Effects of Composting on the pH and NPK Contents of Palm Oil Mill Effluents (POME)

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Abstract

Decomposition of palm oil mill effluent (POME) is as an essential process in reducing its inhibitory effects on plant growth and also in influencing the release of nutrients such as N and P to the growing plants. This study was carried out at the Teaching and Research Farm of Ekiti State University, Ado-Ekiti to monitor the effects of composting on some chemical properties of POME. Palm Oil Mill Effluent was measured on two separate heaps each of 1 m tall and 1.5 m wide. Sawdust was mixed with POME in one of the heaps at the ratio 1:1. The heaps were turned and watered weekly. The temperature of the heaps was measured at a week interval; before each turning and watering. Samples were taken from each of the heaps for analysis after each turning. Results indicated that change in pH was inconsistent but the trend indicated increase in values with the weeks of composting with a notable decrease recorded at 11 and 14 weeks of composting. N values recorded for all samples during composting were lower than the fresh POME except for POME + Sawdust at 13 weeks into composting whose N value was higher than fresh POME. The highest N recorded was from POME + Sawdust at 13 weeks into composting. P in the composts were positively affected by composting, as P values in the two compost forms were higher than the P content of the compost materials throughout the weeks of composting. This is an indication that composting of POME is necessary to improve the P content of POME which was low. Values of K obtained throughout the period of composting were higher than the initial K values obtained for the compost materials (POME and sawdust); an indication that composting of POME had reasonable positive effects on the K content of POME. Composting of POME is therefore recommended for its better performance as nutrients source and also a sustainable fertility management strategy for crop production.

Keywords: Composting, inhibitory effect, nutrient content, palm oil mill effluent,

Introduction

The threat to sustainable crop production is nutrient depletion and its accentuation where the low native soil fertility has emanated from intensive weathering and leaching such that land development and the adoption of poor bush fallow practices destroy the fertility restoration mechanisms and predispose the land to soil erosion (Zingore *et al*., 2003). The resultant negative nutrient budgets from natural nutrient cycling processes cause declining yields of crops and reduction in food production which make the addition of nutrients from external sources the path to tread. This is because rapid and uninterrupted growth and development through which crops would manifest full yield potentials and profitable production would require addition of adequate amounts of nutrients through the use of inorganic or organic fertilizers.

The application of inorganic fertilizer enhances crop growth and nutrient uptake through the increased availability of nutrients needed for larger dry matter production and yield (Isherwood, 2000). However, the crop yield response to inorganic fertilizer follows the law of diminishing returns which is responsible for decrease in the yield value per unit material at the higher application rates. The indictments include: poor crop quality, disease susceptibility and environmental pollution even as the continuous application of inorganic fertilizers at high rates have reduced microbial population and soil organic carbon content, increased soil acidity and caused the degradation of soil physical properties and increased rate of erosion due to instability of soil aggregates (AdeOluwa and Adeogun, 2010). Besides, the use of inorganic fertilizers has become very expensive to resource poor farmers in Nigeria because of scarcity engendered by deregulation of fertilizer marketing (Banful *et al.*, 2010), hence the need to search for alternative cheaper sources of nutrients.

Large quantities of organic waste materials are generated in the agricultural value-chain and several studies have demonstrated the positive effects of the application on soil properties and crop performance which supported the use as soil amendments (Hossain *et al.*, 2017). The benefits include: higher availability of plant nutrients, better water holding capacity, cation exchange capacity (CEC), lower bulk density and fostering beneficial microorganisms (Pimentel *et al.*, 2005); pH stabilization and faster water infiltration rate due to enhanced soil aggregation (Pacini *et al.,* 2003; Wood *et al.*, 2005); increase in the soil organic matter and reduced nitrate runoff (Drinkwater *et al.*, 1998). The activities relevant to the palm oil value-chain generate huge wastes and one of these is the focus of this study.

Palm oil is the edible oil that can be extracted from the fleshy mesocarp of the fruits contained in the fresh fruit bunch of the oil palm tree (*Elaeis guineensis*). The oil palm is one of the priority crops to benefit from the policy thrust and objectives in the Agriculture Promotion Policy 2016-2020 and whose expansion in production to meet domestic supply and export potentials would diversify the economy from petroleum products (FMARD, 2016). The establishment of plantations in about 24 states where oil palm production can be supported by the agro-ecological conditions will mean the adoption of oil extraction technologies that vary from manual processing techniques involving mortar and pestle to mechanized processing operations in mills attached to the plantations and estates (PIND, 2011). The basic steps: steam sterilization of bunches; stripping fruits from bunches; crushing, digesting and heating of fruits; extracting oil from macerated fruits with hydraulic press; and clarifying to obtain crude palm oil require large amounts of water, most of which ends up in the ensuing separated wastewater (palm oil mill effluent, POME) generated during oil extraction, washing and cleaning operations. POME is mainly the wastewater left in the container after the oil clarification in the manual processing sheds while mechanized mills generate steam condensate coming out of the sterilizer and clarification wastewater or separator sludge (Rupani *et al.*, 2010).

