Original Research Article

Maturity indices of composting plant materials with *Trichoderma asperellum* as activator

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Abstract

Compost maturity is a major factor in its use for nutrient supply without adverse effect on crop germination. Composting may be accelerated with inclusion of some microorganisms as activators. This study was conducted to determine the effect of *Trichoderma asperellum* and length of composting of different plant materials and cattle manure on compost maturity in Ibadan, Nigeria. Composting of two plant materials with cow dung at ratio 3:1 was done in triplicate with or without *Trichoderma* activation to obtain twelve heaps of four different types of composts; Panicum-based compost with *Trichoderma*, Tridax-based compost with *Trichoderma*, Panicum-based compost without *Trichoderma* and Tridax-based compost without *Trichoderma*. The process was a 2×2 factorial experiment, laid out a completely randomized design. The *Trichoderma* activated compost (TAC) at four weeks of composting (4WC) had 56% total N, 21% organic matter, 38% total K, 51% total P and 66.6% microbial biomass N increase over non-activated compost (NAC). Carbon to nitrogen ratio was within the ideal range (10–20) in TAC while it was greater than it in NAC. Microbial biomass and lignin contents had a 56% and 41% increase, respectively, in NAC over TAC. *Trichorderma*-activated compost has a potential to hasten maturation and makes the compost ready for field on or before four weeks without posing a threat to crop germination.

Keywords: Compost activator; maturity; organic materials; nitrogen; phosphorus; potassium; organic matter.

INTRODUCTION

Bulking materials, duration of composting and some techniques constitute a main hurdle to effective production and utilization of composts. Compost is a result of aerobic process during which microorganisms play an essential function of breaking down raw organic materials such as crop residues, animal wastes, food garbage, a few municipal wastes and suitable industrial wastes into a stable organic matter in order to enhance their suitability for application to the soil as a fertilizing resource for improving soil quality and fertility (Tiquia, 2002; Borken et al., 2002; Rynk, 1992). Composting is an accepted method for the recycling of organic wastes for the manufacture of soil enhancers (Rabia et al., 2014); there are recalcitrant organic substrate like lignin, cellulose and hemi-cellulose which degrade partially and transform to organic matter at a lower rate (Adejuyigbe et al., 2006), however, research has shown that some cultured microorganisms – particularly bacteria and fungi – when introduced into a compost pile have the ability to speed up the rate of decomposition of these recalcitrant organic substrates. Thus, the cultured microbes serve as compost accelerators. The microbial community in composts converts degradable organic matter to more stable, humidified forms and products together with carbon dioxide, water, ammonia, nitrate and methane, releasing heat as a metabolic waste product (Ciavatta et al., 1990; Boulter–Bitzer et al., 2006). Factors influencing the rate at which composting proceeds consist of raw material, particle size, aeration, moisture content, and the carbon-to-nitrogen (C/N) ratio (Mahimairaja et al., 2008).

Production of stabilised compost is highly important in agriculture. Well matured compost provides a stabilised form of organic matter (humus) and has the potential to enhance nutrient availability in the soil more than raw organic waste and other soil additives (Saviozzi et al., 1988). Maturity is an

important factor in determining compost quality because immature compost may create anaerobic conditions in the rhizosphere or induce phyto-toxins which inhibit plant growth (Raghavendra et al., 2009). Compost maturity is a function of composting plant materials and duration of composting (Ofosu-Budu et al., 2010; FAO, 2012); the duration of composting can be accelerated by introduction of cultured microbes like bacteria and fungi into the compost piles. The application of *Trichoderma* spp. into the compost pile accelerates composting of organic materials which improve soil properties and fertility through rapid composting (Hermosa, 2012). In this study, it is hypothesised that the effectiveness of *Trichoderma* in hastening compost maturity is not a function of the type of compost materials. Thus, this study aimed at determining the effect of *Trichoderma asperellum* and length of composting on compost maturity and also to determine temporal changes in biochemical properties considered for maturity and nutrient composition of composts made with *Trichoderma* addition.

