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Compost stability, phytotoxicity and nutrient quality as influenced by carbon to nitrogen ratios of feedstock

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Abstract

Effects of three C/N mixes of groundnut husk (GNH) and Wister rat litter (RL) on stability, nutrient quality and phytotoxicity of compost were tested and compared with the conventional carbon and nitrogen feedstock mix on 1:3 w/w modality respectively. The GNH and RL were respectively composted in a windrow at three proportionate levels (14.7+105.3, 39.2+80.8 and 63.7+56.3 kg) to achieve C/N nutrient ratios of 20:1, 30:1 and 40:1 respectively using the Pearson square method. A control pile containing GNH+RL (tagged conv. 1:3) applied at 30 kg GNH and 90 kg RL using the conventional 1:3 w/w modality was compared in triplicate. Data were taken on daily compost temperature, pH, EC and nutrient content of stabilized composts. Phytotoxicity was assessed by using two compost extract concentrations of 100 and 50% per compost. There were three replications laid in CRD. Data were statistically analyzed. Number of days to compost stability was significantly influenced by C/N with values increasing with decreasing C/N in the order of 59 < 69 < 74 < 77 days for 40:1, 30:1, 20:1 and conv. 1:3 respectively. Increasing C/N decreased pH (range of 7.3 – 9.0), EC (range of 1.2 – 2.7dS/m), ash (range of 44.2 – 55.5%), total macronutrient (N+P+K) (range of 3.56 – 5.15%) and calcium content (range of 3.3 – 6.5%) and increased organic C (range of 22.4 – 29.6%) of the resultant composts and GI (range of 25 – 76%) of cowpea. The 100 and 50% concentrations supported higher GI of cowpea in composts produced from lower and higher C/N respectively.

1.0 Introduction

Compost is a stabilized humic-like substance produced from an effective composting process. The aerobic decomposition of organic matter under a controlled environment to produce CO_2, water vapour, ammonia, inorganic nutrients and stable organic materials containing humic-like substances is greatly influenced by the moisture content of the composting pile, rate of aeration, the initial chemical composition of the composting feedstock of which carbon and nitrogen proportions is notable (Oguwande *et al.,* 2008; Gao *et al*., 2010; Wang and Schuchardt 2010; Makan and Mountadar 2012; Nayak *et al*., 2013). The C/N is an important biochemical property of the composting feedstock that significantly controls the rate of temperature buildup and destruction of the pathogen in the composting pile (Macias-Corral *et al*., 2019) which directly affects compost stability and maturity (Gao *et al*., 2010).

A C/N feedstock ratio of 25 – 30 is generally considered suitable for ideal compost (Guo et al, 2012). Biological residues with lower C/N ratios are easily attacked by the decomposing microorganisms leading to improved decomposition activities compared to those higher in C/N during composting process (Macias-Corral *et al*., 2019). Composting raw materials with a C/N ratio lower than 20 leads to poor utilization of nitrogen in the feedstock as large proportions are lost into the atmosphere in form of ammonia or nitrous oxide while a C/N ratio of above 40 was opined to prolong the period of the composting process (Antil *et al*., 2014).

Majority of the published works on compost production in Nigeria (Musa *et al*., 2020; Oyeyiola and Omueti 2019a; Oyeyiola 2016; Ogunbanjo *et al*.,2007; Kolade *et al*., 2006; Fadare *et al* .,2000), utilized the weight by weight (w/w) feedstock combination modality of which ratio of carbon to nitrogen feedstock source of 1:3, 3:1, 1:2 and 1:4 are common The use of the w/w modality is limited in the sense that the initial C/N of the combined feedstocks in the composting pile may be variable for different compost types despite the use of the same w/w initial ratio.. Therefore, there is a need to consider using known initial C/N ratios estimated from nutrient analysis of feedstock prior to composting process especially when different carbon and nitrogen feedstock sources are to be assessed for compost stability and maturity.

Compost stability is a measure of complete decomposition of all degradable components in the composting feedstock while maturity quantifies how safe a composted material is to the plant and environment after its application unto the field. Compost is also termed matured when the quantities of C and N gains and losses in and out of a composting system is kept at equilibrium such that phytotoxic components are at safe concentrations and there is no more change in microbial activity and composting materials (Azim *et al*., 2014).

Compost stability and maturity rates are largely controlled by the C/N ratio of the initial feedstocks and turning frequency during the composting process (Zhang *et al*., 2019; Azim *et al*., 2014; Wang and Schuchardt, 2010). Assessment of compost maturity has been reported by many authors to be best done using more than one indicator since compost is a heterogeneous material produced from a variety of organic feedstocks. Compost maturity indicators that have been reported include use of total nitrogen (Zhang *et al*., 2019; Griffin and Hutchinson 2007), carbon to nitrogen ratio (Zhang *et al*., 2019; Iwegbue *et al*., 2006), cation exchange capacity (Iwegbue *et al*., 2006), total nutrient content (Zhang *et al.,* 2019; Nayak *et al*., 2013), temperature (Oyeyiola and Omueti 2019a; Oyeyiola 2016), odour and colour (Wang and Schuchardt, 2010) of the final compost and germination index of crop raised on the compost extract (Azim *et al*., 2018; Oyeyiola 2016; Guo *et al*., 2012; Selim *et al*., 2012; Wang and Schuchardt 2010; Tiquia and Tam 1998; Zucconi and de Bertoldi 1987). The use of spectroscopic analysis such as the UV -visible and FTIR (Azim *et al*., 2018; Iwegbue *et al*., 2006; Zbytniewski and Buszewski 2005; Baddi *et al*., 2004), degree of humification and microbiological parameters such as total aerobic heterotrophs, ATP content, oxygen consumption rate, the intensity of dehydrogenase activity and microbial biomass C and N have also been reported for compost maturity assessment (Chen *et al.,* 2008; Iwegbue *et al*., 2006; Tiquia, 2005; Baddi *et al*., 2004).

Compost production and use are not common practices among farmers in southwestern Nigeria despite the massive agro-waste generated from local farms every cropping season. These wastes are spot blazed (for crop residues) while the farmyard manures are disposed of recklessly where the leachates find their route into both surface and underground water. In an attempt to sensitize local farmers on the conversion of these large tonnage wastes from their agricultural venture into environmentally safe organic fertilizers like compost, there is a need to compare compost quality from different feedstock combination modalities such as the conventional weight/weight commonly used on the experimental field and the initial C/N feedstock ratios. This work, therefore, focused on assessing the stability, phytotoxicity and nutrient quality of composts produced from groundnut husk and Wister rat litter combined differently using their initial C/N ratios. the

2.0 Materials and Methods

2.1 Feedstock Collection and Proximate Analysis

The 80 day composting process was carried out at the compost garden of the Department of Crop Production and Soil Science, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria located on 08 10” N and 04 10” E. The lowest and highest ambient temperature range during the composting was 20- 31°C.

