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Effects of turning frequency on composting of chicken litter in turned windrow piles

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A b s t r a c t. Composting of chicken manure mixed with sawdust (chicken litter) was performed using the turned windrow method. The aim was to investigate the effects of turning frequency on some physicochemical properties of chicken litter. The three turning frequency treatments were: no turning, turning every 3 days and every 7 days. The initial physicochemical properties of chicken litter were determined. The moisture content of the treatments was adjusted to 55% (w.b.) at the beginning of composting and no moisture adjustment was done thereafter. The results showed that turning frequency did not affect ($P > 0.05$) pH, temperature, rate of composting and maturation time, but it affected ($P < 0.05$) moisture content, dry matter, total carbon, total nitrogen and carbon to nitrogen ratio of composting piles. Losses were observed in moisture content (61.82-75.8% of the initial moisture content), dry matter (7.68-13.01% of the initial dry matter), total carbon (51.71-62.24% of the initial total carbon) and total nitrogen (45.36-79.61% of the initial total nitrogen). The losses of total carbon were attributed to organic matter degradation, while those of total nitrogen were largely attributed to ammonia (NH_3) volatilization. Moisture loss and C:N ratio increased as turning frequency increased. All the treatments reached maturation at about 70 days, when the pile temperatures dropped to near ambient temperature. C:N ratio increase and losses in total carbon and total nitrogen were significantly higher in the turned windrows (treatments TF7 and TF3) than in the unturned windrow (treatment TF0). In conclusion, the short maturation time was attributed to low moisture levels in the piles.

K e y w o r d s: composting, turning frequency, moisture content, total nitrogen, total carbon, C:N ratio

INTRODUCTION

Wastes generated form poultry farms are highly polluted and, if discharged directly onto land or into water bodies, can cause undesirable effects such as unproductive crops, dissolved oxygen depletion and eutrophication. Composting is one of the few natural processes capable of stabilising organic wastes. The stabilisation process destroys most parasites, pathogens, and viruses contained in the waste, considerably reduces odour emissions by reducing levels of biodegradable hydro-carbons, and dries up the waste, making it unattractive to insects (Barrington *et al*., 2002). Composting also converts organic wastes into a product to be used as a soil conditioner and organic fertiliser (Brake, 1992); it improves the storage and handling characteristics of the manure by reducing its volume and weight, and kills weed seeds (Tiquia and Tam, 1998). Composting immobilises nutrients. The slow release of nutrients from composted poultry litter may lessen adverse environmental effects from leaching of nitrogen (N) in runoff from farmlands (Chang and Janzen, 1996). The disadvantages of composting organic wastes include loss of N (through NH_3 volatilization) and of other valuable nutrients, time for processing, cost of handling equipment, available land for composting, odours amongst others (Eghball, 1997). Apart from N, carbon (C) is another element that is most likely to be lost during the composting process. Carbon may be lost due to either bio-oxidation, in which carbonaceous materials are lost as CO_2 (Bishop and Godfrey, 1983; Eghball *et al.*, 1997), or mineralization of C, in which inorganic C are converted to organic C (Bernal *et al.*, 1998). Therefore, acceptance of composting depends on how well the operating strategies being employed are developed for both product quality (Tiquia *et al*., 2000) and environmental protection (Savage, 1996). A major advantage of the turned windrow method is the homogenisation of the pile. Turning frequency is commonly believed to be a factor which affects the rate of composting as well as compost quality. Turning is often cited as the primary mechanism of aeration and temperature control during windrow composting (Tiquia, 1996). The parameter most widely used for composting is the C:N ratio

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of the initial composting material; high initial C:N ratio will cause a slower beginning of the process and the required composting time to be longer than usual (Tuomela *et al.*, 2000), while low initial C:N ratio results in high emission of NH_3 (Tiquia and Tam, 2000). If the water content of the composting litter is not maintained at a proper level, undesirable factors may arise, such as a longer composting period (Eghball, 1997). Brake (1992) reported that with too little water, the heat required for proper composting will not be attained, while anaerobic conditions may set in with too much water. Near-neutral pH is preferred for most efficient microbial activity during composting. Moore *et al.* (1997) found that NH_3 volatilisation from poultry litter increases once pH rises above 7.0. Temperature is a simple and excellent indicator of how well the composting process is progressing and how much O_2 is being used (Walker, 2004). Misra *et al.* (2003) reported that high temperatures during composting contribute to the killing of weed seeds and pathogenic organisms.