POME is brownish and acidic (pH=3.5-5.0) on account of the cellulosic materials, fat, oil and grease as suspended and total dissolved solids in the range of 18,000 and 40,000 mg L^{-1} respectively (Ma, 2000). Rupani *et al.* (2010) observed that POME consists of 4-5% soluble and suspended solids, 0.5-1.0% residual oil and 95% water. Oviasogie and Aghimien (2003) noted that POME contains vast amounts of nutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) which can enrich the soils such that proper land application would improve soil fertility and contribute to environmental sustainability. The disposal of this waste has usually involved discharge on land within the vicinity of the mill or in special pits (waste stabilization ponds) which can fill up and later drain to surface and underground water sources. POME indiscriminately discharged on land around mills killed vegetation on contact and resulted in clogging of soils and water logging; contaminated streams and rivers due to biological oxygen demand (BOD) in excess of 25,000 $mg.l^{-1}$ (Rupani *et al.,* 2010). The death of fauna and flora due to discharge on arable land is due to inhibitory effects of fresh POME on living tissues caused by the presence of lipids, volatile organic compounds, water-soluble phenolic acids, heat and acidity of the effluent (Komilis *et al.*, 2005; Perez *et al.*, 2007; Nwoko and Ogunyemi, 2010). MohdNazeeb *et al.* (1984) had observed that the presence of high lipid and volatile substances in POME could cause clogging of soil which subsequently inhibited root growth in oil palm seedlings. Thus, the discharge and disposal of untreated POME can have huge potentials as a land and water pollutant.

The growth of vegetables was reduced in soil to which undecomposed POME was applied which informed the option of normally leaving it to decompose in the soil for 4 to 6 weeks before use as an organic fertilizer or soil conditioner (Zulkifli and Rosmin, 1990). The organic acids produced during fermentation and the high organic content (cellulose, protein, fats, carbohydrates and minerals) make POME amenable for re-use in biotechnology (Habib *et al.,* 1997) and would favour its bio-degradation or conversion by microbial processes into useful and environment-friendly materials. The process of decomposition reduced the inhibitory effects of POME on plant growth and also ensured the release of essential nutrients into the soil (Hashim, 1990). The microorganisms identified during the different stages of POME decomposition include several fungal species which were probably responsible for breaking down the inhibitory compounds (Palaniappan *et al.*, 1984).Thus, one efficient treatment and effective disposal technique through which POME, as waste and a burden, can be turned into useful product is composting. This is nature's way of recycling nutrients as the process biodegrades bulky organic wastes under controlled aerobic conditions in heaps or pits and turns them into a valuable organic fertilizer (Müller-Sämann and Kotschi, 1994). The compost is smaller in volume/weight compared to the organic wastes and has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth through the improvement of the chemical, physical and biological characteristics of soils. The addition of compost to soils increases the fertility and can reduce the fertilizer requirements of crops by up to 50% (Isitekhale and Osemwota, 2010; Adediran *et al.*, 1999).

The oil processing mills in Ekiti State do not have facilities to treat the wastewater (slurry) but discharge it on the adjoining land or in small pits where the supernatant infiltrates into the soil leaving the solid portion (Palm Oil Mill Sludge, POMS). The POMS can be dried and used as fertilizer given its N, P_2O_5 and K_2O content at 3.6, 0.9 and 2.1% respectively (Rupani *et al.,* 2010) while composting would convert the high concentration of protein, carbohydrate, N-compounds, lipids and minerals into useful nutrients through microbial processes. The use of co-composting with other biodegradable wastes is recommended so as to attain the optimum C/N ratio of about 30 in compost (Müller-Sämann and Kotschi, 1994). The saw mills and furniture factories are sources of sawdust which is routinely burnt causing air pollution. Thus, the co-composting of sawdust-POMS mixture would mitigate pollution and improve composting efficiency. (Yaser *et al.* 2007) co-composted POMS-sawdust and obtained compost with comparable nutrient content and fertilizer value to industrial sludge composts. Since these agricultural by-products offer potentials as resources rather than wastes, the composts can be used as alternatives to expensive inorganic fertilizer for crop production. The objectives of this study therefore were to monitor the temperature, pH, N, P and K contents of POME and POME-sawdust during the weeks of composting.

Materials and Methods

The study was conducted at the Teaching and Research Farm, Ekiti State University, Ado-Ekiti. Ado-Ekiti (long. 7º47'N and lat. 5º22'E) and 456 meters elevation above the sea level. It is located in the dry forest zone and experiences a warm sub-humid tropical climate with a distinct bimodal rainfall pattern with mean annual rainfall of 1,367 mm received in 112 days between March and November. Palm Oil Mill Effluent (POME) was collected from a pit used for the discharge of the effluent in a Palm Oil Mill at Are-Ekiti, Ekiti State while sawdust was collected at Anisulowo sawmill in Iworoko-Ekiti.

