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Sludge Composting: A Case Study on Palm Oil Mill Sludge (PO*ms*)

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Current disposal technology for palm oil mill sludge (POMS) creates problems such as sludge flooding insects, and bad odor mainly during the rain season. This study we present in-vessel composting system as an alternative process for disposal of POMS. Maximum temperature achieved for reactor was about 40^{0}C. It can be verified that the composting process followed first order kinetic equation with degradation rate $k = 0.014$ day^{-1} with maximum degradation rate of 51%. POMS compost has potential to improve performance of *C. citratus* growth in sandy soil that usually lacks nutrients and has poor soil structure.

Keywords: compost, passive aerated, palm oil mill sludge (POMS), sawdust

INTRODUCTION

Composting is a microbial technology that is used to stabilize many types of industrial sludges from pulp and paper mill, sugar, oleochemical, pig rearing, and olive milling. Composting is attractive because it can reduce the volume/ weight of sludge. Besides that, the composted sludge is easy to handle and can be used as soil conditioner, thus providing additional income (Rahman, Kahlil, and Yaser 2003).

Palm oil mill effluent (POME) is generated mainly from the oil extraction, washing, and cleaning up processes in the mill that contains and, hence, will contain cellulosic material, fat, oil, and grease (Agamuthu, 1995). Currently, most palm oil mill wastewater treatment methods are comprised of anaerobic pond/digester followed by either aerobic pond or aerobic and facultative pond. Biological treatment and presence of suspended solids from influent generated palm oil mill sludge (POMS) that accumulate at the bottom of the digester/pond must be desludged after undergoing biological treatment to maintain the efficiency of wastewater treatment. In Malaysia, POMS is usually dried up and then used as fertilizer. Drying is done in open ponds, but during the rainy season, the process creates problems such as sludge flooding, insects, and bad odor.

On another note, the burning of sawdust from sawmills and furniture industries can also create air pollution problems. Mixing POMS with sawdust can improve the efficiency of the composting process by increasing porosity, retaining nutrient, reducing odor, and providing additional carbon (Bhamidimarri and Pandey 1996). Using sawdust as amendment in compost mixture can also reduce air pollution.

METHODOLOGY

Materials and Bioreactor

Sludge from an anaerobic digestion pond was collected from Sri Ulu Langat Palm Oil Mill in Dengkil, Selangor, Malaysia. Sawdust was collected from various furniture factories around Bangi, Selangor. Then 52kg sludge and 28kg sawdust were manually mixed. Mixture of POMS–sawdust was put in $0.3m^3$ bioreactor. Experiments were done in duplicate. The physicochemical analysis of the mixture is shown in Table 1. The bioreactor was made from cylindrical polyethylene vessel measuring 0.9m (height) by 0.6m (diameter). For aeration purposes, holes with 2cm diameter each were made at the bottom of the bioreactor (Figure 1).

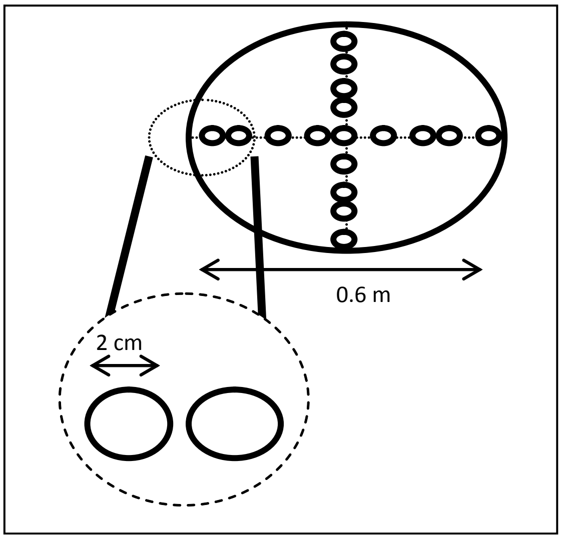

Figure 1. Bottom View of In-vessel System

Pot Trial

Pseudostems of *C. citratus* were bought from market and submerged in tap water. After 3 days, *C. citratus* plants that had leaves approximately 0.5 cm long and roots approximately 0.5cm long

Table 1. Physicochemical Analysis of Initial POMS–Sawdust Mixture

Parameter	POMS	Sawdust	POMS–Sawdust
Moisture content, %	85±3.5	10±0.7	58±4.9
Wet bulk density, kg/m^3	1100±21.2	100±7.1	400±35.4
pH	8.4±0.1	5.8±0.1	7.5±0.1
Organic matter, % dry weight	60±3.5	100±7.1	84±3.5
Total Nitrogen (TN), % dry weight	3.6±0.3	0.1±0.1	1.9±0.1
C/N	9	550	25

were transferred to 2-liter plastic pots. The pots were filled with different volumes of sand (bought from a hardware shop) and compost or sludge. The plants were placed on the cement floor put under the sun, and watered with distilled water every 2 days. No additional nutrient was added to the distilled water. After 2 months, the plants, excluding roots, were harvested, dried, and weighted by putting the leaves and pseudostems in a beaker. All experiments were done in six replicates.