The carbon feedstocks used for the trial were groundnut husk and sawdust while rat litter and poultry manure were the nitrogen sources. The groundnut husk was from the Odo-Oba market while the sawdust was obtained from sawmill all in Ogbomoso. The rat litter was obtained from wister rat farms at Olomi area in Ogbomoso and the poultry manure was collected from Teaching and Research Farm Ladoke Akintola University of Technology. All the feedstock were tested for their nitrogen, phosphorous and organic carbon content prior to use following standard method (IITA, 1978) from where individual C/N ratios were calculated (Table 1). These values were thereafter used to estimate quantities of each feedstock mix that will satisfy the 20:1, 30:1 and 40:1 C/N ratios using the Pearson square.

2.2 Compost Preparation, process monitoring and data collection

Four groundnut husk (GNH) and rat litter (RL) based compost types were produced which included three C/N ratio feedstocks combination modality (20:1, 30:1, and 40:1) and a conventional weight by weight modality (w/w 1:3 where 30 kg of GHN was mixed with 90 kg RL). There was an absolute control compost pile for comparison which was produced from sawdust (SD) and poultry manure (PM) combined using the conventional weight by weight ratio of 1:3 (30 kg SD + 90 kg PM being the reference compost commonly produced at the institution composting garden). The quantities of feedstock combinations using individual feedstock C/N ratio were calculated using the Pearson square method as presented in Table 2.

Table 1. Initial nutrient composition of the composting feedstock

Compositing feedstock	**Nitrogen**	**Phosphorus**	**Organic carbon**	**C/N**
	←	g/kg	→	
Groundnut Husk	9.4	0.5	588.5	62.6
Rat Litter	33.6	11.5	466.1	13,9
Saw Dust	2.2	0.5	618.9	281.3

Table 2: Quantities of composting feedstock mixed in each pile based on C/N ratio using Pearson square calculation and conventional weight by weight (w/w) method

Compost types	Groundnut husk	Rat Litter
	Kg/ pile	
C/N 20:1 (GNH+RL)	14.7	105.3
C/N 30:1 (GNH+RL)	39.7	80.8
C/N 40:1 (GNH+RL)	63.7	56.3
Conv. w/w 1:3(GNH+RL)	30	90
Control w/w 1:3(SD+PM)	30	90

The weighed out feedstocks were homogenized and piled up on the concrete windrow (measuring 5 m x 2 m x 1 m) using a shovel. The moisture content of each composting pile was at every turning time maintained at 60 %. The composting organic materials were turned every three days for the first two weeks and thereafter once a week till compost maturity for efficient incorporation of air into the composting pile.

Data were taken on daily ambient and composting pile temperatures using a compost thermometer from three randomly selected central points within each compost pile. These temperature readings were used to assess the number of days to compost stability. The compost was adjudged to be stable when the temperature in each compost pile decreased to that of the ambient and maintains this temperature for two weeks (Ogazi and Omueti 2000). Weekly pH and electrical conductivity (EC) of each compost pile were assessed using a pH and EC meter in an aqueous extract of 10 g composting samples with distilled water at a ratio of 1:4. At compost maturity, well cured, air-dried and 0.5 mm sieved compost samples from each pile were subjected to proximate analysis for total nitrogen, phosphorus, organic carbon, moisture, ash, basic nutrient elements (Ca, Mg, K and Na) contents following standard procedures for plant analysis as described by IITA, (1978).

2.3 Compost Maturity Assessment

The maturity status of the final composts was assessed using their C/N ratio, chemical nutrient analysis (N, P and K contents) and germination index.

2.3.1 Germination index procedure using compost extract.

Each of the final compost was extracted with distilled water at a ratio of 10g compost into 100 ml distilled water after being shaken for 1 hour, centrifuged at 2000 rpm for 10 minutes and decanted (Oyeyiola and Omueti 2019a; Azim *et al*., 2014). Two compost extract concentrations: 50 and 100 % were prepared. Ten millilitres of each decanted extract represents 100 % concentration while 5 ml of the same extract mixed with 5 ml distilled water represents 50 % concentration. The phytotoxicity trial was a factorial experiment comprising five compost types and two levels of compost extract concentrations. There were three replications laid out in a completely randomized design. The 100 % level mimicked what happens when seeds are sown immediately after compost application while the 50% mimicked delaying seed sowing for some days or weeks after compost applications as proposed by some authors (Azim *et al*., 2018). Ten even-sized surface treated cowpea seeds were placed evenly on filter paper moistened with appropriate compost extract in Petri dishes. The whole set-up was placed in a dark germination cabinet at room temperature for 72 hours (Oyeyiola and Omueti 2019a). Thereafter, data were taken on the number of germinated seeds and length of taproot for the estimation of:

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated in compost extract}}{\text{Number of seeds germinated in distilled water}} \times 100$$

$$\text{Root elongation percentage} = \frac{\text{Mean root length of seedlings in compost extract}}{\text{Mean root length of seedlings in distilled water}} \times 100$$

and

$$\text{Germination index} = \frac{\text{Seed germination percentage x Root elongation percentage}}{100}$$

as proposed by Selim *et al*., (2012).

2.4 Data analysis

All the data collected were subjected to one and two ways (for the compost phytotoxicity trial) analysis of variance and means were separated using Duncan's multiple range test (DMRT) and least significant difference (LSD) respectively at 5% probability level using Genstat statistical package (8^{th} Edition).

3.0 **Results and Discussion**

3.1 Effects of C/N ratio of feedstock on temperature during the composting process

The ambient temperature ranged from 20- 30°C (mean of 24°C) during the composting process. All the GNH + RL based compost entered the thermophilic phase characterized by temperature 50°C and above on day 2 of composting (D2C) with a temperature range of 55℃ (C/N 20:1) – 68.5℃ (C/N 30:1 and 40:1) (Fig. 1). The control compost (SD+PM in w/w basis of 1:3) made it into the thermophilic phase on D3C with a temperature of 50.5℃. The ability of each composting pile to sustain its initial thermophilic temp of above 50℃decreased with increasing C/N in the order of 22>21>14>9 for 20:1, conv. 1:3, 30:1 and 40:1 respectively. Wang and Schuchardt (2010) observed a similar trend where they submitted that the lower the C/N feedstock mix of Compost, the higher the attained maximum temperature and the longer the number of days to sustain the thermophilic temperature phase. The C/N 20:1 sustained the thermophilic phase for 22 days while 30:1, 40:1, Conv. 1:3 and control 1:3 sustained theirs for 14, 8, 21 and 7 days respectively with highest temperatures of 69 (on D8C), 68.5 (on D2C),70 (on D3C) and 62℃ (on D5C) respectively. These thermophilic temperatures are required for the destruction of pathogens, weed seeds and insect eggs. The temperature thereafter declined into the mesophilic phase. Heat generation during composting increased with an increasing quantity of nitrogen source (rat litter) received per composting pile. Number of days to compost stability was significantly influenced by C/N with values increasing with decreasing C/N in the order of 59 < 69 < 74 < 77 days for 40:1, 30:1, 20:1 and conv. 1:3 respectively. The average temperature trend of 41.0, 36.6, 33.9, 40.1 and 35.4□ recorded for compost type C/N 20:1, 30:1, 40:1, conv. 1:3 and control 1:3 respectively during the composting process corroborate with the work of Macias-Corral *et al*., (2019).

