In the case of lower moisture content, it was adjusted by addition of distilled water to the system. The temperature

Table 1: The mixture composition of POB and PL

	POB	PL
Set 1	100%	0%
Set 2	75%	25%
Set 3	50%	50%
Set 4	25%	75%

was also measured just before daily turning. The control in the temperature is important so that the high temperature does not cause a flame to start. Also the leachate was collected properly and discharged to assure the health and safety issues.

Analyses of Compost Properties: Samples were collected and measured for the chemical properties of the mixture such as pH, Electrical Conductivity (EC), Total Organic Carbon (TOC) and Total Kjeldahl Nitrogen (TKN). The pH values of the compost were measured using a pH digital meter (EUTECH, pH 510) and an EC meter (VSI, Model 30M, 100FT, USA) in aqueous extract (weight: volume = 1:10).

The Moisture Content (MC) of the raw materials was determined by drying the samples at 105°C for 24 hours. Ash was determined in a muffle furnace at 550°C for 24 hours and the Organic Matters (OM) were calculated as the difference between ash and its dry weight, as a percentage. In this study, the TKN content was determined using the Kjeldahl method (K424, Buchi, Switzerland). The content of TOC was determined using a high temperature combustion method (Vario MACRO cube).

Statistical Analysis: All results were analyzed by ANOVA using Design Expert Software (version 6.0.7, USA), to evaluate the relations between different parameters in composting process. The data obtained were fit into a historical design following response surface methodology (RSM) for statistically evaluation of the data.

RESULT AND DISCUSSION

Physicochemical Property of Raw Materials: Certain physicochemical parameters were selected based on the effectiveness of some composting processes properties. The results obtained are tabulated in Table 2. Analysis of selected physicochemical properties of PL, EFB and frond indicated that PL contains high N and low carbon (C/N= 10.38:1). However, EFB shows different properties. Therefore, mixing two materials could provide better C/N and a more balanced nutrition for the microorganisms to carry out the composting process.

Table 2: Physico-chemical characterization of raw materials

Materials	Moisture (%)	EC (mS.m-1)	pH	C/N
Poultry litter	15.67	5.64	7.63	10.38:1
Empty Fruit Bunch (EFB)	15.73	2.68	6.8	38.4:1
Frond	48.75	3.05	6.6	63.08:1

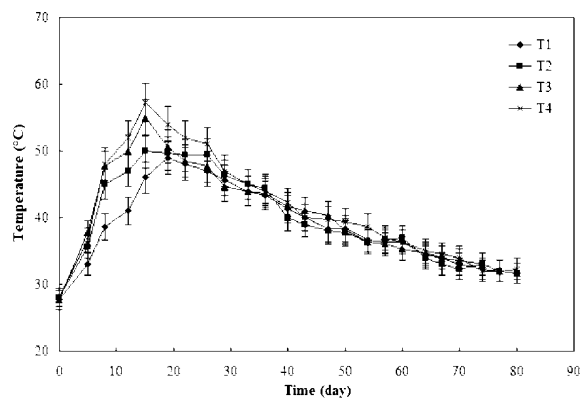


Fig. 1: Changes of temperature in composting in different ratio of POB and PL

Temperature Profiles and Moisture Content (MC):

Temperature is known to be a very important parameter in composting process. It is used to control the process by controlling the microbial activity and biological process during composting [14-17]. Variation in the temperature under different treatment conditions has been demonstrated in Fig.1. The initial temperature for all treatment was $30 \pm 1^\circ\text{C}$ while the, ambient temperature was measured to be $29 \pm 2^\circ\text{C}$. Due to the decomposing of organic matter and nitrogenous compounds, the temperature of all treatments increased to the thermophilic phase. All treatments demonstrated a sharp increase in the temperature to 49 - 57°C during the first two weeks and then decreased in all treatments until the end of process. The highest temperature recorded during treatments of run T₁ to T₄ were 49°C, 50°C, 55°C and 57°C, respectively. According to the results of a study carried out by Albuquerque *et al.* (2006) [18] the highest temperature in treatments confirmed their presence in the thermophilic temperature range between 40 to 65°C. Temperatures more than 55°C could destroy the

pathogenic microorganisms [19]. In this study, it was observed that in treatments T₁ to T₃ the compost did not exceed 55°C; this could be related to the small size of containers which made the heat transfer with the surrounding easier. Also, this phenomenon could be attributed to the high porosity of the material used. However, in T₄ the temperature reached to 57°C, which resulted in higher microbial activity as compared with treatment T₁, T₂ and T₃.