MATERIALS AND METHODS

The experiment was carried out at the Federal College of Agriculture, Ibadan (Longitude 7°33′N, and Latitude 3°56′E). The experiment was a 2 × 2 factorial laid out in a completely randomized design (CRD) replicated three times. The factors included two types of composting materials; (Guinea grass – *Panicum maximum* and Tridax weed – *Tridax procumbens*) and presence or absence of compost activator (*Trichoderma asperellum*). The two plant materials were chopped into particles smaller than 5 cm with a chaff cutter in order to increase their surface area for decomposition. The Indore type of hot heap method of composting was adopted (CIAS, 2002). This involved layer by layer spreading of plant materials and animal dung at the ratio of 3:1 on one another above ground. The dimension of each compost pile was 2 m width by 3 m length and 1.5 m height with substrate weight of approximately 500 kg. The heap sides were lined with black polythene sheet and the plant materials were added in layers with cow dung at a ratio of 3:1 (30 kg plant material: 10 kg cow dung) ratio by dry weights (Adediran et al., 2009). Composting was done in triplicate to obtain twelve heaps of four different types of compost: Tridax-based compost with *Trichoderma* sp. (TBC+T), Tridax-based compost without *Trichoderma* sp. (TBC), Panicum with *Trichoderma* sp. (PBC+T) and Panicum-based compost without *Trichoderma* sp. (PBC).

Inoculation with *Trichoderma asperellum*

Pure cultured plate of *Trichoderma asperellum* was sourced from the International Institute of Tropical Agriculture (IITA) and multiplied on potato dextrose agar in the Microbiology laboratory at Federal College of Agriculture, Moor Plantation, Ibadan, Nigeria, following the procedure of Nusrat et al. (2013). *Trichoderma* application was done at the rate of 500 g compost activator per 1000 kg substrate in accordance with the recommendation of Biospark (2010). Twenty (20) plates of fully-grown *T. asperellum* were added into 1 L of sterile water, mixed vigorously and used to wet compost piles at the rate of 250 ml per heap. Compost piles were turned with the use of gardening fork and randomly sampled bi-weekly for six months to give a total of 144 samples. The samples collected were divided into two. One half was air dried, bagged in polythene, labelled, kept in a carton at room temperature for chemical analysis. The second half of each sample was bagged in polythene, labelled, placed inside an airtight container and refrigerated for microbiological analysis.

Chemical Analysis

The pH of the composts was determined potentiometrically in water 1:1 (w/v) compost/water ratio after shaking for 30 minutes using a pH meter with glass electrode (Suzuki et al., 2004). The organic matter (OM) content of composts was determined by loss on ignition of the dry mass at 550 °C (Navarro et al., 1993). The P concentration was determined colorimetrically as molybdovanadate phosphoric acid after digestion with HNO_3. Sodium and Potassium were determined by flame photometer, whereas Ca and Mg were determined using atomic absorption spectrometry (Roca-Pérez et al., 2009). Dissolved organic matters (DOC) from the composts were extracted with distilled water (1:10 w/v ratio) by shaking for one hour and left for six hours (Ciavatta et al., 1990). The extracts were filtered through a 0.45 µm membrane filter. The concentration of water-soluble carbon (WSC) was then determined from the extract by oxidation with potassium dichromate (Gigliotti et al., 2002). Total nitrogen was determined in compost by micro-kjeldahl method (Gazzetta, 1992). Inorganic nitrogen (NH_4^+-N and NO_3^--N) were extracted with 2M KCl from refrigerated subsample and determined by colorimetric method based on Berthelot's reaction (Sommers et al., 1992), whereas the C/N ratio of each compost was determined by calculation. The exchangeable bases of each of the composts were determined using 1M ammonium acetate following the method of Lax et al. (1986). The exchangeable acidity was determined by titration method. The effective cation exchangeable capacity of the compost was determined by summation of exchangeable bases and exchangeable acidity. The lignin concentration of the compost sample was determined using the acid detergent fibre (ADF) according to Clancy and Wilson (1966).