The POME and sawdust were air-dried and analyzed for nutrient contents using the standard methods described in Udo *et al.*, (2009). Each sample 0.5 g was digested in a fume cupboard using a mixture of concentrated nitric acid (HNO_3) and concentrated perchloric acid ($HClO_4$) in ratio 5:1 respectively until a colourless liquid was obtained. Each digest was made to 50 ml with distilled water. The organic carbon was determined by wet chromic acid oxidation method while total N was measured by the micro-Kjeldahl method (Breminer and Mulraney, 1982). P content was determined by vanado-molybdate method while K and Na by flame photometry, Also, Ca, Mg and micronutrients (Fe, Mn, Cu and Zn) were determined by Atomic Absorption Spectrophotometer (AAS).

The POME was measured into a heap 1 m tall and 1.5 m wide while sawdust was mixed with POME in another heap at the ratio 1:1. The heaps were covered with thick polythene sheets to facilitate weekly turning and watering. The temperature of the heaps was measured and samples were taken for analysis before each turning and watering. The experiment was terminated when the temperature of both heaps became constant.

Results

Table 1 shows the nutrient contents of Palm Oil Mill Effluents and sawdust used for the study. The POME was moderately acid (pH=5.7) while the sawdust was moderately alkaline (pH=8.2). The N and P contents of POME were higher (at 23.3, 4.20 g kg^{-1}) than sawdust (1.4, 0.8 g kg^{-1}) respectively. The sawdust contained higher values of K and Ca (2.3 and 2.6 g kg^{-1}) than POME with 2.10 and 0.80 g kg^{-1} respectively. The respective micronutrients were higher in POME than sawdust.

Table 1: Some Chemical Properties of Palm Oil Mill Effluent and Sawdust

Parameters		Values	
		POME	Sawdust
pH		5.70	8.20
Nitrogen	(g/kg)	23.3	1.40
Phosphorus	" "	4.20	0.80
Potassium	" "	2.10	2.30
Calcium	" "	0.80	2.60
Magnesium	" "	1.80	1.10
Sodium	" "	0.03	0.01
Manganese	" "	2.10	0.33
Iron	" "	0.05	0.01
Copper	" "	0.05	0.02
Zinc	" "	0.40	0.30

POME = Palm Oil Mill Effluent

The effects of composting time on the temperature of the compost heaps are shown in Fig. 1. The temperature at the onset of composting was 28ºC for both heaps but rose to 47ºC and 49ºC after week 1 and to 57ºC and 64ºC after week 2 of composting for POME and POME-sawdust heaps respectively. Thereafter, the temperature decreased progressively until it became constant at 27ºC in the heaps after week 14 and 15 of composting as turning and watering no longer caused re-heating indicating that the composts have attained the curing stage. The POME-sawdust heap had higher temperature values than POME heap throughout the composting period.