During the first 15 days, temperature in all treatments had a sharp increase up to 40 days. There was some fluctuation observed due to the high rate of biodegradation of organic matter by microorganisms during this time. After this period, the temperatures dropped to maintain at temperatures near ambient. This was due to the fact of complete biodegradation of organic matter, making the process stable. The temperature in T₁ increased to 49°C in the first 20 days, while in other treatments this happened in a shorter period of first 15 days. This slower increase in temperature in T₁ was ascribed to the insufficient microorganisms and nitrogen source available in the system (initial N=0.88). However, in other treatments, microorganisms and nitrogen compounds were available with addition of PL to raise biodegradation of organic matter which is the main reason of high temperature in T₄ (57°C) with a high level of confidence ($R^2=0.822$). Table 3 illustrates the regression analysis data for temperature, pH, EC, carbon percentage, nitrogen percentage and C/N ratio obtained for all treated samples. As shown in Table 3, for treatment 1, the obtained R^2 for the temperature gave of 0.93 indicates that 93% of the data were well described by the cubic polynomial model driven by the software to fit the experimental data.

In this study the initial value of moisture for all treatments was $41 \pm 1\%$ obtained during the composting process and the moisture content values dropped gradually to an adjusted optimum range (40-65%) by adding distilled water. According to previous studies the optimum range of moisture content for compost is between 40% - 65% [13-20]. Therefore, the MC value out of this range will affect the microbial activities due to

Table 3: Regression analysis between composting properties

Treated samples	Temperature		pH		EC		Carbon		Nitrogen C/N ratio			
	R ²	P value	R ²	P value	R ²	P value	R ²	P value	R ²	P value	R ²	P value
T 1	0.930	P<0.0001	0.727	P<0.0001	0.720	P<0.0001	0.990	P<0.0001	0.992	P<0.0001	0.992	P<0.0001
T 2	0.885	P<0.0001	0.822	P<0.0001	0.778	P<0.0001	0.965	P<0.0001	0.835	P<0.0001	0.835	P<0.0001
T 3	0.822	P<0.0001	0.474	P=0.0043	0.838	P<0.0001	0.997	P<0.0001	0.946	P<0.0001	0.691	P<0.0001
T 4	0.822	P<0.0001	0.833	P<0.0001	0.864	P<0.0001	0.996	P<0.0001	0.949	P<0.0001	0.929	P<0.0001

Property = A + B × Time + C × Time² + D × Time³ (time = composting time, day)

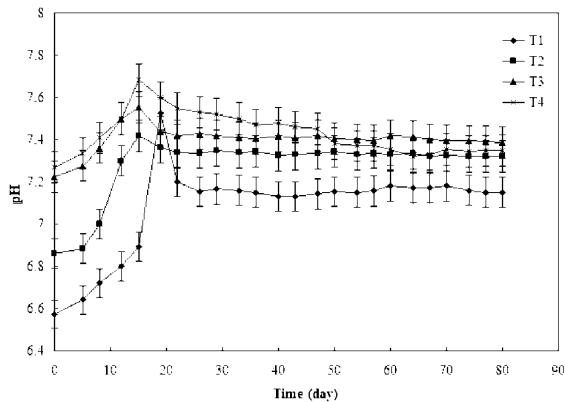


Fig. 2: Changes in pH value in composting in different ratio of POB and PL

higher value generation of anaerobic condition. However, lower MC value showed relatively lower microbial activities as well.

Evolution of pH and Electrical Conductivity: Fig. 2 shows the pH value in all treatments during the composting of POB and PL. The initial pH value of the material was ranged between 6.58 to 7.27. This amounts increased to the highest values of 7.52, 7.36, 7.43 and 7.60 for treatments T₁ to T₄, respectively. This increase was attributed to the release of the ammonia released by microbial activities [18, 21]. Thereafter, pH values decreased gradually and stabilize to near the neutral pH (7.15 to 7.38) until the end of composting process which is because of the formation of acidity condition during evaporation of water and the release of the carbon dioxide [21]. The relationships between time and pH were obtained for treatments during the process (Table 2). Results indicated that treatments T₂ and T₄ gave the best fitted equations for this study ($P < 0.0001$; $R^2(T_2) = 0.822$, $R^2(T_4) = 0.833$).