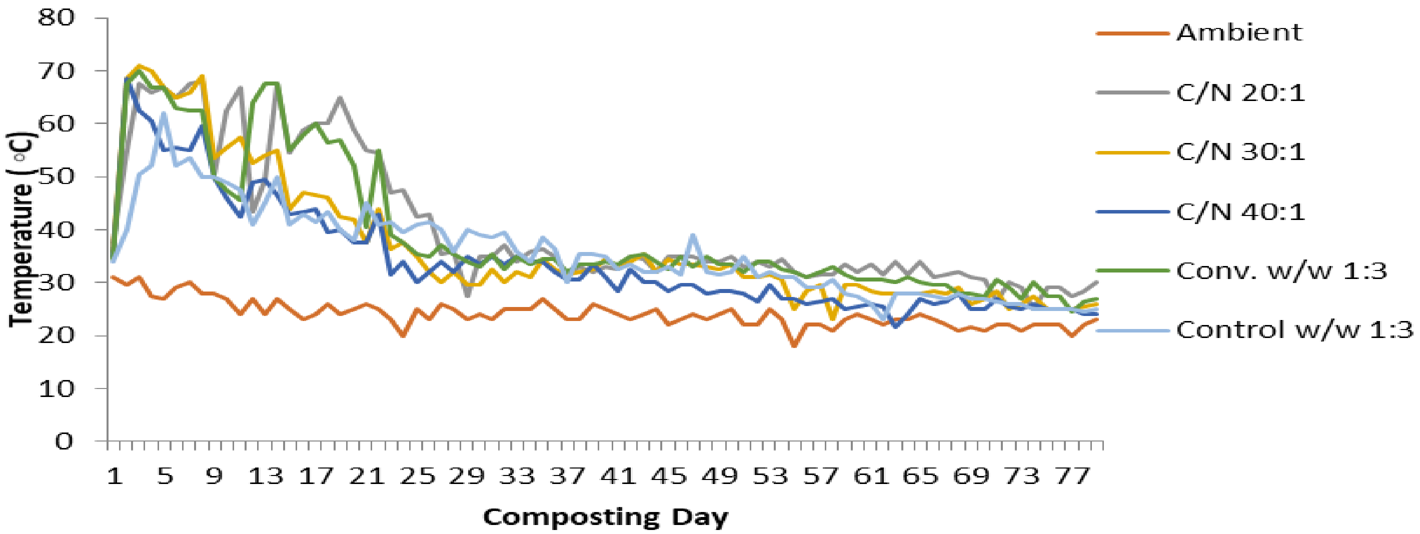


Fig. 1. Temperature changes during the composting process

3.2 Effects of C/N ratio of feedstock on pH and electrical conductivity of the composting piles across weeks of composting.

Figures 2 and 3 show the effect of C/N of feedstock on pH and electrical conductivity (EC) of the composting piles across weeks of composting. The pH and EC of composting pile were significantly influenced by the C/N ratios of the feedstocks tested. Alkaline pH range of 7.3 (in C/N 40:1) – 9.6 (in control w/w 1:3) and EC of about 0.01 (in control w/w 1:3) and 0.5 dS/cm (in C/N 20:1) were observed across all the composting pile all through the composting process. Similar ranges have been reported for compost suitable for use as soil amendments (Wong and Schuchardt, 2010; Azim *et al*., 2018). The C/N ratio tested significantly affected the pH and EC of the compost at each week of composting. The control pile (SD + PM at w/w 1:3 conventional) consistently gave highest pH of compost followed by 20:1 > 30:1 > conventional and 40:1 was least. Conversely, the least EC values were consistently recorded in the control compost w/w 1:3 all through the sampling periods with C/N 20:1 maintaining the highest EC values. Generally, the pH of compost decreased with the increasing week of composting up to seven weeks except in control. Significantly higher EC values were observed in the groundnut husk based compost piles especially C/N 20:1 pile compared to the control where the least valves were obtained.

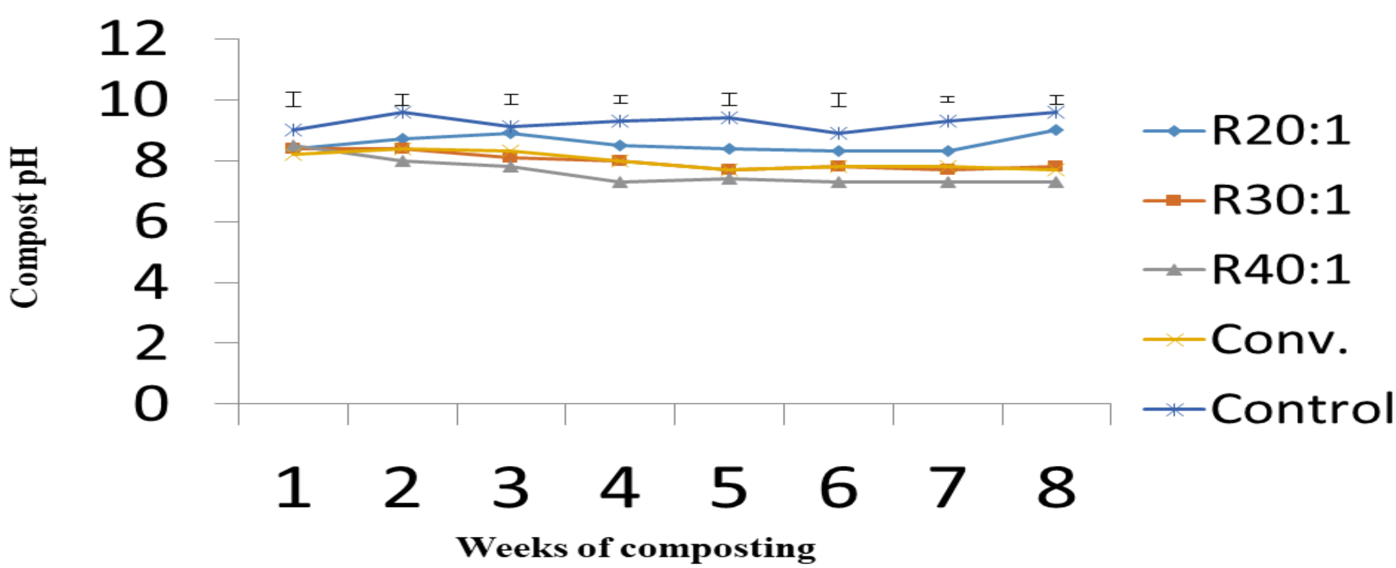


Fig. 2. Effects of C/N of feedstocks on pH of the composting piles across weeks of composting. Vertical bars represent LSD values R20:1 is C/N 20:1; R30:1 is C/N 30:1; R40:1 is C/N 40:1; Conv. is Conventional w/w 1:3 and Control is Control compost w/w 1:3.

3.3 Effects of C/N ratio of feedstock on total nitrogen, phosphorus and potassium contents of the resultant composts.

The different feedstock tested significantly influenced the nitrogen, phosphorus and potassium contents in the final composts (Table 3). The groundnut husk based compost supported higher nitrogen and potassium content in the final composts compared to the control. Compost with a 30:1 C/N ratio produced the highest total nitrogen content (1.80%) while C/N 20:1 compost had the highest potassium content. Phosphorus was however highest in C/N 20:1 and control compost (1.40%). The initial characteristics especially the nitrogen content of the sawdust used as the carbon source for the production of the control, compost contributed to the low N content of the control final compost.