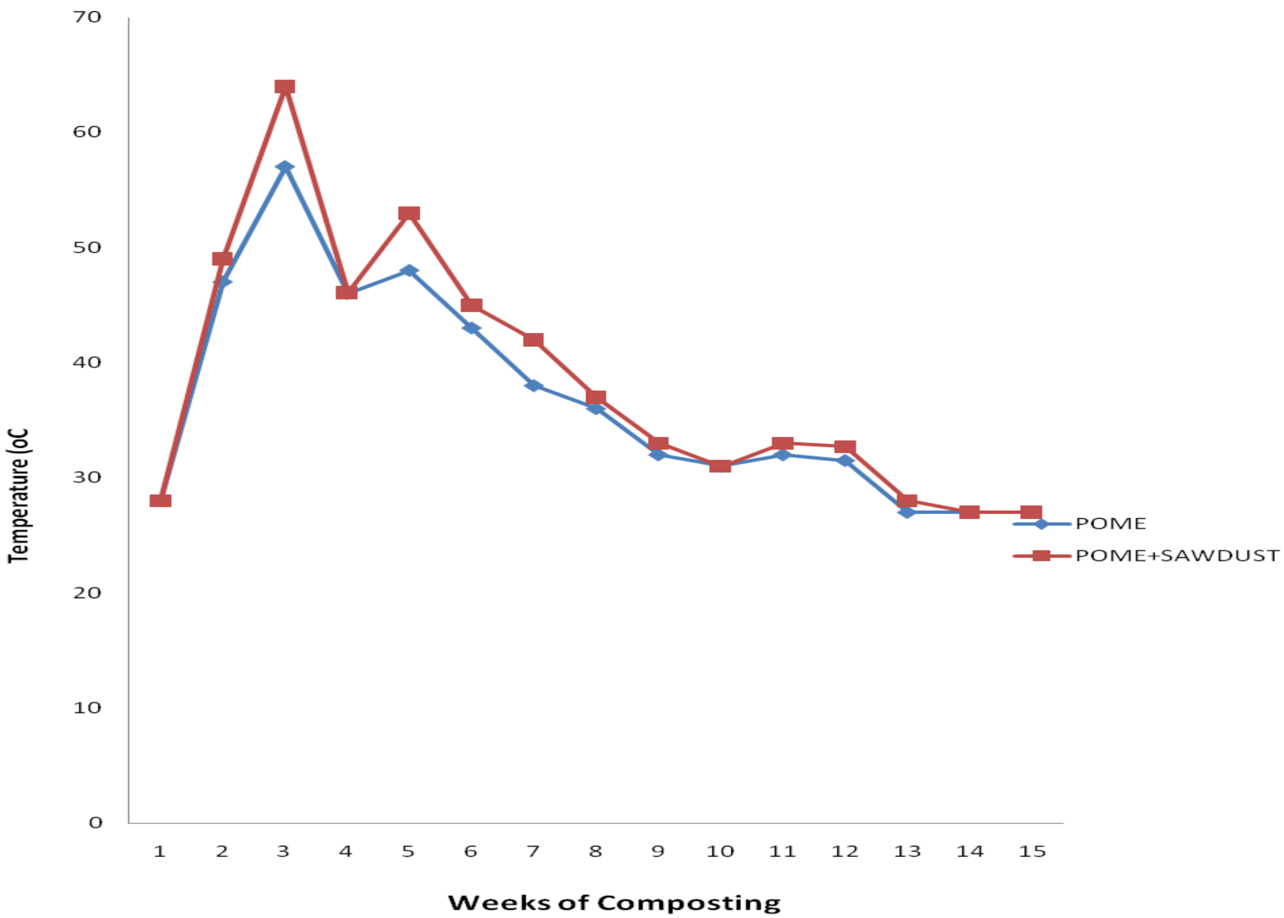

Fig. 1. Changes in temperature of POME and POME+Sawdust during composting

Fig. 2 shows the pH values as affected by the weeks of composting POME and POME-sawdust. The change in pH was inconsistent but the trend indicated increase in values with the weeks of composting. The lowest value (pH = 4.13) was recorded in POME heap at week 1 which increased to pH=7.5 at week 13 but reduced to 5.3 and 6.5 at week 14 and 15 respectively. The POME-sawdust heap had a higher value than in POME heap after week 1 of composting (pH = 6.9) followed by reduction to pH = 4.7at week 2 and somewhat inconsistent increase until week 15 with the highest value (pH = 7.52).