The effects of turning frequency (TF) on composting have been examined (Ogunwande *et al*., 2008; Tiquia *et al*., 1997; Wong *et al*., 2001). However, studies about the effects of turning frequency on composting of chicken litter (CL) using turned windrow method with no moisture replenishment are rather scarce. Therefore, the present study aims to examine the effects of turning frequency on some physicochemical properties of chicken litter during composting with no moisture replenishment.

MATERIALS AND METHODS

Fresh chicken manure was collected in batches from a poultry farm in Ile Ife town, South-West Nigeria, within 4 days prior to composting. Sawdust, a waste from sawmill plant, was collected also from Ile Ife town and mixed with the chicken manure because of its low moisture content (MC), high porosity and C:N ratio. The experiment was carried out during the dry season (between the months of December, 2005, and March, 2006) on an open site at the back of Agricultural Engineering building, Obafemi Awolowo University, Ile Ife, Nigeria. Three piles of CL were built, with turning frequencies at no turning (TF0), every 3 days (TF3) and every 7 days (TF7). Each pile was pyramidal in shape with a height of about 0.76 m and built in a pit of 1.2 × 1.2 m square base and a height of 0.3 m. Each pile was replicated thrice and turned manually using a hand shovel. The initial properties of the chicken manure and sawdust determined are presented in Table 1. The N, P, K concentrations of the sawdust were assumed to be traces (Galler and Davey, 1971; Eghball, 1997), hence they were not determined. The C:N ratio of the chicken manure was raised to 30:1 through the addition of sawdust, as described by Brake (1992), and in conformity with the recommendation of Rynk *et al*. (1992) on rapid composting. The MC of the piles was adjusted to 55% at the beginning of composting, as described by Brake (1992), and no moisture adjustment was done thereafter. The concentrations of ash, total carbon (TC), total nitrogen (TN), C:N ratio, P, K and moisture content of the initial composting mixture were theoretically calculated based on the initial properties of the composting materials. During the composting process, the ambient temperature and the temperatures within each pile at a depth of 0.25 cm from the top and 0.25 cm from the bottom were measured daily and before turning, using a digital dry bulb thermometer. The temperatures were measured between the hours of 06:00 and 08:00 a.m., when the ambient temperature was fairly stable. Chicken litter samples collected at four symmetrical locations in each pile were combined and composited. Composite samples were collected from each pile fortnightly.

The CL samples was analysed for MC (105°C for 24 h), ash content (expressed as a percentage of residues after ignition at 600°C for 5 h), TN using the regular Kjeldahl method (Bremner, 1996), total K (after acid digestion) using atomic absorption spectrophotometer (Alpha 4 model), total P (after acid digestion) using ultra-violet visible spectrophotometer (UNICAM UV1 model) of wavelength 660 nm, pH (1:10 w/v sample: water extract) using a pH meter with a glass electrode. The TC was estimated from the ash content according to the formula (Mercer and Rose, 1968):

$$TC(\%) = [100 - \text{Ash } (\%)] / 1.8 . \quad (1)$$

Losses of dry matter (DM), TC and TN from the pile during composting were calculated according to the equation (Sanchez-Monedero *et al*., 1996):

$$Y \text{ loss } (\%) = 100 - 100 \left[\frac{X_1 Y_2}{X_2 Y_1} \right], \quad (2)$$

where: Y represents DM, TC and TN, X_1 and X_2 represent the initial and the final ash concentrations, and Y_1 and Y_2 represent the initial and final concentrations of Y.

