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Production of Compost from Palm Oil Mill Biogas Sludge Mixed with Palm Oil Mill Wastes and Biogas Effluent

Tanawut Nutongkaew[1], Wiriya Duangsuwan[1], Suteera Prasertsan[2], Poonsuk Prasertsan[1, 3, *]

[1] Department of Industrial Biotechnology, Faculty of Agro-Industry, Prince of Songkla University, Songkhla 90112, Thailand
[2] Department of Mechanical Engineering, Faculty of Engineering, Prince of Songkla University, Songkhla 90112, Thailand
[3] Palm Oil Products and Technology Research Center (POPTEC), Faculty of Agro-Industry, Prince of Songkla University, Songkhla 90112, Thailand
[*]Corresponding author: Tel: +66 7428 6369, Fax: +66 7455 8866,
E-mail: poonsuk918@yahoo.com

Abstract – Analysis of composition of palm oil mill wastes for compost production revealed that palm empty fruit bunches (PEFB) contained the highest total organic carbon (52.83% dry weight), palm oil mill biogas sludge (POMS) and decanter cake (DC) had high total nitrogen (3.6% and 2.37% dry weight, respectively), while palm oil fuel ash (POFA) contained high amount of phosphorus and potassium (2.17% and 1.93% dry weight, respectively). The effect of mixture ratio of POMS and palm oil mill wastes was studied using the mixed culture Super LD1 from Land Development Department as an inoculum. The compost turned to dark brown and attained an ambient temperature after incubation for 40 days. The pH values were stable in the range of 6.9-7.8 throughout the process whereas the moisture content tended to decrease till the end with the final value around 30%. After 60 days incubation, the mixture ratio of POMS: PEFB: DC at 0.5:0.25:0.25 with the addition of biogas effluent (treatment D) gave the best qualities of compost with 31.75% higher nitrogen content than the other treatments. Furthermore, the amount of nutrients (3.26% N and 0.84% P) was higher than the level required for plant fertilizer (0.5% N, 0.5% P) therefore, meet the compost standard.

***Keyword**: Palm Oil Mill Biogas Sludge**;** Composting; Palm Oil Mill Wastes; Empty fruit bunch*

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1. Introduction

Wastewater treatment or biogas production in palm oil mill generate huge amount of sludge every year. This palm oil mill biogas sludge (POMS) from anaerobic reactors contains high moisture content and low carbon content, due to the high nutrient value [14]. POMS is usually discharged to sand bed and dried, then used as fertilizer. However, this process becomes problem during rainy season due to slow rate of drying. Alternative approach to utilize POMS is proposed in this study by mixing with other palm oil mill wastes such as empty fruit bunches (EFB), decanter cake (DC), palm pressed fiber (PPF) and palm oil fuel ash (POFA). Utilization of these wastes, instead of left them unused, could reduce environmental and lifestyle qualities in nearby communities [13] as well as within the palm oil mill .Since these wastes have a high content of organic matter and mineral elements, they can potentially be used to restore soil fertility [11].

Co-composting of POMS with palm oil mill wastes and treated biogas effluent (BE) was proposed to be one option for waste utilization and could offer many environmental and economic benefits. In addition, this process is also a good approach from the standpoint of bioprocess, because POMS has high nutrient and moisture content but low carbon to nitrogen ratio (C/N), whereas palm oil mill wastes have the opposite properties. So, mixing the two types of materials can provide better moisture content and more balanced nutrients for the microorganisms to carry out the composting process.

Composting is useful for waste recycling and produces a chemically stable material that can use as a source of nutrients and for improving soil structure [11]. It has been widely used for converting organic wastes into relatively stable products for use as fertilizer or soil amendment. Composting process is influenced by a number of factors. The most important factors include temperature, moisture content, carbon to nitrogen ratio, degree of aeration rate, pH level, and the physical structure of the raw material [6]. The final compost is stable for storage and application to land without adverse environmental effect [9].

The aim of this present study was to investigate the changes in physicochemical and biological properties of co-composting of palm oil mill biogas sludge with palm oil mill wastes at different mixing ratio.