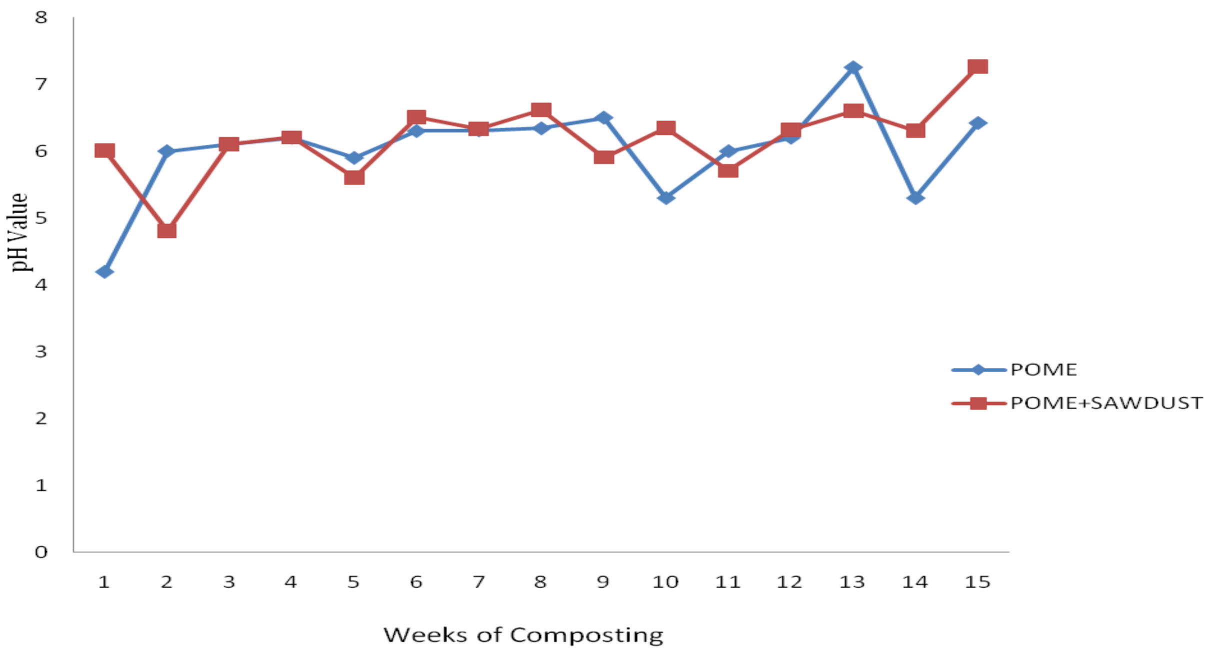

Fig.2. pH values of POME and POME+SAWDUST as affected by weeks of composting

Fig. 3 shows the total N contents of POME and POME-sawdust heaps as affected by number of weeks of composting. The quantities of N in the composts were lower than in fresh POME sample in the earlier weeks of composting but showed inconsistent increase over the period with peaks at week 5, 8, 13 and 15 and dips at week 6, 10 and 14 for POME-sawdust heap while the POME heap had peaks at week 7 and 13 and dips at week 3, 7, 11 and 15. Only POME-sawdust heap at week 13 contained higher total N (27.5 g kg^{-1}) compared to fresh POME (23.3 g kg^{-1}) while the highest N values was 21.4 g kg^{-1} in the POME heap at week 8 followed by decrease and rose to and 21.2 g kg^{-1} at week 13. For the POME-sawdust heap, the N content was 20.3 g kg^{-1} at week 5, decreased thereafter but rose to 27.5 g kg^{-1} at week 13.

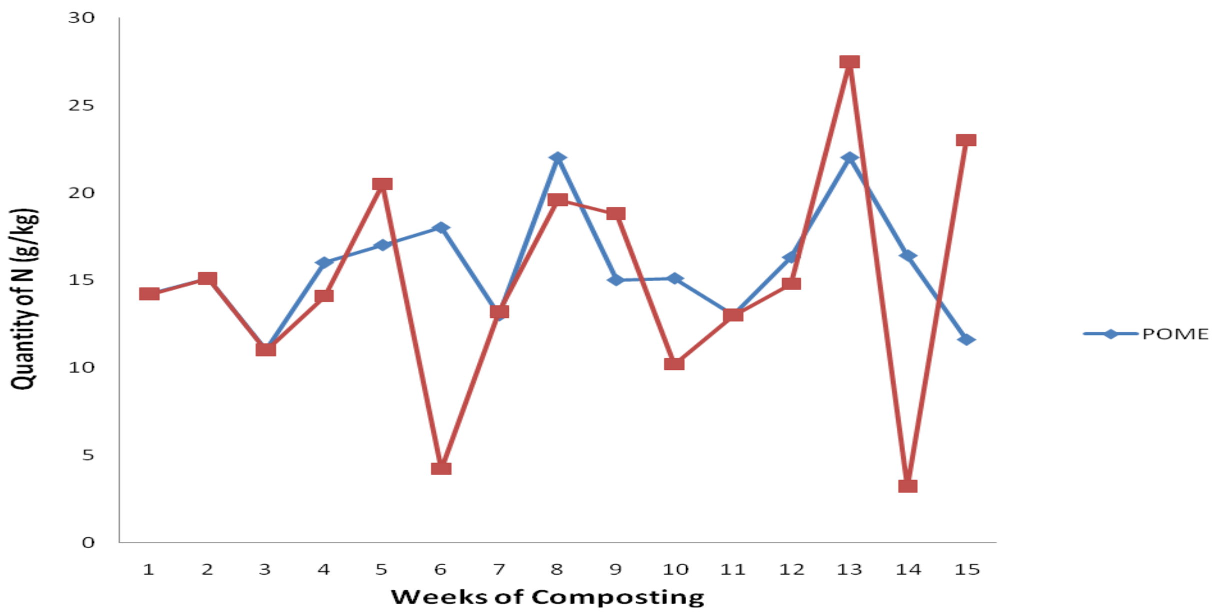

Fig. 3. Total N of POME and POME+sawdust as affected by weeks of composting

Fig.4 shows the effect of composting on the level of P in the POME and POME-sawdust heaps. The P contents showed positive effects of composting as P in the two composts were higher than the P content of the waste materials throughout the weeks of study. POME heap contained higher P values than POME-sawdust heap. The POME heap showed rising P content till week 5, decreased in week 7 and 9, increased to the maximum at week 13 but dipped at week 15. The P content in POME-sawdust heap rose from week 1 till week 3, dipped in week 5 and increased thereafter to fairly constant until the dip in week 15. The highest P content was 10.8 gkg^{-1} in the POME heap at week 5 while POME-sawdust heap had the highest value of 9.3 g kg^{-1}at week 12.

Fig. 5 shows the K contents of the POME and POME-sawdust heaps over the weeks of composting. The K contents obtained throughout the composting period were higher than the values obtained for the compost materials (POME and sawdust) indicating the positive effects of composting POME. The K content in POME heap increased initially till week 5, decreased markedly at week 6 and rose to somewhat constant values until week 14 but showed reduction at week 15. The highest K content was 8.6 g kg^{-1} at week 5. The pattern of K content in POME-sawdust heap was haphazard. It indicated an initial increase at week 2 and decrease to lower values at week 4 and 6 while the subsequent increase till week 8 was followed by decrease at week 9 and remained fairly constant till week 14 and the highest value at week 15 (14.6 g kg^{-1}).