Table 1. Table 1. Nutrient composition of the organic materials and composts used for the study

Nutrients	N	P	K	Ca	Mg	Zn	Cd
	----------g kg^{-1}----------						
Organic materials							
Cow dung (CD)	12.8	20.5	5.4	ND	ND	ND	ND
Tridaxprocumbens **(TP)**	8.6	23.7	13.1	ND	ND	ND	ND
Panicum maximum **(PM)**	17	12	13.2	ND	ND	ND	ND
Composts							
Tridax–based compost with *Trichoderma spp* **(TBC+T)**	22.1	27.6	35	25	55	0.61	0.04
Panicum-basedcompost with *Trichoderma spp* **(PBC+T)**	26.8	11.7	30	33	59	0.56	0.06
Panicum-basedcompost (PBC)	20.1	14.4	52	23	52	0.54	0.04
Tridax-basedcompost (TBC)	15.1	21.6	33	21	48	0.55	0.04

ND- Not detected

Determination of microbial biomass C and N

Microbial biomass C and N were determined using the chloroform fumigation extraction (CFE) method, according to Vance et al. (1987) and Brookes (1995), respectively. Twenty gram (20 g) of each of the compost was fumigated with ethanol-free $CHCl_3$ for 24 hours at 25 °C in a desiccator. After fumigation, the samples were extracted for 60 min with 80 ml 0.5 mol L^{-1} K_2SO_4 solutions (1:4, w/v) and then filtered through a Whatman filter paper No 42. Non-fumigated samples were also extracted following the same procedure. The soluble C in the fumigated and non-fumigated compost extract was determined using the potassium dichromate oxidation method and subsequent back-titration of unreduced dichromate. Total N in the extracts was determined according to the Kjeldahl method. The microbial biomass C (MBC) of the sample was estimated using the following equation:

$$MBC = CE / 0.35$$

Where:
CE = Organic C extracted from fumigated – Organic C extracted non-fumigated

The microbial biomass N (MBN) was estimated using the following equation:

$$MBN = NE / 0.68$$

Where:
NE = total N extracted from fumigated – total N extracted from non-fumigated (Brookes, 1995)

Germination Test

Seed germination test was conducted using the method of Kutsanedzie et al. (2012). Two sterile Petri dishes were padded with five pieces of filter paper each, wetted with 5 ml of 1:10 compost aqueous extract from compost samples representative of each type. The third Petri dish was wetted with distilled water as a control. Ten seeds of maize were placed in each Petri dish and incubated for five days in the dark at 25 °C. The germinated seeds were counted and their root length measured in each Petri dish using a rule and thread. The germination index was then computed using the formula below:

$$GI = (Nt / Ng) \times (AvRLt / AvRLc) \times 100$$
(Kutsanedzie et al. 2012)

Where:
GI = Germination index
Nt = Number of germinated seed in the treated
Ng = Number of germinated seed in the control
AvRLt = Average root length of germinated seeds in the treated
AvRLc = Averaged root length of germinated seeds in the controlled

Statistical Analysis

Data collected from the study were subjected to analysis of variance (ANOVA) using statistical analysis system (SAS) for analysis of variance (ANOVA) while the treatment means were separated using the Duncan's multiple range test (DMRT) at $P < 0.05$.

RESULTS

Organic materials used in composting differed in their nutrient compositions (Table 1). The N concentration in the organic materials was in the order of *Panicum maximum* (PM) > (cow dung) CD > *Tridax procumbens* (TP). The concentration of P was, however, in the order of TP > CD > PM, whereas the potassium concentration was in the order of PM > TP > CD.