Sampling and Analysis

Sampling was done by taking 40g of compost at four different heights (0, 0.3, 0.6, and 0.9m from bottom of the bin). The mixture was manually homogenized. Wet density was estimated by filling a 500mL beaker with material (Schulze, 1962). The pH was determined by adding 5g sample to 50mL distilled water, mixed with magnetic stirrer for 20min, let stand for 24h, and then filtered (Barrington et al. 2003). The supernatant was tested using pH meter (HI 931401, Microprocessor, pH meter, Hanna Instrument Ltd). For moisture content, the mixture was ovendried at 103^{0}C for 24h. Ovendried samples were finely ground and screened to <0.5 mm to represent the whole sample homogenously. The organic matter (OM) was determined as volatile solid. Ash content was determined by burning dried sample at 550^{0}C for 4h (APHA 1985). Total nitrogen (TN) was determined using the Kjeldahl method (Rowell 1994) with C to N ratio determined as TOC/TN. After HCl digestion, *P* was determined volumetrically as ammonium phosphomolybdate and *K* was determined using the cobaltnitrite method (Iswaran 1980). Water-holding capacity and pore size were determined using the Keen-Rackzoowski Box method (Iswaran, 1980). Total organic carbon (TOC) was determined by the following formula (Hoyos et al, 2002):

$$\%\,TOC = \%\,\text{Organic matter}/1.8 = \%\text{Volatile solid}/1.8 = (100-\%\text{ash})/1.8 \qquad (1)$$

Organic matter loss was determined using a formula given by [Paredes et al. 2000]:

$$\text{OM loss } (\%) = 100 - 100 \times (A/B) \qquad (2)$$

where,

a = %Initial ash content x (100 – %Final ash content), and

b = %Final ash content x (100 – %Initial ash content).

RESULTS AND DISCUSSION

Temperature Evolution

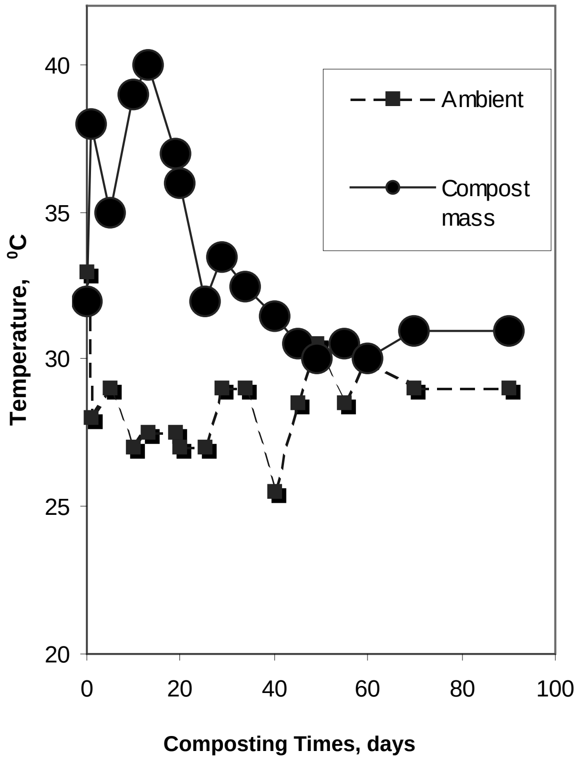

Figure 2. Evolution of Temperature during POMS–Sawdust Composting Process

Temperature is the main indicator for a composting process (Nogueira, Noguierra, and Devens 1999). From Figure 2, the maximum temperature for reactor was about 40 ^{0}C. Secondary peaks in temperature were possibly due to mesophilic organisms recommencing activity. Distinct troughs in the temperature may also be due to the excessive presence of ammonia and phenols, which inhibit bacterial growth and activity. Once most of the ammonia and phenols are released to the air, the bacterial population can resume growth, thus causing minor peaks in temperature (Liao, Vizcarra, and Lo 1994). To achieve temperatures reaching 50^{0}C, more biodegradable carbon sources such as sucrose or green wastes need to be added to the compost mass (Qiao and Ho 1997).

Kinetic Study

From an engineering point of view, kinetics is one of the important factors for scaling up reactor to a larger unit (Levenspiel 1999). The composting of most substrates is characterized by an initial period of rapid degradation followed by a longer period of slow degradation (Diaz et al. 2002). From Figure 3 it can be seen that organic matter is found to be lost in the POME–sawdust compost bed. The OM degradation profile during composting, as determined by OM loss, follows a first order kinetics equation:

$$OM\ loss = A\ (1-e^{-kt}) \qquad (3)$$

where A is the maximum degradation of OM (%OM): k, the rate constant (day^{-1}); and, t, the composting time (day).

