Plant Archives Volume 20 No. 1, 2020 pp. 1303-1310 e-ISSN:2581-6063 (online), ISSN:0972-5210

CHARACTERIZATION OF COMPOSTED POULTRY MANURE WITH OR WITHOUT PLANT RESIDUES

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Abstract

The aim of the study was to investigate composting of poultry manure with or without plant residues as bulking agents. Four piles were carried out with different mixtures : poultry manure alone (p1), 66% poultry manure + 16.5% wheat straw + 16.5% conocarpus leaves (p2), 50% poultry manure + 25% wheat straw + 25% conocarpus leaves (p3) and 33% poultry manure + 33% wheat straw + 33% conocarpus leaves (p4). Composting process was monitored over 14 weeks for physicochemical characteristics: temperature, pH, salinity (EC), total organic carbon, total nitrogen and C/N ratio. Furthermore, field observations of color, odor and loss in weight were obtained at the end of composting. All of the studied parameters were influenced by poultry manure rather than bulking agents, however having same trends. All piles reached a thermophilic stage at 3 weeks of composting. Except pH value, the studied parameters followed the typical pattern during composting process. pH values significantly increased with increasing composting period. Salinity values were lower at the end of composting as compared with initial values, but the values still high than optimum range. At the end of composting process, the total organic carbon decreased, while the total nitrogen increased in contrast with initial values. Also, the initial C/N values were 14.43, 24.77, 26.56 and 31.06 then reached values of 9.38, 12.98, 17.97 and 20.81 at the end of composting process, for p1, p2, p3 and p4, respectively. In conclusion, increasing poultry manure content in the pile is important to improve the biodegradation and produce compost with high quality.

Key words: poultry manure, composting, thermophilic stage, compost stability, C/N ratio.

Introduction

Globally, the steady rise in food production leads to removals soil nutrients, thus, conventional solutions in particular mineral fertilization were proposed (Kasongo *et al*., 2013). This way, although effective in the short term remains unsuitable to the afford part of small farmers because of the relatively high cost (Haefele *et al*., 2013). In addition, the continuous use of this kind of fertilizer leads to environmental concerns (Lee *et al.,* 2013). In this context, organic fertilization may be considered as an appropriate solution for sustainable crop production (Chang *et al*., 2014). Intensified livestock development in urban zone as poultry livestock offers large resource of organic matter to be recycled, which are likely to provide an interesting contribution to cultivated soils. About 70% of the nitrogen and phosphorus stored by poultry is returned through droppings (Chabelier *et al*., 2006). Also, poultry residues are increasingly preferred by farmers compared to other animal residues because of their high macro nutrients content (Duncan, 2005). Improper use and disposal of poultry litter may have detrimental effects on environment and human health, that resulting from NO_3^- leaching and emission of ozone depleting gases (Kelleher *et al.,* 2002).

Composting is a process which deals with the biological decomposition and stabilization of organic substrates which produces compost is dark, crumbly, soil-like materials with a high organic matter content that can be used as a plant fertilizer, soil amendment or growing medium component and other purposes. Compost affects soil properties in periods of structure and increases soil retention water (Islam *et al*., 2017; Liu *et al*., 2017). On the other hand, organic matter is preserved nutrient such as nitrogen from loss through volatilization and may result in improved crop production (Adekya and Agbede, 2016). Composting is the thermophilic breakdown of organic matter by microorganisms in the presence of oxygen for an extended period of time with presence microbial decomposition produce in manure stabilization and maturation (Fornes *et al*., 2012). Mathur *et al*., (1993) pointed out that the compost stability and maturity are important factors affecting the successful use of composts in agriculture this is because the application of unstable composts can reduce plant growth rates and damage crops by consuming for oxygen or causing phyto-toxicity in plants because insufficient biodegradation of organic matter (Keeling *et al*., 1994). Hong *et al*., (1999) reported that the composting produce CO_2, H_2O, NH_3 and biological heat as the major products and final product at the end of the maturation process should be stable and can be applied to soil to improve its physical, chemical and biological properties.