Changes in chemical properties of the composts presented in Table 2 indicated no significant difference in pH, microbial biomass nitrogen (MB-N), cation exchange capacity (CEC), and seed germination index. Higher concentrations of Total N, Organic matter, total K, total P and lignin were observed in TAC than in NAC. Carbon to nitrogen ratio (C:N) and MBC were higher in NAC compared with TAC. Nutrient status of the four composts produced from the organic materials is presented in Table 3. Results showed that the nitrogen concentration was higher in *Trichoderma*

Table 2. Biochemical properties of composts at 4 weeks after process onset

Treatment	pH (H_2O)	Org. M (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Total K (g kg^{-1})	MB-C (mg kg^{-1})	MB-N (mg kg^{-1})	CEC (c mol kg^{-1})	Seed GI (%)	Lignin (%)	C:N
PBC	8.75a	253.7b	12.8b	3.8b	12.0b	2100a	300a	9.6a	95.5a	48.5a	24.5a
TBC	8.69a	230.0b	8.7c	4.2b	12.2b	2100a	300a	11.0a	92.0a	35.5a	22.5a
PBC+T	8.49a	310.0a	24.3a	7.5a	23.7a	1400b	400a	11.5a	92.0a	24.5b	13.2b
TBC+T	8.58a	298.0a	24.4a	8.9a	15.9a	1300b	600a	11.7a	96.0a	21.8c	14.3b

Means with the same letter(s) within the group in a column are not significantly different at 5% probability by Duncan multiple range test.
Legend: PBC– Panicum-based compost with *Trichoderma*
TBC – Tridax-based compost without *Trichoderma*
TPBC – Panicum-based compost with *Trichoderma*
TTBC – Tridax-based compost with *Trichoderma*

Table 3. Biochemical properties of composts at 8 weeks after process onset

Treatment	pH (H_2O)	Org. M (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Total K (g kg^{-1})	MB-C (mg kg^{-1})	MB-N (mg kg^{-1})	CEC (c mol kg^{-1})	Seed GI (%)	Lignin (%)	C:N
PBC	8.26a	233.0b	12.3c	3.3b	27.0a	2300a	600b	11.0a	88.0a	32.7a	20.3a
TBC	8.27a	208.0c	18.7bc	4.3a	12.5b	1500b	400c	11.1a	88.7a	37.7a	12.3b
PBC+T	8.19a	271.0a	29.0a	5.9a	28.8a	2700a	1000a	11.9a	84.9b	30.3a	10.6b
TBC+T	7.96a	252.3b	24.1b	6.3a	25.0a	1900ab	800a	11.7a	94.9a	41.9a	9.5b

Means with the same letter(s) within the group in a column are not significantly different at 5% probability by Duncan multiple range test.
Legend: PBC– Panicum-based compost with *Trichoderma*
TBC – Tridax-based compost without *Trichoderma*
TPBC – Panicum-based compost with *Trichoderma*
TTBC– Tridax-based compost with *Trichoderma* in the levels.

Table 4. Biochemical properties of composts at 12 weeks after process onset

Treatment	pH (H_2O)	Org. M (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Total K (g kg^{-1})	MB-C (mg kg^{-1})	MB-N (mg kg^{-1})	CEC (c mol kg^{-1})	Seed GI (%)	Lignin (%)	C:N
PBC	8.26a	233.0b	12.3c	4.9a	27.0a	1900ab	600b	11.0a	88.0a	32.7b	21.4a
TBC	8.27a	272.3a	18.2bc	6.3a	28.8a	1500b	200c	11.1a	88.7a	37.7a	12.2b
PBC+T	8.19a	231.0b	29.0a	4.3a	25.0ab	2700a	1000a	11.9a	84.9b	30.3b	15.4c
TBC+T	7.96a	208.0c	24.0b	3.3a	12.5b	2300a	800a	11.7a	94.9a	31.9b	11.5b

Means with the same letter(s) within the group in a column are not significantly different at 5% probability by Duncan multiple range test.
Legend: PBC– Panicum-based compost with *Trichoderma*
TBC – Tridax-based compost without *Trichoderma*
TPBC – Panicum-based compost with *Trichoderma*
TTBC – Tridax-based compost with *Trichoderma*