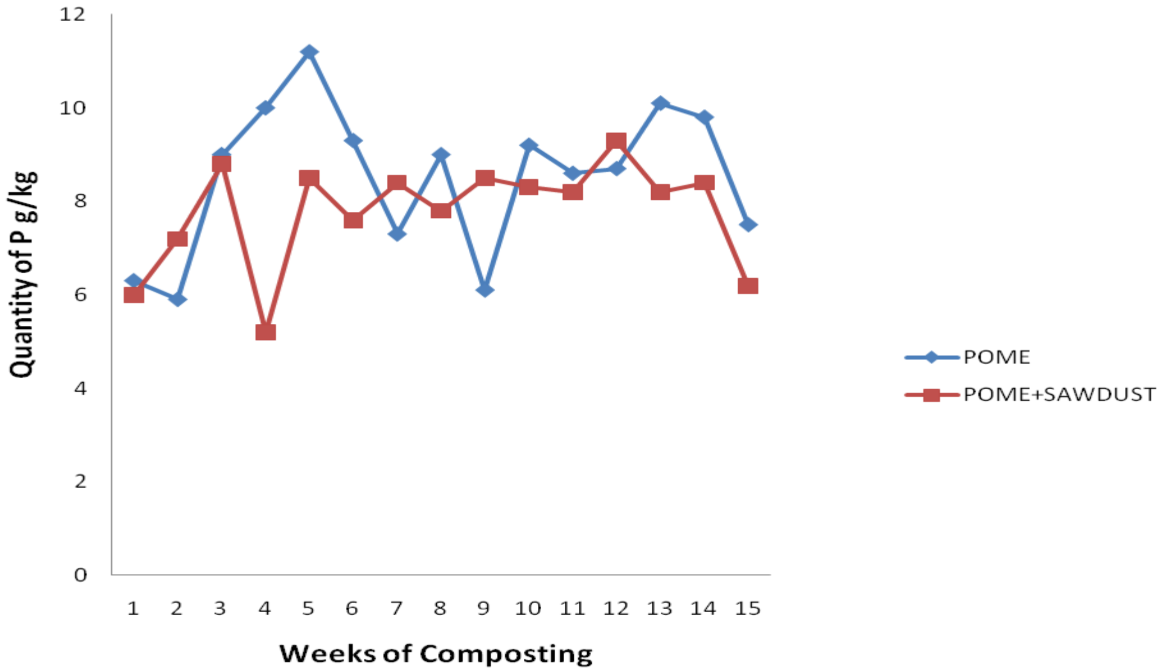

Fig. 4. P content of POME and POME+Sawdust as affected by weeks of composting

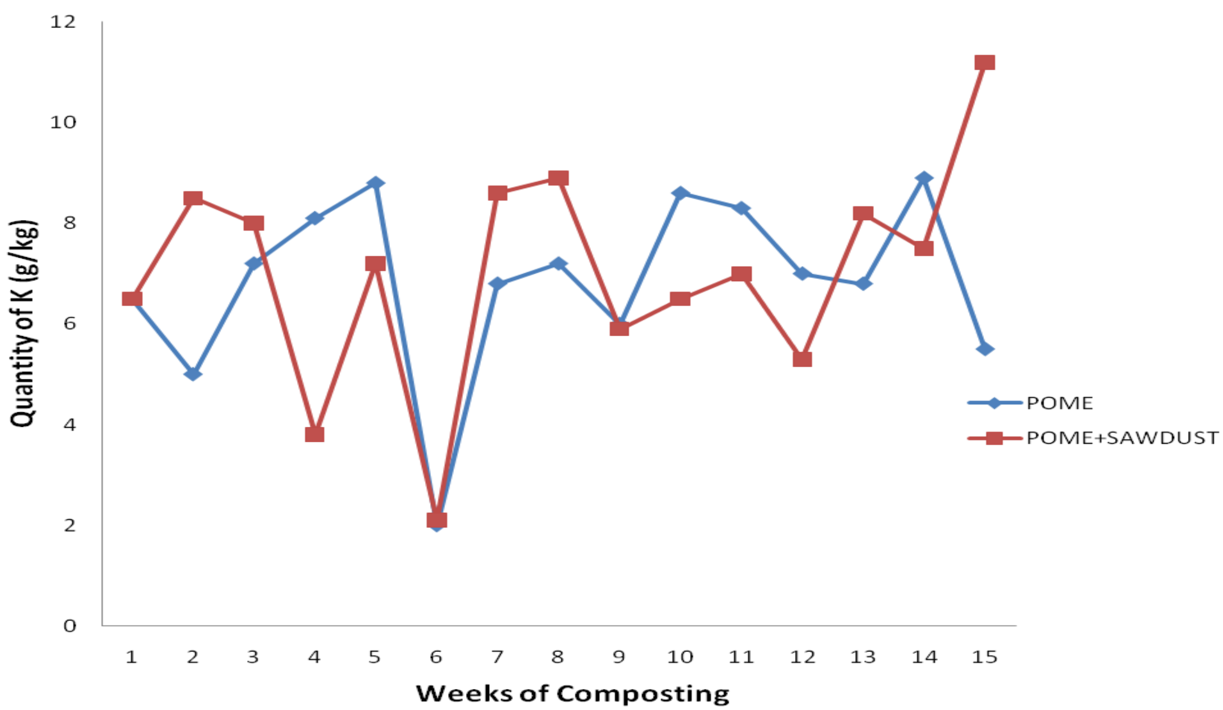

Fig. 5. K Content of POME and POME+Sawdust as affected by weeks of composting

Discussion

The POME was acidic (pH=5.7) but the value is higher than the average value (pH=4.2; range of 3.4-5.2) obtained for fresh effluent (Ma, 2000; Madaki and Seng, 2013). The material used in this study was obtained from a retaining pit for palm oil mill wastewater which has solidified after the water had infiltrated into the surrounding soil. This is different from the sludge obtained from aerobic or anaerobic wastewater treatment plants whose alkaline nature (pH=8.4), low carbon and high nutrient contents confer good fertilizer value but must be dried before use as soil conditioner (Yaser *et al.*, 2007). The N content of the waste was low compared to average value of 750 mg l^{-1} (range of 180-1200 mg l^{-1}) in POME (Madaki and Seng, 2013) and 246 mg l^{-1} in fresh POME (Ermadani, 2013) but higher than 3.6 mg l^{-1} reported for POMS (Rupani *et al.*, 2010).This indicates that the nature of POME can exhibit wide variability between age or type of fruits, production batches and days, processing technologies, factories and the discharge limits. The P content was higher than 2.0 mg l^{-1} obtained in fresh POME and 0.9 mg l^{-1} in POMS while the K content was lower than 105 mg l^{-1} in fresh POME and similar to 2.1 mg l^{-1}in POMS recovered from wastewater treatment plants (Yaser *et al.*, 2007). The sawdust was alkaline (pH=8.2) which is comparable to 8.12 reported by Huang *et al.,* (2004) but higher than 5.7 obtained by Yaser *et al.* (2007). The N content of sawdust (1.4 g kg^{-1}) was higher than 1.0 g kg^{-1}obtained by Yaser *et al.* (2007). The differences in these properties can be attributed to the sources of sawdust as generated during the production of sawn wood from timber logs of various tree species in sawmills or splitting of planks in carpentry workshops. However, the uniqueness is in the low concentrations of plant nutrients and high content of carbonaceous compounds (lignin, cellulose and pectin) as reflected in very high C/N ratio such that microbial decomposition would necessitate the addition of carbohydrates for energy and N to build new bodies as the microbes grow and multiply (Müller-Sämann and Kotschi, 1994).