In these days, there are a lots of plant and animal residues, including poultry manure in many countries throughout the world which daily produce huge amounts of manure, which must be managed under appropriate disposal practices to avoid a negative impact on the environment (Burton and Turner, 2003), In spite of, composting can not be considered a new technology to residues management, it is gaining interest as a suitable option for treatment of residues with economic and environmental profits (Larney and Hao, 2007).

To-date, a large number of studies have mainly focused on monitoring the influence of bulking agents on the composting process of poultry manure (Petric *et al*., 2009). However, there are lack reports describing the effect of bulking agents on the physico-chemical characteristics of composting manures produced from poultry manure worldwide. So far, data about the factors affecting the composting of animal manures, including bulking agents, if there was, very limited in Iraq. Thus, considering the adverse effects food-producing animal manures can have on human and animal health, this study was conducted to monitor the physicochemical changes during composting of poultry manure with various bulking agents in order to get high quality stabilized product.

Materials and Methods

Compost materials

The experiment was conducted at Al-dujaila region of Wasit province, Iraq. Compost materials were poultry manure and two plant materials (wheat straw, *Triticum aestivm* L. and conocarpus leaves, *Conocarpus lancifolius* Engl.). Prior to composting, all materials were analyzed for physicochemical characteristics as shown in table 1.

Table 1: Physicochemical characteristics of raw materials.

Parameter	Poultry manure	Wheat straw	Cono-carpus
Moisture (%)	42.0	10.90	37.30
pH	7.90	6.60	6.94
EC(dSm^{-1})	17.46	12.14	8.19
Total organic carbon (g kg^{-1})	372.10	474.00	419.10
Total organic matter (g kg^{-1})	641.50	817.17	722.52
Total nitrogen(g kg^{-1})	25.40	6.80	18.42
C/N ratio	14.64	69.70	22.75

Each value is presented as a mean of three replicates.

Composting piles preparation

The composting was conducted for 14 weeks from Nov. 2017 to Feb. 2018 on an open site using four windrow piles made with 2m height and 1×1m square base. Pile 1 (p1) contained only poultry manure. Pile 2 (p2) had 65% poultry manure + 16.5 % wheat straw +16.5 conocarpus leaves. Pile 3 (p3) had 50% poultry manure +25 % wheat straw +25% conocarpus leaves. Pile 4 (p4) had 33% poultry manure +33% wheat straw +33% conocarpus leaves. Compost materials were mixed at mentioned ration based on dry weights. Prior to mixing with poultry manure, the wheat straw and Conocarpus leaves were cutting mechanically to yield a 10-20 cm particle size. The piles were manually turned ones a week in order to homogenize the materials as well as to minimize to formation of anaerobic condition. The moisture content was initially adjusted to 60% ±5 and kept within this value along the composting period by addition of water.

Sampling and physicochemical analysis

Temperature of the piles was measured at day zero (initial) and after 1, 3, 8 and 14 weeks of composting using digital thermometer at the depths of 15, 100 and 150 cm from the top of the piles and the mean was obtained. Colour and odor were monitored once a week. The loss in weight of compost (expressed in %) was determined by the difference between pile volume at day zero and pile volume after 14 weeks of composting. Moisture content was evaluated for raw materials and at the end of composting from the weight loss after drying at 105ºC for 24 hr.. Compost samples were collected using compost sampler in triplicate manner at the mentioned dates and analyzed for pH, salinity, total organic carbon, total nitrogen and C/N ratio. pH value was measured in 1:5 (compost : distilled water) suspension using pH meter (page *et al*., 1982). Salinity (Electrical conductivity, EC) was measured in 1:5 (compost : distilled water) extract using conductance meter (page *et al*., 1982). Total organic carbon was estimated from total organic matter content which evaluated by loss-on-ignition method at 558°C (Tiquia and Tam, 1998). Kjeldahl digestion method was followed to measure total nitrogen content (Bremner, 1970). C/N ratio was calculated from total organic carbon and total nitrogen. Table 2 showed the characteristic of piles at the end of composting.

Table 2: Physicochemical characteristics of compost.

