World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Bioconversion of oil palm empty fruit bunches into soil conditioner using in-vessel composting technique

Agnes Monday Jones, Esther Alphonsus Umoh and Aniefon Alphonsus Ibuot *

Department of Biological Sciences, Akwa Ibom State Polytechnic, Ikot Osurua, PMB 1200, Ikot Ekpene, Akwa Ibom State Nigeria.

World Journal of Advanced Research and Reviews, 2025, 26(01), 1412-1419

Publication history: Received on 26 February 2025; revised on 05 April 2025; accepted on 07 April 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.26.1.0980

Abstract

The composting of oil palm empty-fruit-bunches using in vessel composting after 100 days revealed physical properties of the compost changing as the composting proceeded The colour of the compost from brown at day 0 changed to blackish at day 100. The odour changed from ammonia smell to earthly smell at day 100. The nutrients were observed to reduce as the composting continued, phosphorus was observed to increase from 40.2mg kg $^{-1}$ at day 0 to 96.4mg kg $^{-1}$ at day 100. Temperature reduced from 31^{0}C at day 0 to 29^{0}C at day 100. pH value of the compost ranged between 7.50 and 7.82. Moisture content increased from 62 at day 0 to 73 at day 100. The cured compost at day 100 was considered stable for use as soil conditioner judging by the results of the nutrient analysis. Microorganisms, bacteria and fungi were isolated and identified and their total colony count determined. Total Bacterial Count ranged between 5.5 CFU/g and 21.8 CFU/g. Total Fungal Count ranged between 1.5 CFU/g and 4.8 CFU/g. Bacteria isolated and their percentage frequency of occurrence were *Pseudomonas* sp with the highest percentage frequency of occurrence of 28%, *Bacillus* sp with 20%, *Micrococcus* sp with 16%, *Staphylococcus* sp and *Acinebacter* sp with 12%, *Citrobacter* sp with 8% and *Enterobacter* with 4%. Fungal isolates with percentage of frequency were *Penicillium* sp with highest percentage frequency of occurrence 31.25%, *Alternaria* sp 18.75%, *Aspergillus* sp and *Trichoderma* sp and *Rhizospus* with 12.50%, *Fusarium* sp and *Mucor* sp with 6.25%.

Keyword: Bioconversion; Microorganisms; Palm Oil Empty Fruit Bunch; Soil Conditioner

1. Introduction

In Nigeria, palm oil production is a fast growing and speedily becoming an outstanding agriculture-base industry mostly in the southern part of the country. In palm oil production, 5 tonnes of fresh fruit bunches is required for the production of 1 tonne of crude palm oil [1]. Thus in the Southern part of Nigeria, the high production and processing of palm oil points to the fact that environmental pollution as a result of waste generated from the process will soon become an increasing issue. This is not only in Nigeria but in other developing countries where palm oil production is rapidly growing [2].

Several approaches have been adopted to explore the potentials for reusing empty fruit bunches as main feedstocks or substrate to produce activated carbon [3], bioethanol [4], composite (Bakar et al 2010) and others. As empty fruit bunches contain high organic matter and mineral contents, these wastes are also being currently studied as potential feedstocks in composting [5].

For countries like Nigeria with palm oil production growing rapidly especially in the southern part of the country high the use of locally available bio-wastes such as oil palm empty fruit bunches (OPEFBs) to improve soil texture and

* Corresponding author: Aniefon Alphonsus Ibuot

nutrient availability is suggested to enhance food security. Empty oil palm fruit bunches are the remains of the fruit bunches after the fresh oil palm fruits have been removed. Generally, vast amounts of OPEFB is produced from palm oil plantations, and are often disposed of as waste where sometimes it is improperly disposed and causes environmental pollution and undergoes natural decomposition or disposed by burning which increase greenhouse gas emissions such as methane and carbon dioxide. Oil palm empty palm fruit bunch pellets pollution has been a great challenge in recent times as the bulk of waste generated in palm oil mills daily is on the increase. Conventional technique (incineration) is not environmentally friendly as it causes air pollution. Improper disposal of empty fruit bunches has led to pollution of the environment, vector menace and generation of odor.