Table 5. Biochemical properties of composts at 24 weeks after process onset

Treatment	pH (H_2O)	Org. M (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Total K (g kg^{-1})	MB-C (mg kg^{-1})	MB-N (mg kg^{-1})	CEC (c mol kg^{-1})	Seed GI (%)	Lignin (%)	C:N
PBC	7.66a	229.3b	8.4c	5.6a	2.68b	1500b	400a	12.7a	85.5a	12.7a	21.9a
TBC	7.75a	212.5b	15.7b	4.5a	2.86ab	1600b	200a	11.7a	78.1b	14.7a	8.8c
PBC+T.	7.79a	260.8a	23.7a	6.3a	3.04a	2200a	700a	13.5a	87.7a	14.0a	14.1b
TBC+T	7.56a	210.8b	21.8a	8.6a	3.06a	1700b	600a	13.0a	86.7a	14.2a	9.9c

Means with the same letter(s) within the group in a column are not significantly different at 5% probability by Duncan multiple range test.
Legend: PBC– Panicum-based compost with *Trichoderma*
TBC – Tridax-based compost without *Trichoderma*
TPBC – Panicum-based compost with *Trichoderma*
TTBC– Tridax-based compost with *Trichoderma*

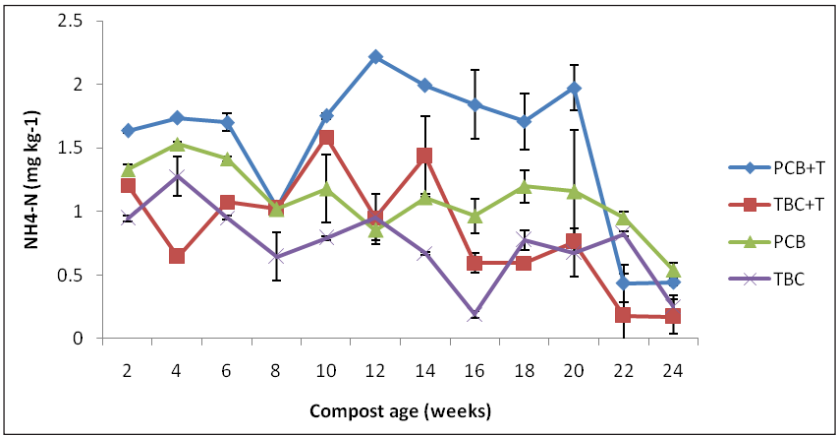

Figure 1. Effect of *Trichoderma asperellum* acceleration on ammonium nitrogen concentration of different composts (Bars indicate SEM).
Legend: PBC – Panicum-based compost with *Trichoderma*; TBC – Tridax-based compost without *Trichoderma*; TPBC – Panicum-based compost with *Trichoderma;* TTBC – Tridax-based compost with *Trichoderma*

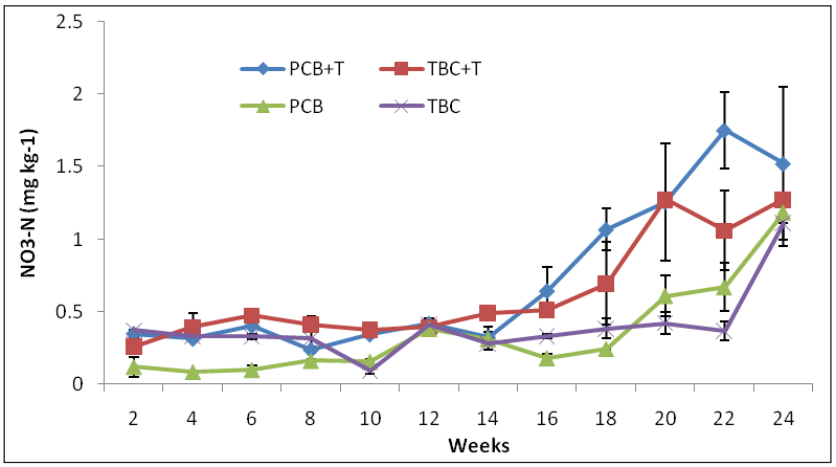

Figure 2. Effect of *Trichoderma asperellum* acceleration on nitrate nitrogen concentration of different composts (Bars indicate SEM).
Legend: PBC– Panicum-based compost with *Trichoderma*; TBC – Tridax-based compost without *Trichoderma;* TPBC – Panicum-based compost with *Trichoderma;* TTBC– Tridax-based compost with *Trichoderma*