T a b l e 1. Initial properties of the chicken manure and sawdust

Parameter	Concentration* (d.b.)	
	Manure	Sawdust
Total N (g kg^{-1})	21.0 ± 0.11	nd
Ash (g kg^{-1})	523.4 ± 1.20	30.0 ± 0.17
Total C(g kg^{-1})	264.7 ± 1.13	538.9 ± 1.71
C:N ratio	13:1	nd
Total K (mg kg^{-1})	203.90 ± 4.10	nd
Total P (mg kg^{-1})	2.70 ± 0.10	nd
pH	8.34 ± 0.04	7.60 ± 0.10
MC (%)	54.0 ± 2.48[a]	30.0 ± 1.10[a]

*Mean values and standard error are shown (n = 3), nd - not determined, [a]values on w.b.

Samples were analysed for MC, pH, ash, TC and TN fortnightly until the end of the composting process, while P and K were analysed only at the beginning of the process. All mass measurements (except MC) were expressed on 105°C dry weight basis.

The mean and standard error of the three replicates were reported for all the parameters measured. To compare the effect of TF on compost parameters, one way analysis of variance (ANOVA) statistical testing was performed. Duncan test was used to compare parameter values ($P < 0.05$) using the SPSS 16.0 program for Windows.

RESULTS AND DISCUSSION

Table 2 presents the loss in compost elements by the end of composting. It was obvious that C:N ratio increase and losses in TC and TN were significantly higher in the turned windrows (TF7 and TF3) than in the unturned windrow (TF0). Losses in compost elements due to leachate were considered insignificant as the piles were not wet enough to drain water. Table 3 shows the results of the ANOVA on the effects of TF on the measured compost parameters. Duncan test showed treatment(s) that was significantly different for each of the measured parameter (Table 4).

Table 2. Losses in compost parameters

Treatment	Losses* (%)		
	DM	TC	TN
TF0	13.01 ± 0.86	51.71 ± 0.82	45.36 ± 0.82
TF7	7.68 ± 0.73	60.55 ± 1.63	68.81 ± 0.55
TF3	11.59 ± 1.04	62.24 ± 0.42	79.61 ± 0.76

*Mean and standard error are shown (n = 3).

Table 3. Results of ANOVA showing effects of TF on compost parameters

Effect	DF	SS	MS	F-value	P>F
Temperature	2	8.84	4.42	0.50	0.63
Error	6	52.67	8.78		
MC	2	361.83	180.91	64.15	<.0001
Error	6	16.92	2.82		
DM	2	45.71	22.86	8.06	0.02
Error	6	17.01	2.84		
pH	2	0.02	0.01	4.09	0.08
Error	6	0.01	0.00		
TC	2	191.81	95.91	22.99	0.002
Error	6	25.03	4.17		
TN	2	1996.84	998.42	195.07	<.0001
Error	6	30.71	5.12		
C:N ratio	2	1298.38	649.19	94.03	<.0001
Error	6	41.42	6.90		