The use of OPEFB on the soils applied raw as organic mulch, or composted before application has been reported [6]. When applied as a mulch, OPEFBs primarily increases soil water retention. When applied on the soil in composted form, OPEFBs enhances soil water retention and nutrients content [7], could possibly be due to the losses of carbon from the anaerobic respiration involved in composting. Composting of OPEFB involves the fast degradation of the organic matter by microorganisms under controlled conditions which are temperature, humidity and aeration, the OPEFB (organic waste) undergoes process of degradation that cures the organic waste and also completely remove pathogenic microorganisms, hence making it suitable for use as soil conditioner.

In-vessel composting makes use of controlled conditions such as humidity, temperature and aeration to augment the anaerobic decomposition process. The study is aimed at converting oil palm empty fruit bunches into soil conditioner to improve soil fertility. The physiochemical and microbiological characterization of the composting has been investigated to assess its quality.

2. Methodology

2.1. Description of Study Area

The research was done in Ikot Ekpene Local Government Area, Akwa Ibom State, Nigeria GPS coordinates 5'' 10'54'' N. 7'' 42' 53'' E. Latitude 5.174447 and longitude 7.714515

2.2. Construction of composting vessels/collection and heaping of oil palm empty fruit bunches

Oil palm empty fruit bunches (OPEFB) were dried and blended to a size of about 1.0 to 2.0cm to provide a good aeration and moisture retention and heaped in the composting vessel, three plastic containers with diameter 30cm and a height of 40cm, closed with a lid .The grinded empty fruit bunches heaps were moistened and turned at 5 days intervals for aeration at intervals to increase microbial activities. The compost heaps in the plastic containers were kept under shade to avoid rain water.

2.3. Physicochemical characterization of oil palm empty fruit bunches composting

Temperature variation, change in colour, odour and size of the composts were checked at 10 days interval and recorded. pH and moisture content (MC). Total Khejdal nitrogen were determined using the air dried samples. Moisture content, Potassium, phosphorous and other metals were determined using the method of Association of Organic and Analytical Chemist.

2.4. Microbiological characterization of empty fruit bunches compost

Total Bacterial Count (TBC), Total Fungal Count (TFC) of the empty palm fruit compost were determined at 10 days intervals. Bacteria and fungi were isolated and identified using appropriate culture media and their total colony count noted.

3. Results

Table 1 Changes in the physical properties of oil palm empty fruit bunches during composting period

Parameters	composting period	
	Day 0	**Day 100**
Sze	1.0 cm – 2.0 cm	Normal Soil texture
Odour	Ammonia smell	Earthly smell
Colour	Brownish	Blackish

Table 2 Composition of nutrients and metal elements of oil palm empty fruit bunch during composting

Nutrients and metal elements	**Composting period**	
	Day 0	Day 100
Carbon (%)	51.73	9.62
Nitrogen (%)	2.094	1.112
Potassium mkg-1	158	81.4
Phosphorus mg kg^{-1}	40.2	96.4
Magnesium mk kg^{-1}	21.01	9.09
Calcium mkg -1	44.54	9.98
Nickel mkg-1	4.8104	5.3231

Table 3 Temperature of oil palm empty fruit bunch during composting

Day	**Temperature (^{0}C)**
0	31
10	34
20	33
30	32
40	30
50	30
60	29
70	29
80	29
90	28
100	29

Table 4 pH of the oil palm empty fruit bunch during composting

Day	**pH**
0	7.50
10	9.12
20	9.08
30	9.05
40	8.65
50	8.60
60	8.05
70	6.88
80	6.09
90	7.58
100	7.82

Table 5 Moisture content of the oil palm empty fruit bunch during Composting

Day	Moisture (%)
0	62
10	64
20	66
30	68
40	72
50	72
60	73
70	74
80	73
90	72
100	73