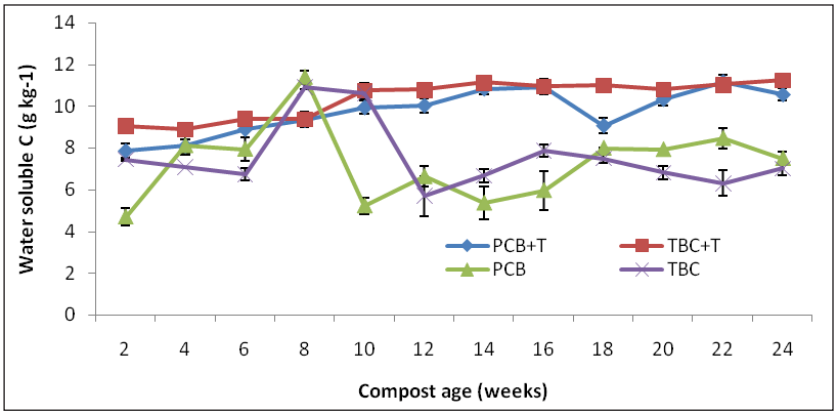

Figure 3. Effect of *Trichoderma asperellum* acceleration on water soluble carbon concentration of different composts (Bars indicate SEM).
Legend: PBC– Panicum-based compost with *Trichoderma*; TBC – Tridax-based compost without *Trichoderma*; TPBC – Panicum-based compost with *Trichoderma;* TTBC– Tridax-based compost with *Trichoderma*

activated compost (TAC) than in the non-activated compost (NAC). The trend of N content in the compost was: Panicum-based compost with *Trichoderma* (PBC+T) > Tridax-based compost with *Trichoderma* (TBC+T) > Panicum-based compost without *Trichoderma* (PBC-T) > Tridax-based compost without *Trichoderma* (TBC-T). Phosphorus concentration was generally higher in Tridax-based composts.

At eight weeks after the onset of composting processes compost types differed significantly ($P \leq 0.5$) in most biochemical properties except for pH, CEC and lignin (Table 3). The pH ranged from slightly alkaline to moderately alkaline. The total N concentration was highest in PBC+T followed by TBC+T and lowest in PBC–T. Phosphorus concentration in TBC+T was not significantly different from PBC+T and TBC-T. Addition of *Trichoderma* improved the K content of TBC. Panicum-based compost, irrespective of *Trichoderma* addition, had higher MBC content than Tridax-based compost. *Trichoderma* activated composts had a higher MBN than NAC.

There were no significant differences observed in pH, total P and CEC concentrations of composts at 12 weeks after the onset of composting (Table 4). Total N concentration was higher in PBC+T and lowest in PBC–T. Non-activated composts had higher contents of K, though comparable to PBC+T whereas TBC+T had the least. Microbial biomass nitrogen (MBN) was higher with *Trichoderma* activation than NAC. *Trichoderma* activation improved the microbial biomass carbon (MBC) content of TBC. At 24 weeks (Table 5), the pH, total P, MBN, CEC and lignin were not significantly affected by the treatments. *Trichoderma* activated compost was significantly higher in Total N and K compared to NAC. Microbial biomass carbon (MBC) content was significantly higher in PBC+T than all other compost types while C:N of PBC-T was higher than those of other compost types. *Trichoderma* activation improved the percentage seed germination index of TBC.