Parameter	Pile1	Pile2	Pile3	Pile4
Moisture (%)	50.00	47.30	43.40	40.60
pH	6.87	6.73	7.14	7.45
EC(dSm^{-1})	17.18	16.63	16.42	13.45
Total organic carbon (g kg^{-1})	277.30	321.20	330.60	315.10
Total organic matter (g kg^{-1})	478.06	553.74	569.95	543.23
Total nitrogen(g kg^{-1})	29.60	22.20	18.40	16.10
C/N ratio	9.36	14.46	17.97	19.57

Each value is presented as a mean of three replicates.

Statistical Analysis

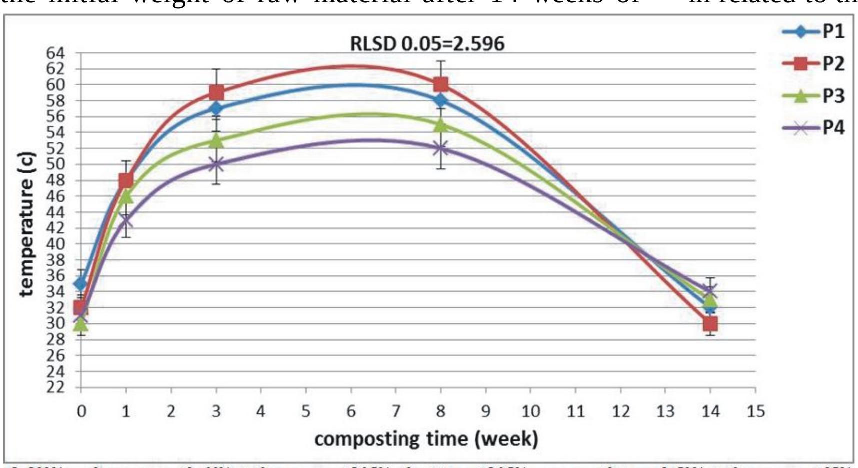
Analysis of variance (ANOVA) was used to evaluate the effect of main factors and their interactions of the parameters using GenStat procedure Library release pL18.2. The revised LSD was calculated at 5% level of significant F test.

Results and Discussion

From the field observations of composting process for the four piles, it was noticed that the color of the compost was yellow at the beginning of the process (< 3 weeks), because of present of straw and green leaves which easily distinguish in the early stages of composting. After that the color was changed to dark brown, mainly due to presence of particulate and dissolved organic matter and the plant raw materials well mixed with poultry to give a fragile and soft paste easy to disintegrate by hand. As composting progress, the release of gaseous compounds (odour) has been found to be less for all piles. Schleamilch *et al.*, (2005) reported that optimization of composting conditions has been suggested as a method of avoiding a large portion of odorous emissions produce from NH_3, CH_4, N_2O, H_2S and volatile organic compounds. In terms of the weight resulted from composting process, there are lost between 20-38% of the initial weight of raw material after 14 weeks of composting increasing poultry manure content in pile increased the loss portion in weight. Stanchev *et al.*, (1990) stated that at the end of composting the total dry weight of compost reduces for about 20-30% due to loss in CO_2, CH_4 and water vapor.

Temperature

Results in fig. 1, showed that temperature variation during composting period was as the same behaviors of all composting piles. Overall, temperature significantly increased until the 8 week then significantly decreased until the end of composting (14 weeks). That means the presence of the plant materials with poultry manure did not affect the reaching of thermophilic stage (3 weeks) and maturity stage (14 weeks). The average temperature after 3 weeks of composting was 55ºC which not differ from the period of 8 weeks, which gave a rate of 56ºC and then declined sharply after 8 weeks to reach 32ºC. Similar result have been obtained by Silva and Bras, (2016) who achieved an increase in temperature up to 25 days of composting and reaching more than 45ºC. Zhang *et al.*, (2012) attributed the gradient of pile temperatures during composting process to the fact that the balance between mass and energy is not linear. If the thermophilic stage continues beyond three days, the compost will be devoid of weed seeds and pathogens and sanitation requirements could be achieved (Zhang and Sun, 2014). Rich and Bharti, (2015) pointed out the optimum temperature for composting is 40-65ºC. In our study we observed that the temperature immediately increased from the first week reaching the higher values (56ºC) at the eighth week of composting with non-significant deference for the third week period, indicating that all piles reached the thermophilic stage from the first week and continued until the third week. The decrease in the temperature at 14 weeks of composting was 43% in related to the temperature at 8 weeks, Indicating that all piles started to inter the maturing stage after 8 weeks.