Table 6 Total bacterial count of oil palm empty fruit bunch during composting

Day	Total colony count per gram (x 10^4 CFU/g)
0	5.5
10	8.5
20	10.5
30	18.5
40	20.4
50	21.8
60	18.9
70	15.8
80	13.9
90	10.4
100	11.9

Table 7 Total fungal count of oil palm empty bunch during composting

Day	Total colony count per gram (x 10^4 CFU/g)
0	1.5
10	2.5
20	3.3
30	3.5
40	3.5
50	4.0

60	4.8
70	4.1
80	4.3
90	3.8
100	3.9

Table 8 Percentage frequency occurrence of bacterial isolates

Bacteria	Frequency occurrence (n=50)	Percentage frequency (%)
Citrobacter sp	4	8
Pseudomonas sp	14	28
Enterobacter sp	2	4
Staphylococcus sp	6	12
Micrococcus sp	8	16
Acinebacter sp	6	12
Bacillus sp	10	20

Table 9 Percentage frequency occurrence of the fungal isolates

Fungi	Frequency occurrence	Percentage frequency %
Penicillium sp	5	31.25
Aspergillus sp	2	12.50
Alternaria sp	3	18.75
Trichoderma sp	2	12.50
Rhizopus sp	2	12.50
Mucor sp	1	6.25

4. Discussion

4.1. Physical properties of oil palm empty fruit bunch

Physical properties which includes odour, colour and size of the compost material suggest a stage reached in the decomposition process, though not sufficient to ascertain the level of maturation, however these properties gives an idea of the compost maturation when observed to be blackish in colour, with soil texture and earthly odour as shown in Table1 . Blending the OPEFB particle to smaller size particles before composting gives higher surface area and enable microbial decomposition, however the particle size were large enough to retain water. Kalamdhad [8] reported that porosity greater than 50% allows the windrows to remain at low temperature due to energy loses. During the OPEFB decomposition, the pore was filled with air, water or both

4.2. Temperature of oil palm empty fruit bunch

The metabolic activity, growth rate, and microbial community of the compost can be influenced by the temperature of the compost. Using a mercury thermometer, variation in temperature were recorded during the composting process. Highest temperature was recorded as 34°C for day 10 (Table 3). This could be due to the metabolic heat generation by highly cellulosic material (OPEFB). The highest temperature did not exceed 35°C because the anaerobic condition created with closed container performed at low temperature. Grigatti et al.,[9] reported that compost temperature recorded was higher than 50°C after one month and then decreased after two months to 20°C, suggesting the presence of high quantities of degradable organic matter. The temperature regime (Table 3) showed that the maturation was achieved. However, 50 ± 60°C has been reported to be the optimum temperature for effective composting [10]. From the temperature profile (Table 3), the temperature of the compost at day 100 was 29°C which is a little higher than room temperature (28°C). Low temperatures may permit microbial activity, however, composting temperature below 20^0C have been shown to slow and even inhibit composting process [11].

4.3. pH of oil palm empty fruit bunch during composting

During composting, decomposition of the organic matter resulting in the formation of acid which changes the pH of the compost. The composting pH initially was 7.50 and later increased to 9.12 at day 10. (Table 4). The increase in pH in the compost is expected due to organic matter decomposition, this is as a result of the degradation of acidic compounds which include carboxylic and phenol groups and also the microbial conversion of matter such as amino acids, peptides and proteins to ammonia [12]. The pH value increased from 7.50 at day 0 to 8.60 at day 50 and decreased to 7.82 at day 100. The decrease in pH from day 50 was as a result of degradation of organic matter and acidic metabolites formation [13]. The matured compost had the pH 7.82, at this point stabilized because of the buffering characteristic of the humic substances .pH value of compost in the range of 5.8 to 8.8 allow microbial activity of most microbes

4.4. Moisture Content

One of the factors necessary to help maintain efficient microbial activity throughout the composting to achieve a cured end-product is moisture. Moisture enhances the transport of dissolved nutrients needed for metabolic and physiological activities of microbes 16. The moisture content of the final compost was 73%, slightly higher than that of the initial compost which was 62% (Table 5). Yahya et al. and Wong et al.[14-15] reported that maximum microbial activities decomposition of organic compounds is observed at the moisture content range of 60%- 70% . The anaerobic condition of the composting process would reduce the heat of reaction and that would lead to decrease in the temperature level and would retain excess moisture. Moisture content of the compost around 40 to 60% was needed for microorganisms to thrive while moisture content of the compost that exceeds 80% could cause death of aerobic microorganism.