Composting of organic substrates is characterized by an initial period of rapid degradation marked by rising temperature to a maximum value followed by a longer period of slow degradation with progressive decrease in temperature until a constant value is attained (Diaz *et al.*, 2002). The rapid increase in temperature of the compost heaps is attributed to the invasion by the microorganisms responsible for breaking down of POME and indicates the progress of the composting process (Nogueira *et al.*, 1999). Palaniappan (1984) had noted the presence of several fungal species at different stages of POME decomposition and these microorganisms are probably responsible for breaking down the compounds which inhibit plant growth. The higher temperatures recorded from the POME-sawdust heap, during the first 2 weeks of incubation are indicators of higher or more intense microbial activity due to the presence of lignin material provided by the sawdust (Robert *et al.*, 2000). The maximum temperatures at 57 and 64ºC in POME and POME-sawdust heaps are within the optimum range of 50-60ºC but higher than the maximum temperature of 40ºC obtained during the composting of POMS-sawdust (Yaser *et al.*, 2007; Zahrim *et al.*, 2007).The thermophilic stage of POME sludge compost was 57.5ºC attained at 24 days into composting (Ramli *et al.*, 2016). The POME and POME-sawdust heaps had temperature troughs at 3 weeks probably due to excessive ammonia and phenols which inhibited bacterial growth and activity while the resumption of mesophilic microbial activity caused further slight increase at 4 and 10 weeks of composting. The peak temperature is important for the compost quality as the heat kills pathogens, especially those originating from animals, which cannot survive at the high temperature (Müller-Sämann and Kotschi, 1994; Hoitink, 1998).The lower and constant temperature values (27ºC) obtained at 14 and 15 weeks when turning no longer reheated the heaps is an indication that the composts have attained the curing stage marked by a lower level of microbial activity but chemical reactions would continue to occur in order to make the products of the active composting period more stable and suitable. Curing also allows certain fungi species to inhabit the pile and contribute to the disease suppressant qualities of the compost (Müller-Sämann and Kotschi, 1994). At the end of the composting period, the composts obtained from the two heaps became dark brown/black in colour indicating that they were matured and ready for use (Healthy Soils, Healthy Landscapes, 2012).