The electrical conductivity shows the amount of salinity in compost which influences the growth of plant if it is used in soil as a fertilizer [22-24] Compost production with high EC must mix with other compost with lower ECs to make it balanced. High EC is reported to be unfavorable for plants [25]. Fig. 3 presents the change of EC values under different treatment conditions in this study. Initial EC increased from 2.9, 3.7, 4.18 and 4.66 mS.m⁻¹ to reach a peak at values of 3.97, 4.98, 4.93 and 5.27 mS.m⁻¹ for treatments T₁ to T₄, respectively and then decreased until the completion of the process to give values of 2.8, 3.35, 4.28, 3.7 in that order. The initial increase in EC values is due to the loss of weight and

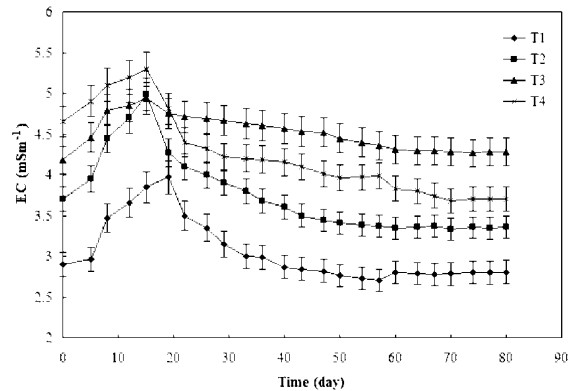


Fig. 3: Changes of electrical conductivity during the composting in different ratio of POB and PL

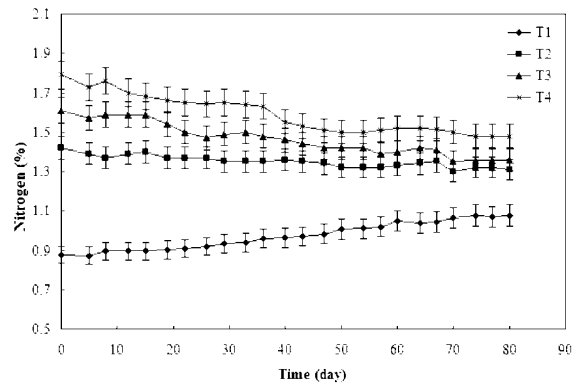


Fig. 4: Changes of nitrogen during the composting in different ratio of POB and PL

release of other mineral salts through the decomposition of organic matters [26]. The reduction was caused by volatilization of ammonia and the precipitation of mineral salts. For mature compost, the proper amount for EC is less than 4 mS.m⁻¹ [27-23]. However, in this study almost all treatments are in suitable range except treatment T₃ that is above the range.

As observed in Table 3, the relationship between EC and time was statistically significant for treatments T₁ to T₄ showing a P-value of < 0.0001). The models derived by the software could support the experimental data with high coefficient of determinations (> 0.8). Experimental data from treatment 4 showed the best fitting to the model ($R^2 = 0.864$).

Changes in Nitrogen Concentration: Fig. 4 shows the change of nitrogen concentrations for different treatments. It is observed that total nitrogen in treatments T₂ and T₃ decreased during the composting

process. This reduction was linked to the high initial ammonia concentration and possibly the presence of easily mineral soluble N compounds, such as uric acid. Such compounds could be easily released during the initial phase of composting. The use of poultry litter in composting led to discharge of enormous amount of N during the process and consequently, enhancing the quality of the mature compost [6, 28]. Total N losses recorded during the composting process ranged from 7.75% to 17.32%, in treatments T₂ to T₄, respectively. Usually nitrogen losses are related to the initial C/N ratio, pH value and also degradation of organic matter in the composting mixtures. Initial C/N ratio indicates ratio of available carbon to available nitrogen. Optimum range of C/N ratio (25 to 30) is the best ratio for composting which causes the conservation of nitrogen, binding it in cell material and preventing its escape. Increasing the pH is due to the nitrogen losses as ammonia hydroxide. Materials which contain high amounts of organic matter have high pH also lead to loss of more nitrogen [6, 28]. In treatment 1, nitrogen value increased from 0.88 to 1.08 which was due to dry mass weight reduction caused by degradation of organic carbon compounds [15]. Table 3 shows the statistical relation between time and nitrogen value in this process. According to Table 3 it is observed that the data for treatment 1 were well fitted to the polynomial model with high level of accuracy R²= 0.992 for both nitrogen and C/N ratio.