2. Materials and Methods

2.1. Raw materials

Palm oil mill biogas sludge (POMS), biogas effluent (BE), decanter cake (DC), palm oil empty fruit bunches (PEFB) and palm oil fuel ash (POFA) were collected from palm oil mills in Southern Thailand. They were measured for pH and determined for moisture content, organic matter (OM), total organic carbon (TOC), ash, phosphorus (P), total Nitrogen (TN) and potassium (K)

2.2. Experimental set up

The mixing ratio among waste materials used are presented in Table 1. Seven grams of Super LD1 was used as an inoculum, treated BE to adjust the moisture content to 60-70% (by weight) and added POFA to adjust pH to 7-7.5. After well mixing, each treatment materials was put in a reactor (0.60 m W × 1.0 m L × 0.60 m H) with an initial total weight of 50 kg. During 60 days incubation period, the BE was used to keep the final moisture content of 60-70% and turned of each pile every 10 days for aeration. The turning process could maintain the distribution of moisture, oxygen level and prevent the build-up of heat. The addition of BE was stopped 1-2 weeks prior to harvesting in order to avoid the final product from being too wet.

Table 1. Summary the employed compost treatment

Compost treatment	POMS:PEFB:DC ratio
A: POMS	1.0:0:0
B: POMS+PEFB	0.5:0.5:0
C: POMS+DC	0.5:0:0.5
D: POMS+PEFB+DC	0.5:0.25:0.25

Palm oil mill biogas sludge (POMS); palm oil empty fruit bunches (PEFB); decanter cake (DC)

2.3. Sampling

Temperature was measured at core of the reactor every day. Sampling of compost was collected at different locations (the center of the four sides of each reactor/pile). The mixture was manually mixed. The pH and moisture content were determined every 5 days. The organic matter, TOC, and TN were determined on day: 0, 10, 20, 30, 40, 50 and 60. Phosphorus and potassium were determined every 20 days. All experiments were done in triplicates.

2.4. Analytical methods

Thermometers were used for temperature measurement at center point of the piles. The compost pH was determined by adding 10 g sample to 100 ml distilled water, mixed well on a rotary shaker for 30 min before measured by using pH meter. For moisture content, the mixture samples were oven-dried at 105 °C for 24 h [1]. Oven-dried sample were finely ground to represent the whole sample. The organic matter (OM) was determined as volatile solid. Ash content was determined by burning sample at 600 °C for 3 h [1]. Total organic carbon (TOC) was determined by the following formula [4]:

$$TOC (\%) = Organic\ matter (\%) / 1.8$$

Total nitrogen (TN) was determined using the Kjeldahl method [1] with C to N ratio determined as TOC/TN. Phosphorus (P) and potassium (K) was determined using $HNO_3/HClO_4$ Digestion [1]. Chemical oxygen demand (COD) was determined using commercial test kits from Spectroquant (Merck Ltd., Germany). The data were the average of three replicates and the standard deviation (±SD).

3. Results and Discussion

3.1. *Characteristics and chemical composition of raw materials*

The chemical compositions of raw materials are shown in Table 2. The content of TOC of the PEFB (52.83%) was highest while the nitrogen content of the POMS (3.6%) was highest compared to those of the other raw materials. POFA contained high amount of phosphorus (2.17%) and potassium (1.93%). The C/N ratio of POMS, PEFB, DC and BE were 10.12, 58.70, 20.14 and 1.21, respectively.

Table 2. Characteristic and chemical composition of the POMS, PEFB, DC, POFA and BE

Composition	Raw materials				
	POMS	PEFB	DC	POFA	BE
pH	8.41	6.35	4.81	10.00	7.58
Moisture (%)	22.23±0.72	45.51±0.94	78.42±0.12	ND	ND
TOC (%)	36.06±0.03	52.83±0.05	47.73±0.11	-	ND
TVS (%)	64.91±0.06	95.10±0.08	85.92±0.21	13.27±0.75	ND
Oil & grease (%)	1.15±0.03	1.85±0.10	0.92±0.12	0.65±0.06	ND
Nitrogen (%)	3.6±0.30	0.9±0.10	2.37±0.10	-	1,880*
Phosphorus (%)	1.58±0.09	0.37±0.03	0.33±0.03	2.17±0.01	15.9*
Potassium (%)	1.72±0.10	1.73±0.04	0.85±0.10	1.93±0.11	2.00±0.9
Ash (%)	35.09±0.06	4.90±0.08	14.08±0.21	86.73±0.75	ND
COD (mg/L)	ND	ND	ND	ND	2,270
C/N	10.12	58.70	20.14	-	1.21