The pH of a medium is relevant to the extent that it determines the biological activity of the microbial population. The increase in pH during the weeks of composting might be associated with the microbial breakdown of the organic acids and which hardly reduced the concentrations of Ca, Mg and K that are mainly responsible for basic or alkaline reactions. The initial drop in pH observed in the POME-sawdust heap was probably needed to encourage the growth and multiplication of the fungi species responsible for the breakdown of lignin and cellulose. The increase in pH is necessary to attain the optimum for compost microorganisms at pH=5.5-7.0but the addition of wood residue would lower the pH to around 4.5 (Carry on Composting, 2018).The pattern differs from the progressive decline in pH from 7.5 to 6.1 and 5.8 after composting POMS-sawdust for 105 and 300 days respectively (Yaser *et al.*, 2007). Finished composts should have neutral pH and this was achieved in the POME and POME-sawdust composts at 13-15 weeks of composting. The pH of compost is important since the application to soil is expected to alter the soil pH which can affect the availability of nutrients.

The lower N contents of some POME-sawdust heap samples than the fresh POME can be due to dilution effect and the fact that N is needed for the rapid growth and multiplication of the microbial population involved in organic matter decomposition. The N necessary for cell growth and functions is incorporated into microbial cells until the organisms die. As the organic materials further decompose, N is tied in the microbial tissue and becomes less available such that the lower N content due to N fixation is in response to the increase in microbial population (Harrison and Henry, 1994). Also, the differences in the N contents between POME and POME-sawdust compost heaps could be due to the factors that determine the rate of decomposition of the compost materials which include the quality of the material especially the N and carbon contents as reflected in the C/N ratio (Ribeiro *et al.*, 2010).

The P content of POME which was considered to be low (Lim *et al.*, 1993) and composting had a positive effect on it. Nutongkaew *et al.*, (2011) observed that composting increased the P content of fresh POME from 2.0 mg l^{-1} to 1.85% $P_2O_5$and decreased the P content of POMS on dry weight basis from 1.58 to 1.21% P_2O_5 whereas the total P content of POMS-sawdust compost was 0.90% P_2O_5 (Yaser *et al.*, 2007). However the differences observed in the values of P in ordinary POME and POME-sawdust could be due to the dilution in the latter and which is believed to have attracted higher/more intense microbial activity needed to decompose the lignin material from the sawdust (Robert *et al.*, 2000) more so as the ensuing higher microbial population would need more P for growth and development.

Composting had positive effect on the K content but this was slight in the POME heap compared to POME-sawdust which indicated 41.9 and 135.5% increase at week 15 respectively. There are no reports on the K content of composted POME but co-compost with poultry manure and lime showed that the nutrients, especially K, increased compared to fresh POME. Yaser *et al*. (2007) noted that K content of POMS decreased when co-composted with sawdust from 2.1 to 1.6% K_2O on dry weight basis.

Despite the high N content of fresh POME, the direct use as fertilizer is hindered by the because of heat and acidity of the effluent and the presence of lipids, volatile organic compounds, water-soluble phenolic acids (Nwoko and Ogunyemi, 2010) which cause soil clogging to inhibit plant growth. However, the higher P and K contents in the composts show the importance of composting in managing fresh effluent from palm oil mills while co-composting with sawdust showed similar benefits. The composts produced from week 13 to 15 had approximate nutrient composition of 27.5, 9.4, 8.8; 21.3, 8.6, 7.6 g kg^{-1} for POME and POME-sawdust composts which represent fertilizer grade of 2.75%N, 2.15% P_2O_5 and 1.06% K_2O; and 2.13%N, 1.97% P_2O_5 and 0.91% K_2O respectively. With about 970,000 t of palm oil produced in Nigeria in 2017 (Akomolafe, 2018) and average 3.0 t POME generated to obtain 1.0 t of the oil (Madaki and Seng, 2013), the estimated POME will be 2.910 million tonnes whose nutrient content as compost will be 8,965MT N, 7,009MT P_2O_5 and 3,455 MT K_2O.

Summary and Conclusions

The nutrient analysis of all the compost materials (sawdust and POME) and the composts was carried out. Palm Oil Mill Effluent was measured on two separate heaps each of 1 m tall and 1.5 m wide. Sawdust was mixed with POME in one of the heaps at the ratio 1:1. The heaps were turned and watered weekly. The temperature of the heaps was measured at a week interval before each turning and watering. Samples were taken from each of the heaps to the laboratory for analysis after each turning. The heaps were covered during rainfall to prevent the materials from being washed away. The experiment was terminated when the temperature of both heaps became constant. The findings of the studies are summarized as follows:

1. High contents of N, K, Ca, Mg and Mn and the low value of P were recorded from the analysis of POME.
2. POME is naturally acidic.
3. There was a rapid rise in temperature which indicated that intense microbial activity took place on the heaps.
4. The pH values increased with the weeks of composting.
5. Lower N values were recorded for some of the samples of POME-sawdust than for the fresh POME.
6. Composting had positive effects on the P content of POME; an indication that composting of POME is necessary to improve the P content.
7. Composting also increased the K content of POME.

In conclusion, the results have shown that composting of POME is necessary to improve the nutrient contents of POME; especially P which was reported to be low. It is suggested that POME composted with sawdust be used at 13 weeks into composting for maximum N supply since P and K contents are adequate at all weeks of composting.

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