The ammonium N contents decreased with length of composting (Fig. 1). There was a slight increase at 8 to 12 weeks which gradually decreased till 24 weeks in all compost types, the effect of treatments on NH_4-N levels was highly significant at 10 weeks though comparable to 4, 6, 12, 14 and 20 weeks. The levels of NH_4-N generally reduced at 24 weeks after onset of composting irrespective of the compost types. Panicum-based compost with *Trichoderma* activation had higher NH_4-N levels than other composts. The level of N-NO_3 in compost increased with length of composting (Fig. 2). NO_3-N was significantly higher in TAC than NAC. Generally, addition of *Trichoderma* increased the level of WSC irrespective of the composting materials (Fig. 3).

DISCUSSION

The higher pH, though not statistically significant, of TAC and PBC over NAC and that of TBC, respectively, is in agreement with the findings of Sánchez-Monedero et al. (2001) and Zaha et al. (2013) who reported the pH values of compost between 6 and 9. The higher pH in PBC though not statistically significant could be traced to biodegradation of organic matter and morphology of the material involved as related to the biodegradation. The organic matter concentrations of all the composts produced decreased as the length of composting increased regardless of compost types; due to decomposition of the organic materials during the composting process. Mineralization of organic carbon by feeding activities of microorganisms continued throughout the composting period, leading to decrease in the weight of pile as well as reduction in the C:N ratio of the composts. This is in agreement with the findings of Xi and Liu (2002) that as the composting process takes place, the organic matter concentration decreases gradually while the microorganism concentration increases. Kalamdhad and Das Ayan (2011), Henry and Harrison (1996) and Adani et al. (1995) also stated that compost stability and maturity are comprehensive properties indicating degree of organic matter decomposition of compost which plays an important role in determining the microbial status. Changes that take place in composting materials are one of the essential factors for determining whether the compost produced is of high quality or not. Maturation of compost starts at the thermophilic (curing) phase of composting; the rate of organic matter decomposition reduces, less heat is given off and already digested organic matter is converted into humic compounds.

Water soluble carbon (WSC) which is regarded as one of the most readily active biological variables to determine compost maturity (Castaldi et al., 2008) produced with or without compost activator showed higher concentrations regardless of the compost types at the onset of composting before gradual fall in the concentrations. This is probably because organic compounds solubilization is greater than its mineralization or utilization by microorganisms. Also, TAC produced more stable WSC all through the weeks of composting compared with NAC which had lower concentration of WSC as compost aged. This may be attributed to the opportunity that activated composts had in manufacturing more microbial growth than non-activated ones which then leads to synthesis of new WSC as the composting process continues. This corresponds to the findings of Castaldi et al. (2008) who reported that organic carbon in water extracts increased gradually during the first 14 days (32.34 mg g^{-1} dm) due to solubilization of organic

compounds being greater that the utilisation by microorganisms. However, after the second week, the WSC concentration decreased until day 56, which indicated that the microbial population is supported by growth on easily degraded substrates while adjusting to the degradation of more recalcitrant substrates. The conclusion of Castaldi et al. (2008) was that there is a possibility of increase in the concentration of WSC which may originate from microorganisms (or microbial growth) since composting is also a process of synthesis.

Higher total nitrogen content found in Tridax-based compost plus *Trichoderma* (TBC+T) revealed that either of the composting material will thrive through the release N in the presence of compost activator (*Trichoderma*). But, if *Trichoderma* is not available, Tridax-based compost (TBC) will release N prior Panicum-based compost because Tridax-based compost contains more labile organic substrate and transforms the composting material to organic matter at faster rate compare with Panicum-based, which by morphology has more recalcitrant organic matter (Adejuyigbe et al., 2006). Initial increase in total nitrogen concentration observed in the study followed by a decline and thereafter an increase as the week of composting could be attributed to concentration effect. This confirms with the results of Zaha et al. (2013) and Bernal et al. (2008) that the rate of utilization of organic carbon by the decomposers for their metabolism was higher than that of nitrogen. This provided a rich microbial activity to biodegrade protein and amino acids into simpler compounds such as amides, amines etc. and a slower biodegradation for poly carbohydrates due to inhibiting influence of saw dust over microorganism's activity.