Changes in Carbon to Nitrogen ratio: Fig. 5 presents the total organic carbon of the material during the composting process. It is observed that the amount of TOCs decreased from initial values 48.87%, 41.50%, 40.05% and 39.22% to 39.83%, 34.25%, 30.88% and 26.6% for treatments T₁ to T₄, respectively. This drop is possibly due to the microbial activity, which consumes the carbon as a source of energy. This leads to production of heat and carbon dioxide (CO₂) [29].

The C/N ratio is one of the important key factors in mature compost which reveals the degree of decomposition of materials [30]. During the composting process the C/N ratio decreased gradually in all treatments as could be observed in Fig.6. This pattern is due to the mineralization of the organic matter by microorganisms [19]. The initial C/N ratios of T₁ to T₄ were 55.81, 29.22, 24.88 and 21.91, respectively. The C/N ratio of the compost for treatment T₁ even after 80 days still was higher than other treatments, which was because of the lower microbial degradation activity as compared to the

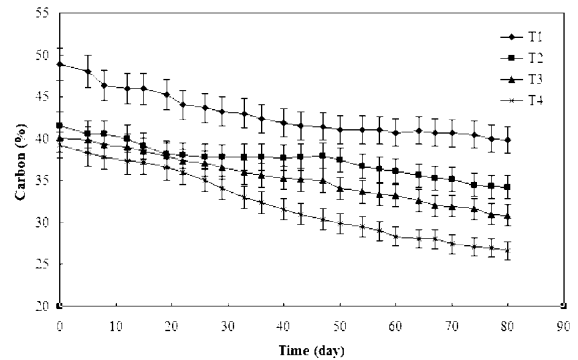


Fig. 5: Changes of carbon during the composting in different ratio of POB and PL

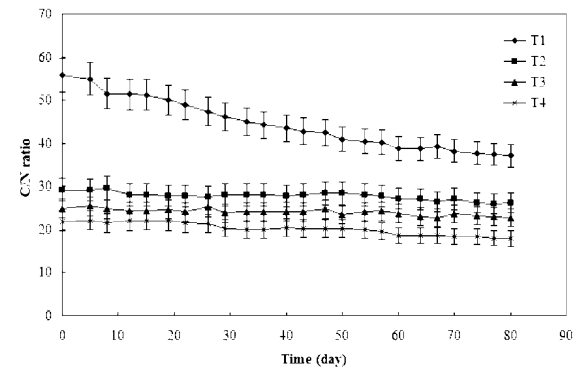


Fig. 6: Changes of C/N ratio during the composting in different ratio of POB and PL

other treatments. According to Shilev *et al.*, (2007) [27] the C/N ratio for mature compost should not exceed 25. In T₂, the final C/N ratio was 26.1% which was found to be outside the suitable range for mature compost. TKN could affect the C/N ratio directly. In a constant amount of carbon the higher the amount of nitrogen is the smaller will be this ratio. The C/N ratio in treatments T₃ and T₄, were measured to be 22.7 and 17.6, respectively showing a suitable value as a mature compost.

CONCLUSION

In this experiment, the effect of using poultry litter in palm oil biowastes composting was studied. Results demonstrated that PL is a suitable nitrogen and microbial source for enhancing the composting of POB. It was observed that all treatments reached to thermophilic phase. The EC and pH first increased and then decreased, attaining to optimum range 2.8 to 4.28 mS.m⁻¹ and 7.15 to 7.38, respectively. The TOC, TKN and C/N ratio reduced

to the appropriate amounts of 26.6 to 39.8, 1.08 to 1.84 and 18 to 37.1, respectively. Nevertheless, treatment 4, showed the best results among all treatments. For T₄ the temperature was found to be 57°C, EC 3.7 mS.m-1, pH 7.3, TOC 26.6%, TKN 1.48% and C/N ratio was fixed at 18. As a conclusion POB is a low cost abundantly available material to be converted to compost as a method of waste treatment.

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