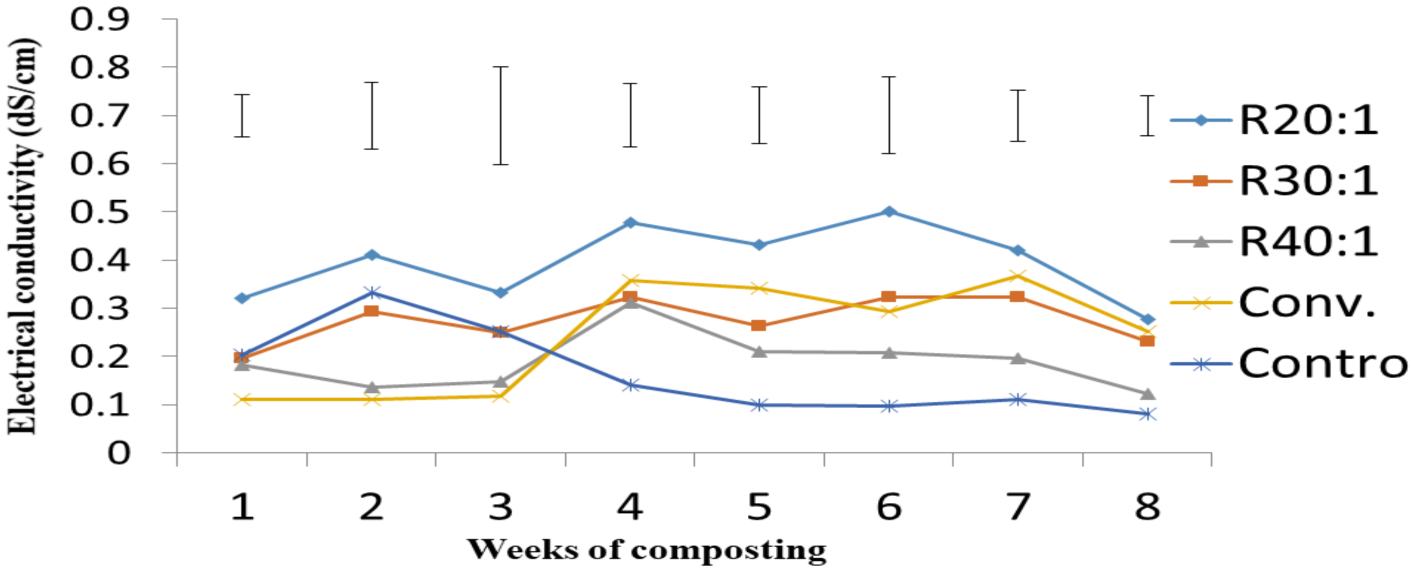


Fig. 3. Effects of C/N of feedstocks on the electrical conductivity of the composting piles across weeks of composting. Vertical bars represent LSD values. R20:1 is C/N 20:1; R30:1 is C/N 30:1; R40:1 is C/N 40:1; Conv. is Conventional w/w 1:3 and Control is Control compost w/w 1:3

Of all the groundnut husk based compost 40:1 had the least total nitrogen (1.60%) as a result of its receiving the least nitrogen source (rat litre of nitrogen content 3.36%). The high phosphorus in control compost which was similar to 20:1 C/N compost could be traced to the similar initial phosphorus contents (0.05%) of the two carbon sources tested. 40:1 C/N compost again was the poorest in total phosphorus content of all the composts produced. The phosphorus and potassium contents in all the final composts produced were similar to those reported by Selim *et al.,* (2012).

The total macronutrient content of each compost taken as the sum of N, P and K was significantly influenced by the initial C/N ratio of the composting feedstock with values decreasing with decreasing quantity of nitrogen source (rat litter) in the composting mix of the groundnut husk based compost (Table 3). All the groundnut husk based compost had higher total macronutrients compared to the control w/w 1:3 compost from sawdust and poultry manure. The C/N 20:1 compost gave the highest total macronutrients content (5.15 %) compared to the control compost (3.36 %). Total macronutrient content of >5% was suggested by Zhang *et a*l. (2019) as a good compost for profitable crop production.

Table 3. Effects of C/N ratio of feedstock on total nitrogen, phosphorus and potassium contents of the resultant composts.

Compost type	**N**	**P**	**K**	**Total macronutrient**
		%		
C/N 20:1	1.65b*	1.4 a	2.1a	5.15 a
C/N 30:1	1.76a	1.2 b	1.6c	4.56 b
C/N 40:1	1.56c	0.9 d	1.1d	3.56 c
Conv. w/w 1:3	1.64b	1.1 c	2.0b	4.74 d
Control w/w 1:3	0.86d	1.4 a	1.1d	3.36 e

*Means followed by the same letter (s) in the same column are not significantly different by DMRT at $p<0.05$.

3.4 Effects of initial C/N ratio of feedstock on organic carbon and organic matter content of the resultant composts.

The C/N ratios of the feedstock tested significantly ($P<0.001$) affected organic carbon and organic matter of the resultant composts produced (Fig. 4). The 40:1 C/N compost had the highest organic carbon (29.6%) and organic matter (50.9%) contents while control w/w 1:3 had the least organic carbon (18.8%) and organic matter (32.5%) contents. All the compost produced were below the range of organic carbon and the organic matter reported by Tiquia, 2005. Too high organic content (of more than 70%) will hinder the easy release of nutrient (especially nitrogen and phosphorus) elements from the compost when applied to soil as a result of nutrient immobilization by soil microorganisms. These present result show that all the compost produced have high potentials for excellent or easy release of the nutrient element from them when applied into soils.