p1: 100% poultry manure, p2: 66% poultry manure + 16.5% wheat straw + 16.5% conocarpus leaves, p3: 50% poultry manure + 25% wheat straw + 25% conocarpus leaves, p4: 33% poultry manure + 33% + 33% conocarpus leaves .

Fig. 1: Temperature variation during the composting process.

Piles 1 and 2 registered the highest temperatures at all composting periods except at 14 weeks. In contrast piles 3 and 4 registered the lowest temperatures. The temperature variation among piles could be attributed to the amount of poultry manure added, the highest the poultry manure,the highest temperature evolution. This means that poultry manure controls the biodegradation of pile materials because of it high content of N and other nutrients as well as low C/N ratio (Table 1). Kulikowska, (2016)

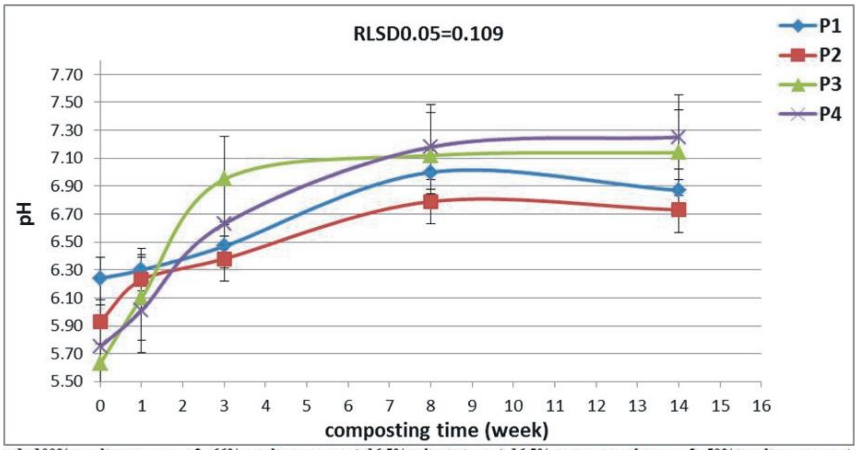


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Fig. 2: pH values during the composting process.

noted that composting is an exothermic process that depends on biodegradability of substrate and the initial temperature.

pH

The pH variation during composting is presented in fig. 2. All piles showed similar trend. In general, the pH values significantly increased with increasing composting time. This trend in pH variation did not follow the typical pattern : decline in the early stages of composting then elevation in the later stages (Turan, 2008). The accumulation of ammonia resulting from the decomposition of protein and the complete decomposition of organic acids resulting in elevation in pH levels (Hachicha *et al*., 2009 and Chen *et al*., 2016). At piles 1 and 2, the pH values of the initial and final compost were found to be in an acid range, while at pile 3 and 4, the pH values rise from acidic to slight alkaline range. These differences in pH value among piles may be attributed to the amount of poultry manure included in the pile. The high amount of poultry manure (piles 1 and 2) enhanced microorganisms activity at thermophylic stage caused an increase in organic acids and CO_2 resulting in decreased pH values. Kelleher *et al*., (2002) pointed that the poultry manure is rich in organic nitrogen in the form of uork acid and protein (60-80%). Nevertheless, the final pH values of the compost at all piles ranged 6.73-7.25 which were within the optimum range (5.5-8.0) as reported by Chen *et al*., (2015) and (6-9) as reported by Silva and Bras, (2016).