The means of the two temperature readings in the piles were used. Turning frequency did not affect ($P > 0.05$) temperature of composting piles (Table 3), rate of composting, and the time the temperatures reached stability. The slopes of the temperature curves showed that temperatures of the composting piles dropped at approximately the same rate ($\approx$0.30 °C day^{-1}) in spite of the different turning frequencies. This is contrary to findings by Tiquia *et al.* (1997). The maturation time of compost piles (time at which the temperatures within the piles were stabilised) (about 70 days) was greater than 63 days (Wong *et al.*, 2001), less than 87 days (Ogunwande *et al.*, 2008), and within the range of 15 and 180 days (Rynk *et al.*, 1992). This may have been a result of non replenishment of MC which may have, consequently, slowed down the activities of the microorganisms in the piles during composting. Brake (1992) reported that at moisture level <45%, length of temperature rise and maintenance will be shortened. Previous studies on composting have also shown that temperature can be used as a parameter to indicate the rate and extent of composting and maturity of composts (Tiquia *et al.*, 1997). At the beginning of the composting process, the pile temperatures were notably higher than the ambient temperature at between 62 and 68°C (Fig. 1). Within three days, the temperatures reached peak values of between 67 and 69°C, an indication that pathogens and weed seeds would have been destroyed (Eghball, 1997). However, as composting proceeded, the temperatures of the three piles dropped to below 45°C by the second week and dropped further to between 33 and 35°C by the fifth week. The short thermophilic phase, ranging between 11 and 14 days, is associated with the turned windrow method (Diaz *et al.*, 2002), and also related to the small size of piles used (Ogunwande *et al.*, 2008). The slight increases in the pile temperatures immediately after each turning operation in the early days of composting were responsible for the rise and fall pattern of the temperature profile and have been reported as the re-activation of the composting process, which is explained by the incorporation of external material into the pile, providing degradable substrate for the microbial biomass (Garcia-Gomez *et al.*, 2003).

Turning frequency had a significant ($P < 0.05$) effect on moisture and DM losses (Table 3). Increase in moisture loss was associated with increase in TF (Table 4). Figure 2a shows the variation of MC with composting time. By the end of the fourth week, 67.79-93.32% of the total moisture losses had occurred when the pile temperatures were above 32°C. The high rate of moisture loss was likely due to the small size of piles used and to the dry season in which the experiment was conducted. Increase in DM loss was associated with decrease in TF. The DM losses (7.68-13.01%) were within the range of 7.72-22.86% (Ogunwande *et al.*, 2008), but lower than the range of 35-50% (Kithome *et al.*, 1999).

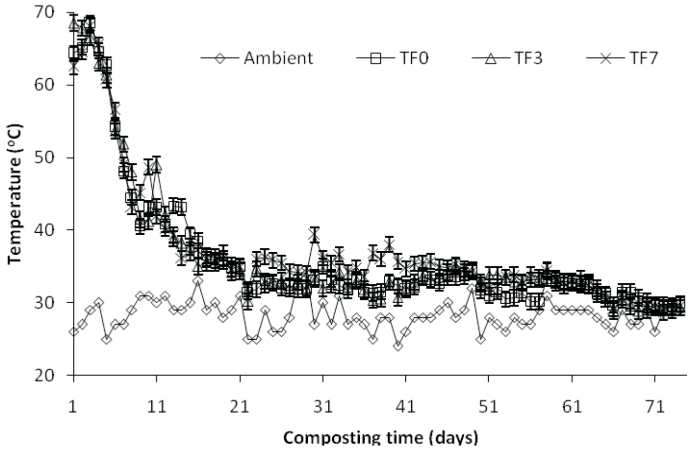


Fig. 1. Air and pile temperature changes during composting. Error bars show standard errors of means (n = 3).

T a b l e 4. Duncan test on compost parameters

Parameter	Turning frequency		
	TF0	TF7	TF3
Temperature (°C)	ns	ns	ns
MC (%)	60.29a	67.33b	75.80c
DM (%)	13.01b	11.59b	7.68a
pH	ns	ns	ns
TN (%)	44.03a	68.81b	79.61c
TC (%)	51.71a	60.55b	62.24b
C:N ratio	26.46a	38.02b	55.67c

Values followed by the same superscript letter are not statistically significant at $P < 0.05$, according to the Duncan test.