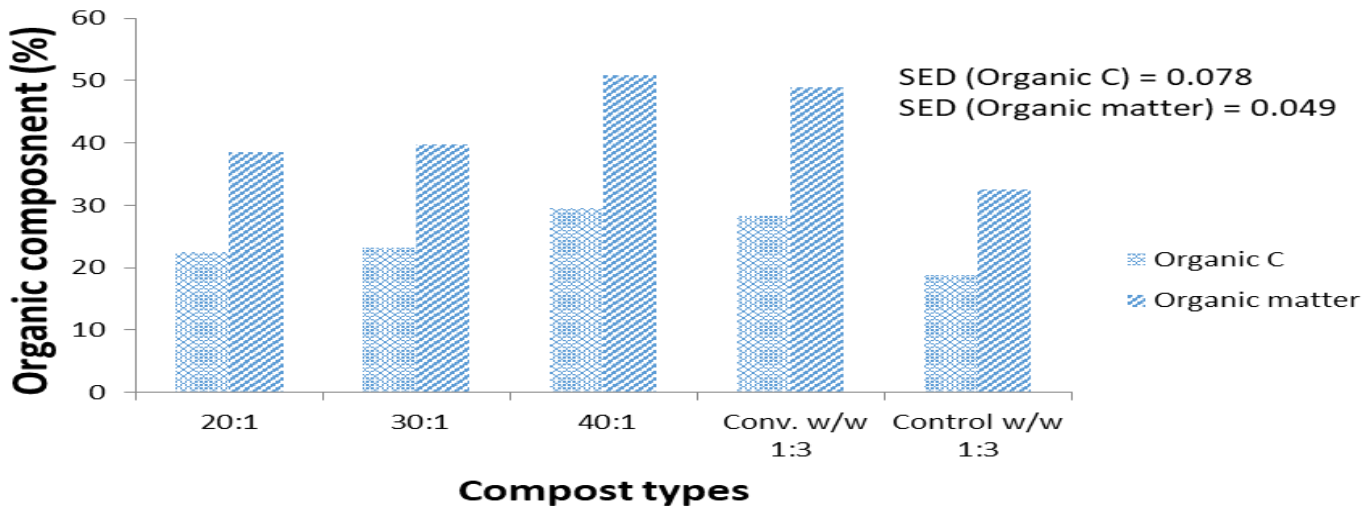


Fig. 4. Effects of initial C/N ratio of composting feedstock on organic carbon and matter in final compost types
SED is the standard error of means

3.5 Effects of initial C/N ratio of feedstock on C/N and C/P ratios of the resultant compost.

The C/N ratio of the feedstock significantly affected the carbon to nitrogen (C/N) and carbon to phosphorus (C/P) ratios of the resultant composts (Fig. 5). The C/N ratios of the final compost decreased from the initial 20 (C/N 20:1) to 90 (control w/w 1:3) to a range of 13 (C/N 20:1) – 22 (control w/w 1:3) after the 80 days of composting. The C/N ratio is considered a useful indicator in compost maturity assessment (Zhang *et al*., 2019; Iwegbue *et al*., 2006). Lower C/N and C/P ratios of composts are desired for good compost that will encourage a faster mineralization process when such composts are applied to the soil. The 20:1 and 30:1 C/N composts have the least C/N ratios (13.0 and 13.7 % respectively) while control compost had highest value (22.0 %). Implying that the rate of nitrogen release from 20:1 and 30:1 C/N compost types will be faster compared to other compost types. FAO (2003) gave the C/N ratio of final compost to range between 10 and 15. A C/N range of 10 – 20 in compost assures no occurrence of nutrient immobilization, retention of higher nitrogen content in the final compost and increase in nitrogen availability in the soil (Macias-Corral *et al*., 2019; Zhang *et al*., 2019; Dadi *et al*., 2019). The 40:1 C/N compost again was the poorest of the groundnut husk based compost although with values superior to control w/w 1:3 compost. The higher values of recalcitrant organic matter such as lignified materials in the sawdust used for the preparation of the control compost is implicated for the higher C/N ratio of the final control compost (Azim *et al* ., (2014). The C/N of all the final composts except the control conform with the findings of Zhang *et al*. (2019); Macias-Corral *et al*. (2019); Azim *et al*.(2018); Azim *et al*. (2014). The C/P ratio on the other hand was least (best) in control compost (14.3%) and highest (poorest) in 40:1 C/N compost (31.7%).

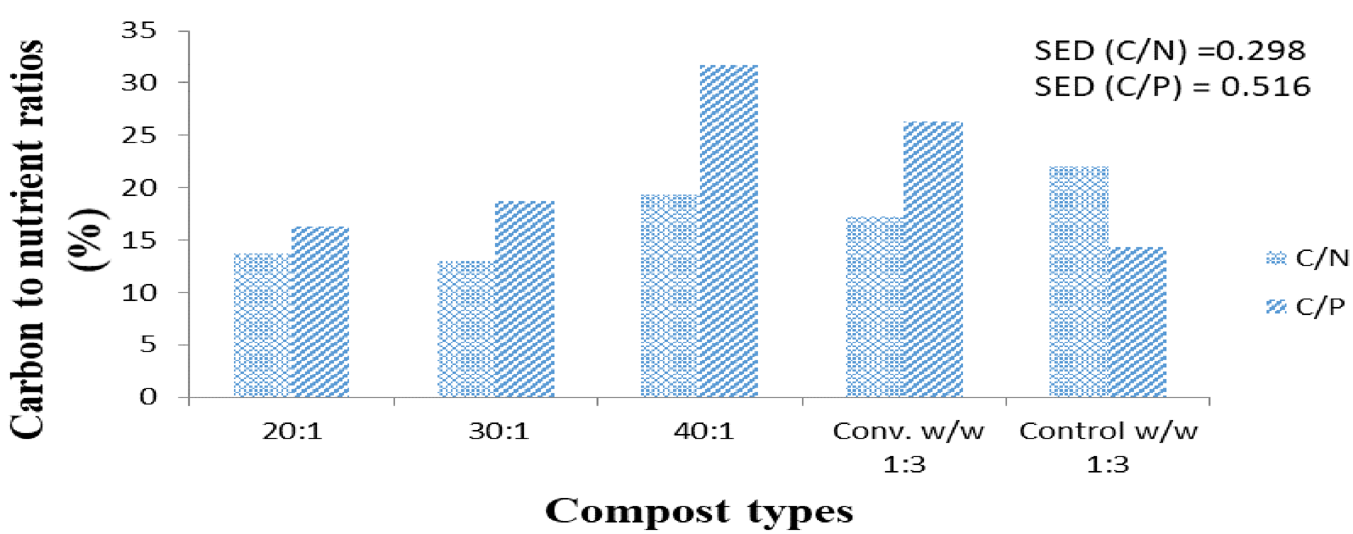


Fig. 5. Effects of initial C/N ratio of feedstock on C/N and C/P ratios of the resultant compost.
SED is the standard error of means

3.6 Effects of C/N ratio of feedstock on the basic nutrient of the cured compost

The C/N ratio of the feedstock tested significantly influenced the concentration of the basic nutrients (Ca, Mg, K and Na) in the compost produced (Table 4). Calcium was highest in the control compost followed by 20:1> 30:1> Conv.1:3 > 40:1 C/N composts. Calcium content in the compost produced seem to reduce with decreasing quantities of rat litter composted in each feedstock combination such that the 20:1 C/N ratio that received the highest quality of rat litter (105.4kg) was highest in calcium content (6.5%). The very high calcium content in the control compost could be traced to the possible high calcium content in the tree from which sawdust was obtained. The tree being a permanent crop would have accumulated large quantities of basic elements in its tissue over the years which had contributed to the very high calcium content in the compost produced. The 20:1 C/N and Conv. w/w 1:3 composts gave the highest potassium content while the highest magnesium content was from 20:1 C/N compost. The compost produced from the combination of groundnut husk and rat litter had very high sodium content compared to the control with values decreasing with decreasing rat litter quantity and increasing groundnut husk quantity. The higher sodium contents in the groundnut based final composts could be traced to the fact that most of the groundnut are brought from the northern arid region of Nigeria with soil characterized by high sodicity, which had resulted in high sodium content in the groundnut husk used for the trial. This also explains the generally high EC values of the groundnut husk based compost compared to the control w/w 1:3 compost prepared from sawdust and poultry manure mix.