4.5. Total microbial count

Microorganisms play a significant role in the bioconversion of waste [16]. In this study, bacteria and fungi were isolated and the total microbial count noted. Each microorganism (both bacteria and fungi) isolated had different cultural characteristics. Some were turbid, while some of the bacteria were gram positive while some were gram negative. Bacterial count of the compost was seen to be increasing from day 0 to day 50 where a decrease in bacterial count was observed from day 60 to day 100 (Table 6). The increase in the bacterial count could be as a result of the degradation of organic matter in the compost and the reduction in the degradable organic matter could be the cause of the reduction in the total bacterial count from day 60 to day 100, A similar trend was also observed in fungal count as there was increase between day 0 and day 60. While fungal count reduction was observed from day 70 to day 100 (Table 7)

4.6. Percentage frequency of occurrence of bacterial isolates

The percentage frequency of occurrence of bacteria revealed *Pseudomonas* sp with the highest frequency of occurrence (28%) followed by *Bacillus* sp with the frequency of occurrence of 20%. The dominance of these two bacteria is observed due to their enzymatic ability to degrade acidic compounds which include carboxylic and phenol groups and also the microbial conversion of matter such as amino acids, peptides and proteins to ammonia [12]. These bacteria are soil bacteria and could be expected to be a major part of the composting process. *Staphylococcus* sp could have been there from human contamination during the regular moistening and turning of the compost.

4.7. Percentage frequency of occurrence of fungal isolates

The percentage frequency of occurrence of fungi isolates showed *Penicillium* sp with the highest dominance (31.25%) followed by *Alternaria* sp with 18.75%. The dominance of these fungi could be a demonstration of their ability to degrade acidic compounds, cellulose, hemicellulose and lignin in the oil palm empty fruit bunches. *Penicillium* is a soil fungi and its present in the compost was not a surprise. Other fungi isolated from the compost were *Aspergillus* sp with percentage frequency of occurrence of 12.50%, *Trichoderma* sp and *Rhizopus* sp with 12.50%, *Fusarium* sp (6.25%) and *Mucor* (6.25%). Tahir et al [17] reported abundance of fungal isolates from oil palm empty fruit bunches decomposition. Despite the recalcitrant nature of lignocellulose, several fungi and bacteria, are known to be actively involved in lignocellulose degradation [18]. Microorganisms are commonly found in decaying plants. Decomposition processes by microorganisms are complex and important in nutrient cycling, and carbon stability [18] Microorganisms commonly decompose most plant cell wall polymers into simpler compounds by their enzymatic activities under aerobic or anaerobic conditions [19]. Some microorganisms may produce enzymes that simultaneously or selectively degrade lignocellulose.

5. Conclusion

The biological nature and high organic content of empty palm fruit bunch makes composting the best approach for its disposal. The final compost which has been cured is best for use as soil conditioner. Microorganisms in abundance during composting process and the nutrients analysis of the final compost shows it has substantial amount of nutrients to improve soil fertility. The metal analysis of the final compost revealed very low quantity of metal which is appropriate for the soil.

Compliance with ethical standards

Acknowledgments

The article was sponsored by TETFund research grant, Nigeria

Disclosure of conflict of interest

The authors declare no conflict of interest

References

[1] Stichnothe,H., Schuchardt F 2011 Life cycle assessment of two palm oil production systems Biomass and Bioenergy 36, 9 2011, 3976-3984

[2] Zhao, Y., Huang, J., Zhao, H. & Yang, H. 2013. Microbial community and N removal of aerobic granular sludge at high COD and N loading rates. Bioresource Technology 143: 439-446.