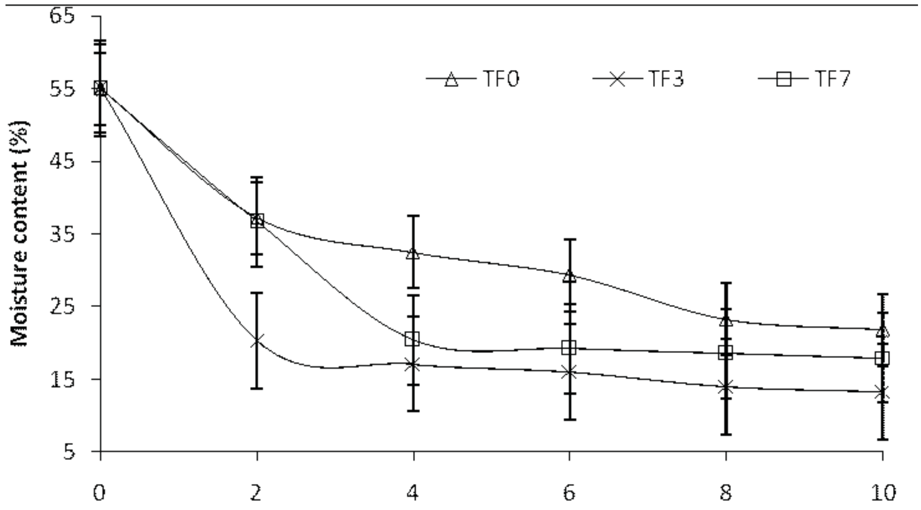
Initial pH values which were between 8.43 and 8.59 increased slightly during the second week to between 8.5 and 8.68 and decreased afterwards to final values between 7.24 and 7.33 (Fig. 2b). Turning frequency did not affect ($P > 0.05$) pH of composting piles (Table 3). The high values of pH observed during the second week, when temperature values were above 39°C, may be due to the decomposition of easily degradable OM in composting piles. The continuous drop in pH values of the three treatments after week 2 may be due to production of organic acids and, in this study, low MC in composting piles.

Total carbon loss increased significantly ($P < 0.05$) as TF increased. By the end of composting, cumulative TC losses ranged from 51.71 to 62.24% of the initial TC content (Table 2). More than half of the total losses (57.55-77.96%) were recorded within the first four weeks of composting, which showed that the CL had a high proportion of easily degradable OM. Figure 2c shows the variation of TC concentration with composting time. The results of the regression analysis showed that the rate of TC loss with composting time was the highest in treatment TF3 (1.498 g kg^{-1} TC $week^{-1}$, R^2=0.85), followed by treatment TF7 (1.296 g kg^{-1} TC $week^{-1}$, R^2=0.96) and then treatment TF0 (0.913 g kg^{-1} TC $week^{-1}$, R^2=0.96). Increase in ash concentration cor- responded with increase in TC loss and this clearly showed that effective OM degradation occurred during the composting process (Baeta-Hall *et al*., 2005).

Turning frequency had a significant ($P < 0.05$) effect on TN concentration (Table 3). Increase in TN loss was associated with increase in TF. The cumulative TN losses ranged between 44.03 and 79.61% of the initial TN concentration in the three piles, with the least loss in treatment TF0 (Table 2). Over 50% (51.49-71.88%) of the total losses occurred within the first four weeks of composting when the MC was >17.13% and pile temperature and pH values were above 32°C and 7.4, respectively. Figure 2d shows the variation of TN concentration with composting time. The results of the regression analysis showed that TN concentration decreased faster in treatment TF3 (0.089 g kg^{-1} TN $week^{-1}$, R^2=0.83) than in treatments TF7 and TF0 (0.063 and 0.017 g kg^{-1} TN $week^{-1}$, R^2=0.95 and 0.85, respectively). As in previous studies (Cayuela *et al*., 2006; Ogunwande *et al*., 2008; Tiquia and Tam, 2000), a significant part of the TN losses was probably by NH_3 volatilisation which was favoured by high temperature and pH values in this period. The TN losses were greater than losses reported by Hansen *et al*. (1989) and Kirchmann and Witter (1989) during composting of poultry manure. The high losses may have been due to the small size of piles involved (Ogunwande *et al*., 2008), mineralisation of OM by micro-organisms (Grigatti *et al*., 2004; Laos *et al*., 2002), or exposure of the piles to direct sunlight which may have accelerated the decomposition and loss of valuable nutrients (Kwakye, 1977).