Salinity

The initial salinity values express as electrical conductivity of piles ranged from 12.78 to 17.46 dSm^{-1} significantly increased to values from 14.33 to 19.61 dSm^{-1} after 3 weeks of composting, then significantly decreased to values from 11.95 to 14.18 dSm^{-1} at the end of composting after 14 weeks (Fig. 3). The increasing in salinity levels probably resulted from the release of mineral salts and ammonium ions as a result of organic materials decomposition (Silva and Bras, 2016). The final drop in salinity values is attributed to the volatilization of ammonia and precipitation of salts during the rapid increase in the aerobic microorganisms (Huang *et al*., 2004). Pile 1 registered a highest salinity values ranged from 14.18 to 19.61 dSm^{-1}. In contrast, pile 3 registered the lowest salinity values ranged from 12.42 to 14.41 dSm^{-1}. This means that increasing the percentage of poultry manure in the pile will increase the salinity of the pile due to the initial salinity of the poultry manure (Table 1) and / or is due to the increase in the activity of the microorganisms leads to release of high amounts of ions. The results of Park, (2011) indicate that the increase of salinity at the end of composting is due to the high salinity of the raw materials.

Although the salinity values at the end of composting were lower than salinity at the beginning of composting in all piles with a decrease percent of 19, 9, 3 and 11% for the piles 1, 2, 3 and 4, respectively, but there were higher than the limit value of 4 dSm^{-1} adopted by Chowdhury *et al*., (2015) for the composting to be applied to soil. Epstein, (1997) also suggested that salinity levels in excess of 5 dSm^{-1} lead to phytotoxicity. However, well mixing of compost of high salinity with soil or other materials with low salinity can be used for growing crops (Gao *et al*., 2010). Nevertheless, using the final compost of all piles in our

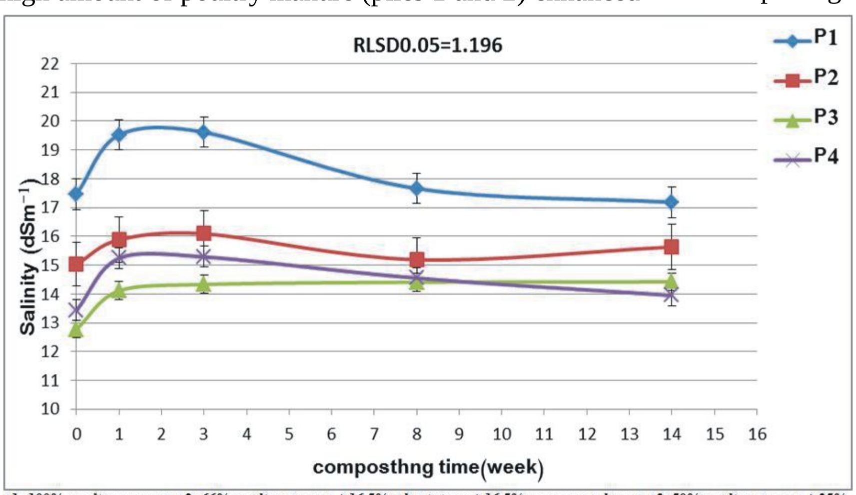

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Fig. 3: Salinity values during the composting process.

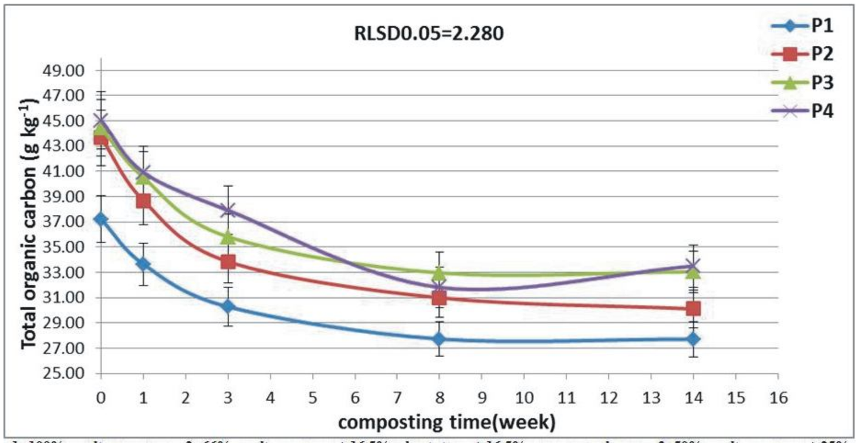

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Fig. 4: Total organic carbon content during the composting process.

study did not cause any negative effect in term of salinity on sunflower growth (data not present).