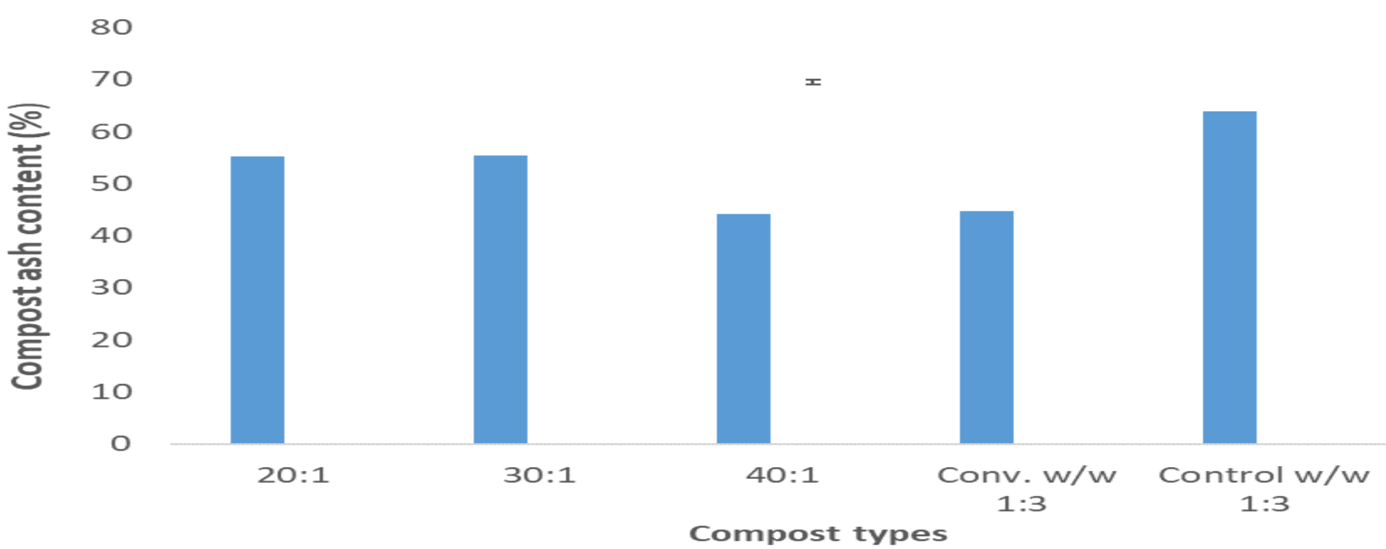
Table 4. Effects of C/N ratio of feedstock on basic nutrient of the cured compost

Compost type	Ca	Mg	K	Na ppm
		………………… %…………………		
20:1	6.5b*	1.6a	2.1a	162.5a
30:1	4.3c	1.1d	1.6c	131.2b
40:1	3.3e	1.0e	1.1d	100.3c
Conv. w/w 1:3	3.9d	1.2c	2.0b	162.6a
Control w/w 1:3	8.2a	1.5b	1.1d	36.4e

*Means followed by the same letter (s) in the same column are not significantly different by DMRT at $p<0.05$.

3.7 Effects of C/N ratio of feedstock on ash content of the resultant compost

Composted feedstocks of different carbon to nitrogen ratios tested had a significant effect on the ash content of the resultant compost (Fig. 6). Highest ash content (63.9%) was produced in the control compost followed by 30:1 > 20:1> Conv.1:3 > 40:1. This implies that the control compost has the highest alkaline property that will be of importance in neutralizing acidity or aluminium toxicity in soils.



*Vertical bar is the standard error of means

Fig. 6. Effects of C/N ratio of feedstock on ash content of the resultant compost

3.8 Effects of C/N ratio of feedstock and resultant compost extract concentration levels on cowpea germination index parameters

The root length and elongation percentage of cowpea were significantly influenced by the compost extract concentration levels of which germination percentage was not significantly influenced by both the compost type and extract concentration levels (Table 5). The 50 % concentration level supported higher cowpea root length, root elongation and germination percentages above the 100 % concentration level across all the compost types produced from varying C/N feedstock ratios. This is in line with the findings of Azim *et al*. (2018). The C/N 40:1 compost was highest in enhancing root length, root elongation and germination percentages of cowpea compared to other compost types. The compost from the least C/N ratio (20:1) produced cowpea seedlings with the least root length (2.9 cm) and elongation percentage (49.5 %) while the control compost (1:3 (w/w)) had the least germination percentage. Nonetheless, all the compost prepared regardless of the feedstock combination had a germination percentage of above 60%, a critical value documented in Azim *et al*. (2018) and Soudi (2005) for a phytotoxic–free compost. These authors opined that compost that supports germination percentage of 50 – 59% should not be seeded immediately after application unto soil but applied 90 days before sowing while germination percentages below 50 imply an immature compost that is not fit for use on soils as such contains phytotoxic components such as ammonia, ethylene oxides and organic acids.

The germination index (GI) values of the different compost types at 50 and 100% concentrations levels are shown in Fig. 7. Generally, the GI of the final composts were below 60 and 80% considered critical for phytotoxic-free compost (Tiquia and Tam, 1998) with values ranging from 25 (in Conv. w/w 1:3 100%) to 76 (in C/N 40:1 50%). Nevertheless, the low compost extract concentration level (50%) supported higher GI in cowpea compared to the 100% concentration with values highest in the highest C/N ratio (40:1) and least in lowest C/N 20:1 ratio. Similar low GI in compost produced from low C/N ratios has been reported (Huang *et al*., 2004; Guo *et al*., 2012) with the authors proposing a longer composting time for such compost to be matured. The work of Zhang *et al*. (2019) indicated that GI alone is not sufficient to prove a compost to be mature or immature. The GI from the plants raised on distilled water (DW) was highest (93%) followed by C/N 40:1 (50%) and conv.1:3 (50%) which gave 76 and 62% respectively**.** The GI range of 40-46% were produced by 30:1 (100%), 20:1 (100%), 20:1 (50%) and 40:1 (100%). Generally, the three -carbon to nitrogen ratios of the feedstock tested gave better germination index values at both 50 and 100% concentration levels compared to the control compost.

Present germination index data showed a direct relationship between the germination index values and the carbon to nitrogen ratio of the final composts. Compost from initial higher carbon to nitrogen ratios (conventional, 40:1 and control) gave better GI values when applied at 50% concentration level. The compost with lower carbon to nitrogen ratios (20:1 and 30:1) gave better GI values at 100%. It is worthy to note that ratio 20:1 compost gave a similar germination index value at both 100 and 50% concentration levels.