Curve fitting of the experimental data which gave the following parameter values: it is justified by r^2,

A = 51.0%

r^2 = 0.9926

FitStdErr = 1.7712

k = 0.014 day^{-1}

DF adj r^2 = 0.9905

Fstat = 1078

Several researchers also found that composting followed first order for OM degradation (Table 2).

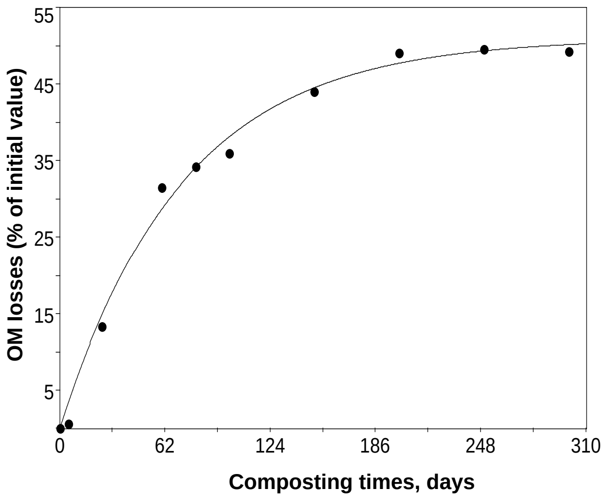

Figure 3. Organic Matter Losses during POMS–Sawdust Composting

Table 2. Degradation rate for various substrate and system

Substrate	Aeration System	A, %	k, day^{-1}	Reference
POMS+SD	Passive	51.0	0.014	This study
SS	Turned	50.0	0.050	Lasaridi Stentiford, and Evans 2000
CW+OMWS	Forced	67.1	0.018	Paredes et al. 2002
PM+CW+OMWS	Forced	55.0	0.059	Paredes et al. 2000
SS+MS+OMWS	Forced	72.5	0.023	Paredes et al. 2000

A – Maximum degradation of OM (%OM), CW – Cotton waste, K – Rate constant (day^{-1}), MS – Maize straw, OMWS – Olive mill wastewater sludge, PM – Poultry manure, POMS – Palm oil mill sludge, and SD – Sawdust

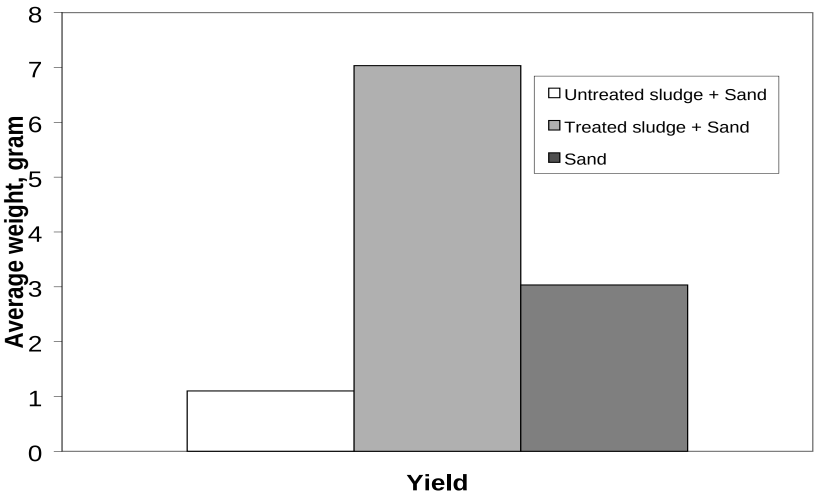

Figure 4. Effect of Untreated Sludge with sand, treated sludge (compost) with sand, and sand (control) on *C. citratus* yield

Citratus Growth in Sand with POMS compost

From Figure 4, the plant that grew on untreated sludge media had the lowest yield (i.e. combination of pseudostems, leaves, and roots) compared with treated sludge and sand alone. Jimenez and Garcia (1989) stated that unstabilized waste causes a reduction in the metabolic rate of plants and a decrease in root respiration, nutrient synthesis, and absorption capability. Other than that, the transportation of cytokinin and gibrelin slows down.

C. citratus in media with treated sludge (compost) has the highest yield, possibly due to the stabilized nutrient content of the compost (Table 2). Table 2 also shows that the nutrient content in POMS compost is comparable with other industrial sludge compost. Nogueira Nogueira, and Devens (1999) stated that good compost should have a P and K content of more than 0.5% and 1.5% respectively. Thus, POMS compost shows the potential to improve the performance of *C. citratus* growth in sandy soil that usually lacks nutrients and has a poor soil structure.

CONCLUSION

During the composting process in an in-vessel system, the maximum temperature for the reactor was about 40^0C. The OM degradation profile during composting, as determined by the OM loss, followed a first order kinetic equation with a degradation rate of 0.014 day^{-1} and a maximum OM loss of 51%. Palm oil mill–sawdust compost mixed with sand improved the growth of *C. citratus*. Thus, composting can be a suitable method for converting palm oil mill sludge into compost that can be used as a pot/container growing medium.

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