Total Organic Carbon

The total organic carbon content significantly decreased during the composting process from 37.21 to 27.73 g kg^{-1} for pile 1, from 43.67 to 30.12 g kg^{-1} for pile 2, from 44.43 to 33.06 g kg^{-1} for pile 3 and from 45.03 to 33.51 g kg^{-1} for pile 4 (Fig. 4). Similar results have been obtained by Lazcano *et al*., (2008), who indicated that compounds with simple carbon decompose during the first stage of the composting process to supply the energy for microorganisms through the metabolism and production of CO_2, NH_3, H_2O, organic acids and heat. Bernal *et al*., (2009) indicates that carbon loses in form of CO_2 during organic matter degradation. Pile 1, with a high content of poultry manure, showed a lowest values of total organic carbon at all composting periods, while piles 3 and 4 showed a highest values of total organic carbon. These differences in total organic carbon is attributed to the initial content of plant residues (wheat straw and conocarpus leaves), with a high content of carbon (Table 1) in the pile. The higher the plant residues content, the higher organic carbon. Furthermore, Kuo *et al*., (2004) stated that C/N ratio of wheat straw ranged 100-150 and of tree leaves ranged 40-80 which are difficult to decompose leading to high residual carbon as compared with the animal residues. As Eghball *et al*., (1997) indicates that the carbon loss from organic residues during the composting process ranges from 46 to 62%, depending on the composting method, the content of lignin in the organic residues and the composting conditions such as temperature and moisture. It is also observed from fig. 4 that the amount of total organic carbon at 8 and 14 weeks were not different in all piles which clearly indicates that the composting reaches a maturity stage and stability after 8 weeks of composting. This result indicated that period of 8 weeks of composting is sufficient to produce a stable compost at all piles under study based on the fact that total organ on the fact that total organic carbon is one of most important indicator for maturity and stability of compost (Onwosi *et al*., 2017).

Total nitrogen

Total nitrogen content increased to approximately 16, 32, 10 and 11 for piles 1, 2, 3 and 4, respectively after 8 weeks of composting (Fig. 5). However, increasing composting period to 14 weeks, total nitrogen still stable at all piles, indicating that composting reached stabilization and maturation after 8 weeks of composting. The increase in total nitrogen content with time, was a result to the reduction in organic matter (Park, 2011). Yagodin, (1984) also stated that the loss of dry matter during composting leads to increase nutrient content. Pile 1 (poultry manure only) registered highest total nitrogen over other piles treatments at all composting periods, while pile 4 registered the lowest values of total nitrogen at all composting periods with average of 27.92, 19,66, 17.47 and 15.19 g kg^{-1} for p1, p2, p3 and p4, respectively (Fig. 5). These results suggesting that presence of poultry manure support high nitrogen content in the pile due to the high content of poultry manure (Table 1) as well as poultry manure support good microbial growth leading to organic matter reduction (Fig. 5), consequently increase nitrogen content.