Table 5. Effects of C/N ratio of feedstock and resultant compost extract concentration levels on cowpea germination and seedling parameters

	Root length (cm) Compost extract concentration (%)			**Root Elongation (%)** Compost extract concentration (%)			**Germination percentage** Compost extract concentration (%)		
Compost types	100	50	Mean	100	50	Mean	100	50	Mean
20:1	2.77	3.04	2.90	46.3	52.7	49.5	86.7	80.0	83.3
30:1	2.71	3.22	2.96	47.3	54.7	51.0	86.7	60.0	73.3
40:1	3.06	4.80	3.93	53.0	82.3	67.7	86.7	93.3	90.0
Conv. w/w 1:3	3.10	2.97	3.04	55.3	51.7	53.5	66.7	73.3	70.0
Control w/w 1:3	2.55	3.92	3.23	44.3	68.0	56.2	60.0	93.3	76.7
Mean	2.84	3.59		49.3	61.9		77.3	80.0	
CT (LSD)	ns			ns			ns		
CEC (LSD)	0.591			10.19			ns		
CTXCEC (LSD)	ns			ns			ns		

CT is compost types, CEC is compost extract concentration, LSD is the Least significant difference of means, ns is not significant

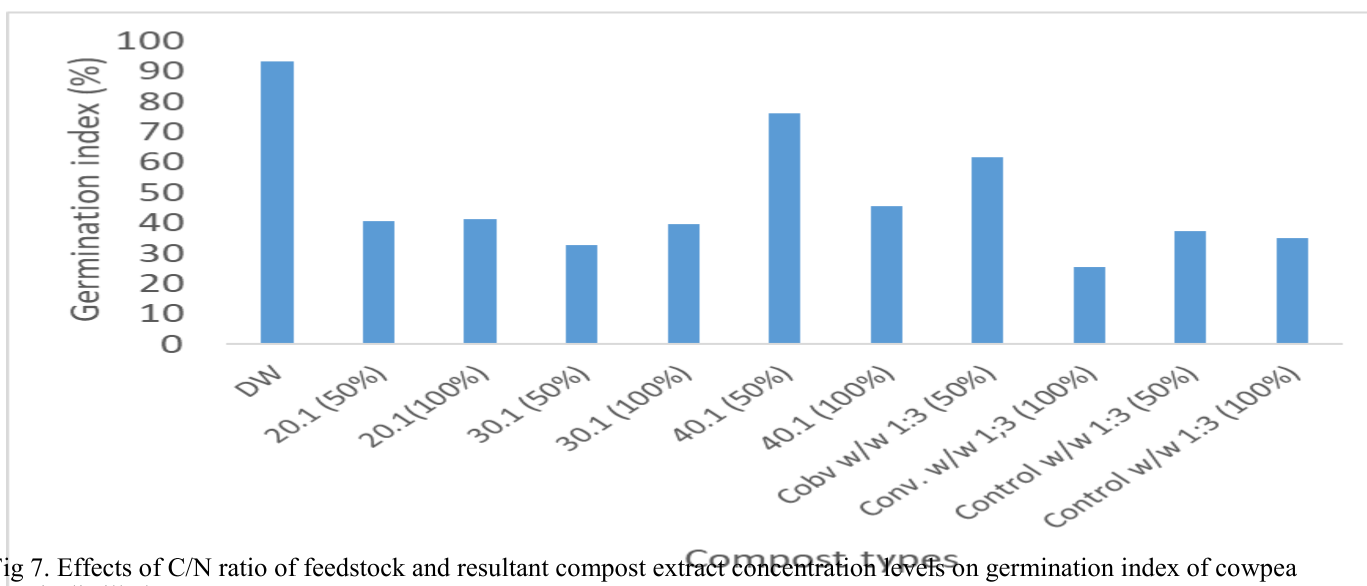


Fig 7. Effects of C/N ratio of feedstock and resultant compost extract concentration levels on germination index of cowpea
DW is distilled water

3.9 Contributions of increasing quantities of nitrogen source (Wister rat litter) and decreasing carbon source (Groundnut husk) to selected compost parameters

The contributions of increasing quantities of the N source (Wister rat litter) and decreasing quantities of the C source (groundnut husk) combined in the composted materials to selected nutrient parameters of the resultant composts are shown in Table 6. Increasing N and/or decreasing C source led to increasing ash and macronutrient (N, P, Ca, Mg, K and Na) contents in the composts produced of which contributions to Ca, Mg, K and Na were significant. Furthermore, the increasing quantity of N and /or decreasing C source reduced C/N, C/P, organic C and days to the stability of the compost as depicted by the negative relationship in the regression equations. These are desirable properties of good compost for use in degraded tropical soils. Surprisingly, the germination index of cowpea at both 50 and 100 % compost extract concentrations decreased with an increasing quantity of N and /or decreasing C source. Increasing release of ammonia into the growth medium is possible in biomass with a low C/N ratio. The ammonia may pose as a toxicant to the tender cowpea seedlings, thus reducing the growth index.

Table 6. Contributions of increasing quantities of nitrogen source and/or decreasing carbon source to selected compost parameters

Compost parameters	Regression Equation	R2 value
Total N	y = 0.0016x + 1.5156	0.17
Potassium	y = 0.0215x - 0.0891	0.95**
Total P	y = 0.0072x + 0.5765	0.75*
sodium	y = 1.3733x + 24.992	0.9**
Magnesium	y = 0.0114x + 0.2743	0.8*
Moisture content	y = 0.0325x + 2.9451	0.59
Calcium	y = 0.0576x - 0.2892	0.72*
C/P	y = -0.2759x + 46.183	0.65
C/N	y = -0.0976x + 23.941	0.45
Organic carbon	y = -0.1218x + 35.996	0.48
Ash	y = 0.1757x + 35.319	0.33
Days to Stability	y = -0.1222x + 81.654	0.23
Stability temperature	y = 0.0468x + 21.535	0.51
Germination index (50%)	y = -0.6163x + 103.93	0.41
Germination index (100%)	y = -0.1758x + 52.559	0.17

*and ** significant at P<0.05 and 0.01 levels respectively. (n=5)

4.0 Summary and conclusions

The variability in the carbon to nitrogen ratio of different composting feedstocks is a major factor affecting proper composting conditions for faster compost stability, higher nutrient content and non-toxic compost production. This work studied the effects of three carbon to nitrogen ratio combinations of groundnut husk and wister rat litter on stability, phytotoxicity and nutrient quality of compost.

The C/N of composting feedstock tested significantly affected all the parameters tested. The pH, EC and organic carbon of all the compost types were within the acceptable range. Organic carbon and organic matter contents of the resultant composts increased with increasing C/N ratio of the composting feedstock while basic nutrients (Ca, Mg, K and Na) content decreased with increased C/N ratio of the composting feedstock. Present results showed control compost mixture using the conventional weight by weight modality to favour least organic carbon, matter and highest calcium and ash contents while the C/N feedstock ratio modality favours higher total N, better C/N ratio, germination index values and faster stability/curing of resultant compost.

The germination index values of crops raised on resultant compost were directly affected by the carbon to nitrogen ratio of the compost. Composts higher in carbon to nitrogen ratio supported better crop performance when seeding is delayed after compost application (50% concentration) while those with lower carbon to nitrogen ratio can be seeded immediately after compost application (100% concentration).

Conclusively, the three-carbon to nitrogen ratios of the feedstock tested gave better germination index values at both 50 and 100% concentration levels compared to the control compost. The control compost (SD+PM w/w 1:3) was also poorest in C/N ratio and total nitrogen content which are factors that directly control nutrient mineralization of applied compost. It is therefore recommended that usage of carbon to nitrogen ratio of composting feedstock modality is better than the broad feedstock combination using weight by weight or volume by volume ratio (such 1:2, 1:3 etc) of carbon to nitrogen sources.