Except for treatment TF0, treatments TF7 and TF3 had increase in the final values of their C:N ratios (Fig. 2e). Turning frequency affected ($P < 0.05$) the change in the C:N ratios (Table 3). The increase in the C:N ratios of treatments TF7 and TF3 could be attributed to vigorous NH_3 volatilisation during composting (Eghball *et al*., 1997; Tiquia and Tam, 2000).

a



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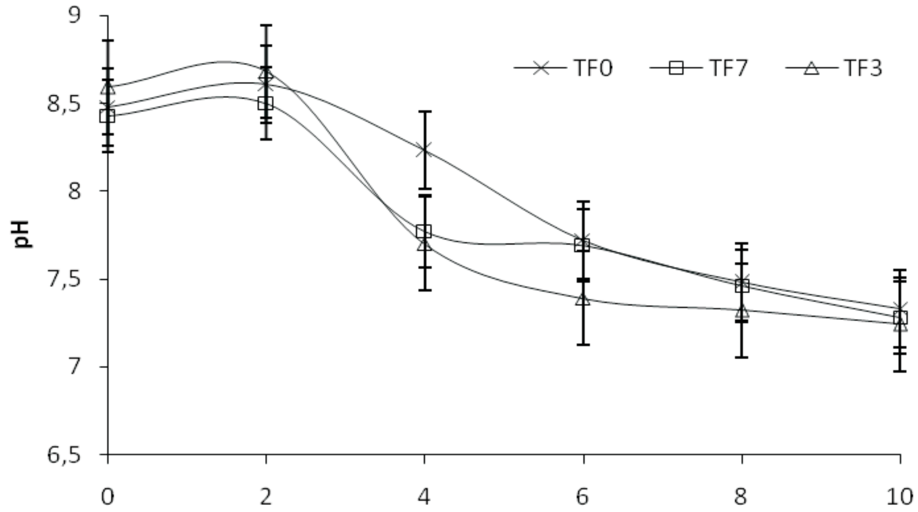

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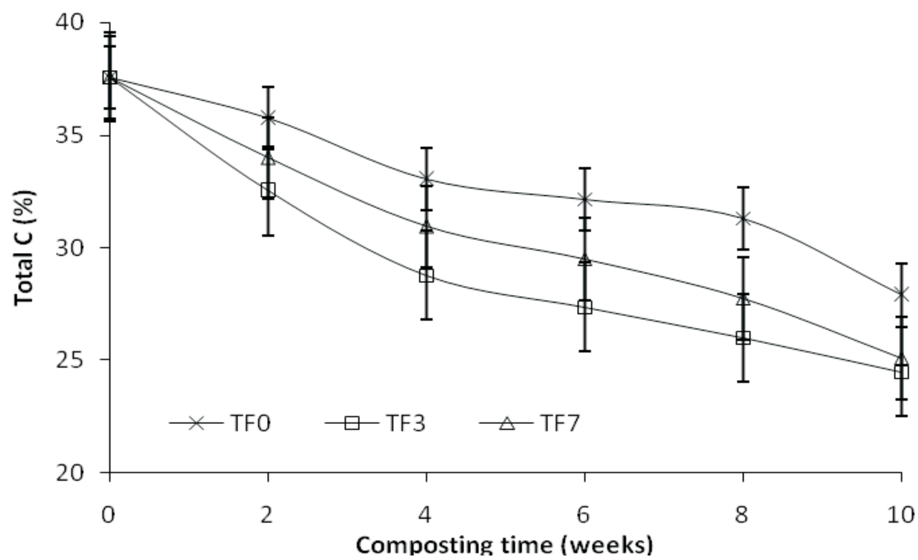
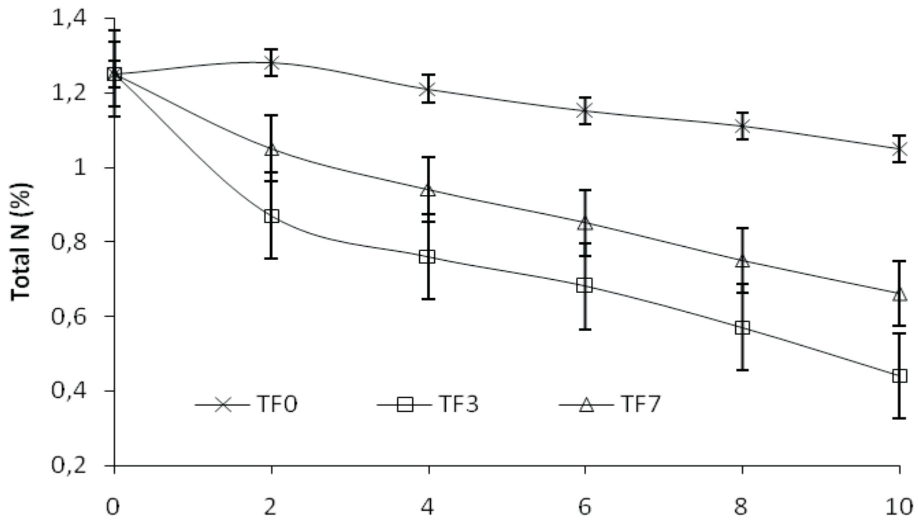