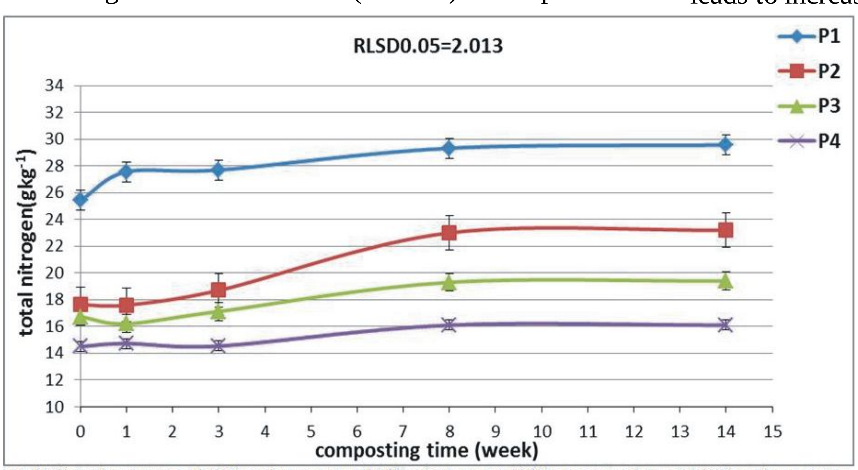

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Fig. 5: Total nitrogen content during the composting process.

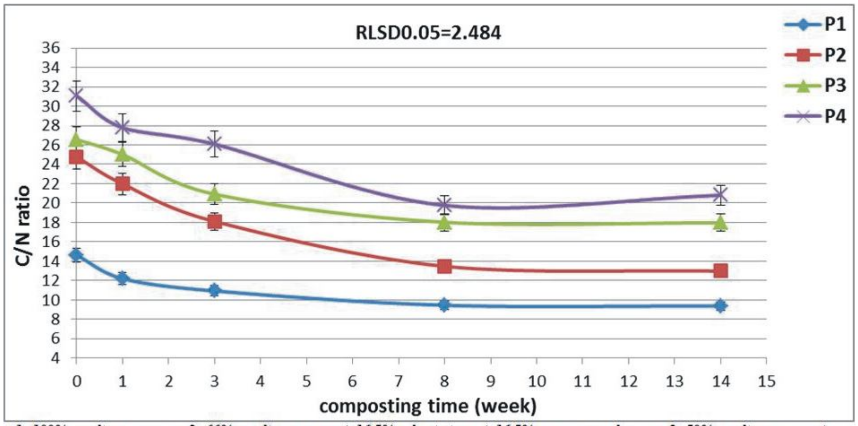

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Fig. 6: C/N ratio values during the composting process.

C/N Ratio

The variation in C/N ratio during composting is presented in fig. 6. All the piles gave a significant decrease with increasing composting time till 8 weeks, then stabled at period of 14 weeks indicating that all piles produced stable compost after 8 weeks of composting. Hachicha *et al*., (2009) revealed that the C/N ratio decreases continuously and then stabilizes without change indicating that the manure reaches the stability stage. According to Yang *et al*., (2015), C/N ratio decreases during composting because the rate of organic nitrogen mineralization is lower than mineralization of organic carbon, while Abu-Rayyan, (2010) attributed the decrease to the increase of nitrogen evolved during composting. Parr, (1975) however explained that the decrease in C/N ratio occurs due to loss of carbon in the form of CO_2 and immobilization of nitrogen. In the present study, the increase of total nitrogen (Fig. 5) and the decrease of total organic carbon (Fig. 4) during composting explains the continuous decrease in the C/N ratio, which indicates that the addition of nitrogen to the compost was more than the addition of carbon. This results are in confirmative with finding of Igoni *et al*., (2008) reported that the value of C/N is an indication that microorganisms use organic carbon 30-35 times faster than their nitrogen conversion rate.

The lowest C/N ratio was observed at pile 1, while the highest C/N ratio was observed at pile 4. The C/N ratios after 8 weeks of composting were 9.46, 13.48, 18.02 and 19.76 for piles 1, 2, 3 and 4, respectively, indicating that all piles reached the maturity after 8 weeks of composting. Awasthi *et al*., (2014) recommended a C/N ratio less or equal to 25 is an indicates for mature compost. Igbal *et al*., (2015) also stated that C/N ratio value below 20 is an index value of acceptable maturity, as well as ratio of 15 or less is preferable.

Conclusion

Increasing the content of poultry manure in pile showed more benefit to produce a higher quality compost. However, the amount of poultry manure did not control the time of maturity stage of piles. For all piles, composting for 8 weeks were so enough to produce a mature and stable compost. The physicochemical characteristics of pile samples during the composting period were generally in the line with expectations in literatures. The only unexpected analysis was the variation in pH values which did not follow the typical pattern.

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