References

Antil R.S., Raj D., Abdalla., N. and Inubushi K. 2014. Physical, chemical and biological parameters for compost maturity assessment: a review. In Maheshwari D. (ed). Composting for sustainable agriculture. Vol. 3. 83-101. Springer. https://doi.org/10.1007/978-3-319-08004-8_5.

Azim K., Faissal U, Soudi B, Perissol C., Roussos S. and Alami I.T. 2018. Elucidation of functional chemical group responsible of compost phytotoxicity using solid-state 13C NMR spectroscopy under different initial C/N ratios. Environmental Science and Pollution Research 25 (4): 3408-3422.

Azim K., Ouyahia K., Amellouk A., Perrissol C., Thami A.I. and Soudi B. 2014. Dynamic composting optimization through C/N ratio variation as a start-up parameter. In: Rahmann G. and Aksoy U (Eds), Proceedings of the 4th ISOFAR Scintific Conference. 'Building Organic Bridges' at the Organic World Congress 2014, 13 -15 October, Istanbul, Turkey.

Baddi G.A., Hafidi M., Cegarra J., Alburquerque J.A., Gonzalvez J., Gilard, V. and Revel J.C. 2004. Characteristics of fulvic acids by elemental and spectroscopic (FTIR and C-NMR) analyses during composting of olive mill wastes plus straw. Bioresource Technology 93: 285-290.

Chen Z., Kin J. and Jiang X. 2018. Survival of *Esherichia coli* 0157:H7 and *Salmonella enterica* in animal waste - based compost as influenced by compost type, storage condition and inoculation level. Journal of Applied Microbiology 124: 1311-1323. https://doi.org/10.1111/jam.13719.

Dadi D., Daba G., Byene A., Luis Pa and Van der Bruggen B. 2019. Composting and co-composting of coffee husk and pulp with source separated municipal solid waste: a breakthrough in the valorization of coffee waste. International Journal of Recycling of organic waste in Agriculture 8: 263-277. https://doi.org/10.1007/540093-019-0256-8.

Fadare, D.A.,Bamiro, O.A. and Oni, A.O. 2000. Energy analysis for production of powdered and pelletised organic fertilizer in Nigeria. *APRN Journal of Engineering and Applied Sciences* 4.4:75-82.

Gao M., Liang F., Yu A., Li B. and Yang L. 2010. Evaluation of stability and maturity during forced aeration composting of chicken manure and sawdust at different C/N ratios. Chemosphere 78: 614-619. https://doi.org/10.1016/j.chemosphere.2009.10.056.

Griffine T.S. and Hutchinson M. 2007 Compost maturity effects on nitrogen and carbon mineralization and plant growth. Compost Science and Utilization 15 (4) 228-236

Guo R., Li G., Jiang T., Schuchardt F, Chen T., Zhao Y. and Shen Y. 2012. Effects of aeration, C/N and moisture content on the stability and maturity of compost. Bioresource Technology 112: 171-178.

Huang G.F., Wong J.W.C., We Q.T., Nagar B.B. 2004. Effects of C/N on composting of pig manure with sawdust. Waste Management 24: 805-813.

Iwegbue C.M.A., EgunA.C., Emuh F.N. and Isirimah N.O. 2006. Compost maturity evaluation and its significance to agriculture. Pakistan Journal of Biological Sciences 9: 2933-2944.

Kolade O.O., CokerA.O., Scridhar M.K.C. and Adeoye G.O. 2006. Palm kernel waste management through composting and crop production. Journal of Environmental Health Research 5(2): 81-85.

Macias-Corral M.A., Cueto-Wong J.A., Moran- Martinez J. and Reynose-Cuevas L. 2019. Effects of different initial C/N ratio of cow manure and straw on microbial quality of compost. International Journal of Recycling of Organic Waste in Agriculture 8:357-365

Makan A. and Mountadar M. 2012. Effects of C/N ratio on the in-vessel composting under air pressure of organic fraction of municipal solid waste in morocco. Journal of Material Cycles and WasreManagement 14: 241-249.

Musa A.M., Ishak C.F., Karam D.S and Jafaar N. 2020. Effects of fruit and vegetable wastes and biodegradable municipal wastes co-mixed composts on nitrogen dynamics in an oxisol. Agronomy 10: 1609; doi: 10.3390/agronomy10101609.

Nayak A.K., Varma V.S., Ajay S.K. 2013. Effects of various C/N ratios during vermicomposting of sewage sludge using *Eisenia fetida.* Journal of Environmental Science and Technology 6: 63-78.

Ogazi J.N. and Omueti, J.A.I. 2000. Waste utilization through organomineral fertilizer production in South Western Nigeria. Conference proceedings of the eight international symposium on animal, agricultural and food processing waste held at Des-Moines, Lowa State USA, 640 – 647 pp.

Ogunbanjo, O.R., Omueti, J.A.I., Jayeoba, O.J., Omolaiye J.A., Abiola I.O. and Uzokwe, N.E. 2007. Yield response of maize to animal manures and bulking agents in fortified compost. *ASSET series* 7.1:87-.

Oyeyiola, Y.B. 2016. Influence of cassava effluent on phytotoxicity, nutrient quality and stability of compost. *Elixir Agriculture,* 92:38910-38914.

Oyeyiola, Y.B. and Omueti, J.A.I. 2019a. Nutrient quality and phytotoxicity assessment of phospho-compost prepared under two bone meal fortification methods. *Malaysian Journal of Soil Science* 23: 119-134.

Soudi B. 2005.The composting of cattle manure and crop residues from greenhouse production system. Bullet Transfer of Technology in Agriculture. PNTTA June edition (2005) N◦129. http://www.agrimaroc.net/129.pdf.

Tiquia S. and Tam N. 1998. Elimination of phytotoxicity during co-composting of spent pig- manure sawdust litter and pig sludge. Bioresource Technology 65 (1-2): 43-49.

Tiquia S.M. 2005. Microbiological parameters as indicators of compost maturity. Journal of Applied Microbiology 99: 816-828.

Wang Y.Q. and Schuchardt F. 2010. Effect of C/N ratio on the composting of vineyard pruning residues. Agriculture and Forestry Research 3: 131-138.

Zbytniewski R. and Buszewski B. 2005. Characterization of natural organic matter (NOM) derived from sewage sludge compost Part 1: Chemical and spectroscopic properties. Bioresource Technology 96 (4): 471-478.

Zhang J., Ying Y. and Yao X. 2019. Effects of turning frequency on the nutrients of *Camellia oleifera* shell co-compost with goat dung and evaluation of co-compost maturity. PLos ONE 14(9):e0222841. https://doi.org/10.1371.

Zucconi F. and de Bertoldi M. 1987. Compost specification for the production and characterization of compost from municipal solid waste. In: de Bertoldi M., Ferranti M.P., L'HHermite P and Zucconi F. (Eds). Compost: Production, Quality and Use. Elsevier, Barking. Pp. 30-50.