Fig. 2. Changes in : a – moisture content, b – pH, c – TC concentration, d – TN concentration, e – C:N ratio; of composting piles due to TF effect. Error bars show standard errors of means (n = 3).

d



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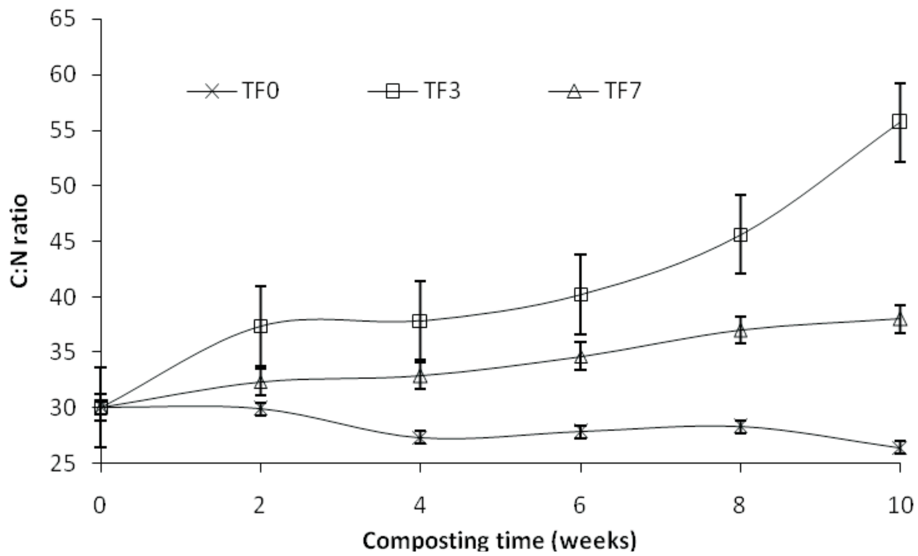

Fig. 2. Continuation.

CONCLUSIONS

1. The results showed that turning frequency did not affect ($P > 0.05$) temperature, rate of composting and maturation time but it affected ($P < 0.05$) moisture content, dry matter, pH, total carbon, total nitrogen, and C:N ratio of composting piles.

2. Final values showed that C:N ratio increase and losses in total carbon and total nitrogen were higher in the turned windrows (treatments TF7 and TF3) than in the unturned windrow (treatment TF0).

3. The short maturation time was attributed to the low moisture levels in the piles.

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