The higher ammonium nitrogen (NH_4-N) over nitrate nitrogen (NO_3-N) at the initial age of composting followed by a decline as the age of compost increased while NO_3-N increased as compost aged may be attributed to the fact that initial stage of composting depicts thermophilic phase. Tiquia (2002) found that the highest NH_4-N concentration occurred during the thermophilic phase but concentration quickly declines as the process progresses. This is due to organic matter degradation (NH_4-N production), aeration demand was at their maxima and nitrification hardly occurs because high temperatures inhibit the action of the microorganisms responsible for the process (Bernal et al., 2008). All these conditions favor NH_3-volatilisation. Nitrification, detected by the formation of NO_3-N, occurs when the temperature falls below thermophilic values (40 °C), the intensity of the process depending on the amount of NH_4-N available to the nitrifying bacteria. This indicated that loss of nutrients during composting can be reduced with inclusion of this fungus while time of compost maturity is equally minimized. This conformed to the findings of Gulser et al. (2010) that addition of organic fertilizer to soil increases soil microbial activity, provides nutrients and also increases NO_3-N content of soil due to mineralization of the organic matter. Ammonium-N was higher than NO_3-N at the initial age of composting but decreased with time while NO_3-N increased. Chukwujindu et al. (2006) noted that during maturation, the ammonium N levels of compost continue to decrease, while the nitrate levels increase. They defined compost maturity in terms of as decrease then stabilizing NH_4^+, and increasing and then stabilizing NO_3^- suitable for evaluation of compost maturity.

The effect of compost activation with *Trichoderma* on P and K at the early stage of composting and on K at end of composting confirms the findings of Tiwari et al. (1999) who accelerated their compost piles with *Azobacter* and phosphate solubilising culture in the presence of 1% rock phosphate in order to obtain quality compost that is rich in N and P_2O_5. They discovered that P and K concentrations increased over time, though not linearly with regards to P. Microbial biomass nitrogen and microbial biomass carbon (MB-N and MB-C) concentrations in composts showed that MB-C concentration increased from 2 to 6 WC after which there was fall in the concentration though not linear, MB-N concentration however increased from 2 to 10 weeks of composting (WC) before gradual fall from 14 to 22 WC and a subsequent rise in 24 WOC. This confirmed the findings of Kutsanedzie et al. (2012) who stated that the total fungi count recorded at 12 week of composting was higher than the initial total fungi count recorded. Composting materials had great influence on lignin concentration in the composts; *Panicum* had higher lignin concentration than *Tridax*, this could be attributed to the fact that *Panicum* had more recalcitrant organic matter in comparison to *Tridax* which by morphology contains more labile organic substrate and this is in conformity with the findings of Adejuyigbe et al. (2006). With reference to parameters for rating compost maturity (Seal, 2016), it was observed that Trichoderma activated compost (TAC) matured earlier than the non-activated compost (NAC).

CONCLUSION

The results showed that Tridax-based compost in the absence of *Trichoderma* decomposes faster and releases more nutrients for crops than the Panicum-based compost in the absence of activator. Is concluded that TAC matured earlier than the NAC, therefore composting of organic waste with the aid of *Trichoderma asperellum* as activator can be made ready for field on or before four weeks with the assurance that it will pose no threat to crop germination while making the nutrients available for crop use.

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Received: August 4, 2019
Accepted after revisions: May 4, 2020

Appendix Analysis of Compost Quality Parameters as per National and International Standards.

Parameters	Ideal Range
Moisture percent (%)	35.0–55.0
pH water (1:5)	7.2–8.5
EC	<4.0
Organic carbon (%)	16.0–38.0
Total nitrogen (%)	1.0–2.0
Total phosphorus (%)	>0.5
Total potassium (%)	>0.5
C/N ratio	10.0–20.0
CMI	0.79–4.38
Total microbial population (log10 value)	>13.00
CO2 evolution rate (mg CO2–C/g OM/ day)	<5.0–stable
Nitrification index	0.03–18.9
Phytotoxicity bioassay	>0.8
Organic matter	>15

CMI: compost mineralization index; EC electrical conductivity
Source: Seal et al. 2016