[3] Firoozian P, Bhat IUH, Abdul Khalil HPS, Md Noor A, Hazizan MA, Bhat AH: High surface area activated carbon prepared from agricultural biomass: Empty fruit bunch (EFB), bamboo stem and coconut shells by chemical activation with H3PO4. *Mater Technol* 2011, 26(5):222-228.

[4] Bakar, K.A., Tarmizi, R.A., Mahyuddin, R., Elias, H., Luan, W.S. and Ayub, A.F.M. (2010) Relationships between University Students' Achievement Motivation, Attitude and Academic Performance in Malaysia. Procedia-Social and Behavioral Sciences, 2, 4906-4910. http://dx.doi.org/10.1016/j.sbspro.2010.03.793

[5] Kananam, W., Suksaroj, T. T., and Suksaroj, C. (2011). "Biochemical changes during oil palm(*Elaeisguineensis*) empty fruit bunches composting with decanter sludge and chicken manure," Sci.Asia 37, 17-23.

[6] Anyaoha KE, Sakrabani R, Patchigolla K, Mouazen AM (2018) Critical evaluation of oil palm fresh fruit bunch solid wastes as soil amend ments: prospects and challenges. Resour Conserv Recycl 136:399 409. https://doi.org/10.1016/j.resconrec.2018.04.022

[7] Ahmad Dani MS (2018) An evaluation of empty fruit bunch (EFB) bio char and EFB compost as growing media for oil palm seedling. Dissertation, Universiti Teknologi MARA, Melaka, Faculty of Plantation and Agrotechnology

[8] Kalamdhad, A. S. & Kazmi, A. A. 2009. Rotary drum composting of different organic waste mixtures. Waste Manage. Res., 27, 129–137.

[9] Grigatti, M., Cavani, L. & Ciavatta, C. (2011). The evaluation of stability during the composting of different starting materials: Comparison of chemical and biological parameters. Chemosp., 83, 41–48.

[10] Wong, J. W. C. et al. (2001). Co-composting of soybean residues and leaves in Hong Kong. Biores. Technol., 76, 99–106.

[11] Chang, C.-H. & Yang, S.-S. (2009). Thermo-tolerant phosphate solubilizing microbes for multi-functional biofertilizer preparation. Biores. Technol., 100, 1648–1658.

[12] Lim, S. H. et al. (2009). Physicochemical changes in windrow co composting process of oil palm mesocarp fiber and palm oil mill effluent anaerobic sludge. Aus. J. Basic Appl. Sci., 3, 2809–2816.

[13] Marttinen, S. K., Hanninen, K. & Rintala, J. A. (2004). Removal of DEHP in composting and aeration of sewage sludge. Chemosp., 54, 265 272.

[14] Yahya, A. et al. (2010). Effect of adding palm oil mill decanter cake slurry with regular turning operation on the composting process and quality of compost from oil palm empty fruit bunches. Biores. Technol., 101(22), 8736–8741.

[15] Wong, J. W. C. et al. (2001). Co-composting of soybean residues and leaves in Hong Kong. Biores. Technol., 76(2), 99–106.

[16] Dermiyah S R, Telaumbanua M., Yosita R., Sari A W., Andayani A P 2020 Abundance and characterization of microorganisms isolated from oil palm empty fruit bunches waste under aerobic, anaerobic and facultative anaerobic conditions. Biodiversitas 21: 4213-4220

[17] Tahir, A A., et al 2019 Diversity in Decaying Oil Palm Empty Fruit Bunches (OPEFB) and Isolation of Lignin-degrading Bacteria from a Tropical Environment Microbes Environ. Vol. 34, No. 2, 161-168, 2019

[18] Bugg T.D., Ahmad M., Hardiman E.M., Singh R. The emerging role for bacteria in lignin degradation and bio-product formation. Curr Opin Biotechnol. 2011; 22:394–400. doi: 10.1016/j.copbio.2010.10.009

[19] Pastorelli R., Agnelli A.E., De Meo I., Graziani A., Paletto A., Lagomarsino A. Analysis of microbial diversity and greenhouse gas production of decaying pine logs. Forests. 2017;8:224