ND: Not detect, *mg/L, Percentage (%) was based on dry weight

3.2. *Temperature and pH distributions of compost materials with time*

Temperature is the most important indicator of the efficiency of the composting process and a maximum temperature of 55-65 °C is necessary to destroy pathogens, but mesophilic temperature of 45-55 °C must be maintained for maximum biodegradation [6]. However, composting temperature must not be too high as this could kill almost all microorganisms and cause the process to cease. In this study, analysis of variance for the temperature of the compost with respect to fermentation time (day) was carried out. The changes in the mean temperatures of 4 treatments are shown in Fig. 1a. The initial temperatures of all treatments were 28 °C and increased quickly during the first day? of composting. The mean temperature of treatment B and D increased sharply to the maxium values of 44.66 and 49 °C, respectively, within the first 2 days incubation. This indicated that the microbes in treatment B and D were more active in the decomposition process than treatment A and C. After reaching the maximum values, the temperature of all 4 treatments decreased sharply. The temperature of compost decreased after adding the BE and turning the piles At the end of composting (60 days), the average temperature in the core of all composts attained ambient temperature (29 °C) which indicated a good degree of stability [10].

The changes in the pH of the 4 treatments followed the same trend as shown in Fig. 1b. Addition of BE to enrich the compost also contributed to the neutral or slightly alkaline condition (pH 6.91-7.82) of the 4 treatments at the end of composting.

3.3. *Moisture content distributions of compost materials with time*

The moisture content was the critical factor that determined the decomposition rate in composting. According to Luo *et al.* [8], microbial dependability of water to support growth could affect biodegradation of organic matters. Moisture content of 50-60% range is recommended for composting [2]. Nevertheless, the ranges of 60-75% enhance maximum microbial activities [7]. In this study, BE was added onto the composting materials to keep the moisture content at 60-70%. The results of the analysis of variance for the moisture content of the compost with respect to time (day) are shown in Fig. 1c. The mean initial moisture content of all composts was in the range of 50-65% and gradually decreased in the later stage of composting process. Turning the piles every 10 days was appropriated to control the aeration of the composting piles. The low oxygen levels would slow the decomposition and increased the opportunity for adsorption of ammonia onto solid materials leading to immobilization [2].

3.4. *Nitrogen and carbon distributions of compost materials with time*

The nitrogen in this study was gradually increased throughout the composting process. The nitrogen content in the range of 2.1-3.8% at the beginning was increased to2.8-4.17% at the end of the composting process (Table 3). The nitrogen content of treatment D increased 31.75% (from 2.47% to 3.26% N) that was higher than those of other treatments (Fig. 2a). In addition, carbon content of the composting materials was gradually decreased throughout the treatment (Fig. 2b). This phenomenon may be the result of microbial growth and production of enzymes using the cellulose as a carbon source [2].

Compost maturity and stability are the key factors during composting. C/N ratio is always used as an indicator of compost maturation and should be stable with time [2]. In this study, high C/N ratio of PEFB (52.83%) could be reduced to a more appropriate level by the addition of nutrient supplement (such as partially treated BE) or urea. The C/N ratio of composting material was around 36 at the beginning, then dropped to less than 20 after 40 days of composting and continued decreasing afterwards. C/N ratio less than 20 could be considered as a satisfactory maturation level of compost [12] and this value is also stated in the compost standard.

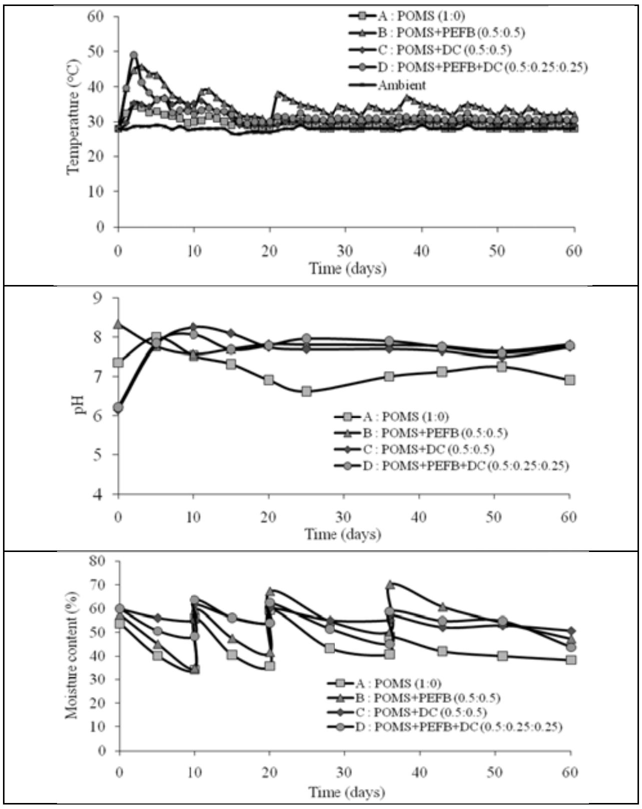

Figure 1. Profiles of compost temperature (a), pH (b) and moisture content (c) throughout composting process by co-composting of palm oil mill biogas sludge mixed with palm oil mill wastes and added biogas effluent

3.5. *Final chemical compositions of the matured compost*

A change in color and texture properties of composting material was observed throughout the composting process. All composts appeared to be dark brown in color, soil texture and had an earthy smell at 60 days. The final chemical compositions of the matured compost were displayed in Table 3. It was found that the mean value for nitrogen, phosphorus and potassium of treatment D (i.e., POMS: PEFB: DC; 0.5:0.25:0.25 and added BE) gave the best results.

The compost of POMS mixed with palm oil mill wastes was compared with those of some other compost (Table 4). Due to the drastic differences in conditions, substrate and other process conditions, so it was difficult to compare the nutrients (N, P and K). Nevertheless, the characteristic values of compost of POMS mixed with palm oil mill wastes were generally similar to or better than most other composts.

The results obtained in this study indicated that the final compost product was suitable for plant nutrients, safe and no detrimental effect.

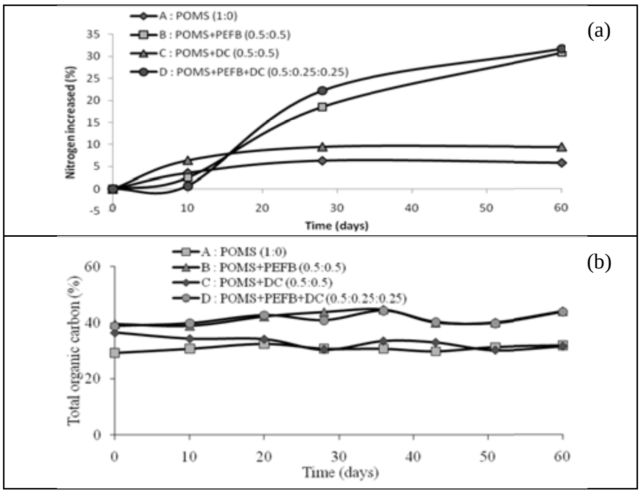

Figure 2. Profiles of compost nitrogen (a) and total organic carbon (b) throughout composting process by co-composting of palm oil mill biogas sludge mixed with palm oil mill wastes and added biogas effluent

Table 3. Final characteristic and chemical composition of the matured composts

Element of compost standard	Treatment			
	POMS (1:0)	POMS+PEFB (0.5:0.5)	POMS+DC (0.5:0.5)	POMS+PEFB+DC (0.5:0.25:0.25)
C:N ratio (<20:1)	8.17	15.77	7.57	13.47
TN % (>0.5%)	3.90	2.80	4.17	3.26
P_2O_5 % (>0.5%)	1.21	0.74	1.00	0.86
Moisture content % (<30%)	38.35	47.35	50.70	43.77
Organic matter % (>25%)	57.36	79.38	56.83	78.99
pH (6.0-8.0)	6.92	7.82	7.75	7.79

Percentage (%) was based on dry weight

Table 4. Chemical composition of the compost using different substrates

Substrates	Nutrients (%)			Final	End time	Reference
	N	P	K	C/N	(days)	
PEFB:Partially treated POME	2.2	1.3	2.8	12.7	60	[2]
PEFB:POME:DC (1.58:1.0:1.28)	2.5	1.18	2.9	18.65	51	[13]
OPMF:POME anaerobic (1:1)	1.9	0.3	1.2	12.6	50	[3]
Pig manure:Sawdust (4:1)	3.25	1.12	-	9	63	[5]
POMS:Sawdust (1.8:1)	-	0.9	1.6	19	300	[14]
POMS:PEFB:DC (0.5:0.25:0.25)	3.26	0.86	-	13.47	60	This study

4. Conclusions

The best compost was obtained by mixing POMS with palm oil mill wastes with the ratio POMS: PEFB: DC of 0.5:0.25:0.25 and added BE.The amount of its nutrients was higher than the level required for plant fertilizers.

5. Acknowledgment

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