The Journal of Animal & Plant Sciences, 23(2): 2013, Page: 500-506
ISSN: 1018-7081

INFLUENCE OF COMPOSTING AND POULTRY LITTER STORAGE METHODS ON MINERALIZATION AND NUTRIENT DYNAMICS

A. N. Chaudhry, M. A. Naeem, G. Jilani, A. Razzaq[*], Dong-mei Zhang [**], M. Azeem and M. Ahmed[*]

Department of Soil Science, Pir Mehar Ali Shah Arid Agriculture University, Rawalpindi 46300, Pakistan
[*]Department of Agronomy, PMAS Arid Agriculture University Rawalpindi-46300, Pakistan
[**]Institute of Environmental Science and Technology, Zhejiang University, Hangzhou 310058, PR China
Corresponding author's email: anch1970@yahoo.co.uk

ABSTRACT

Poultry litter poses serious environmental threats and health hazards while composting offers the convenient and acceptable means of its recycling. This study was carried out by considering the importance of proper storage and composting of poultry litter (PL) for its nutrient conservation and stability. Five storage methods were compared for their effects on nutrient dynamics in PL under composting and un-composting conditions. Storage methods included: shed, covered (plastic sheet), open-air, pit, and lined floor. The pile / pit size was 2 m × 2 m × 1 m (L × W × H or D), and the quantity of poultry litter in each one was 500 kg. Composite PL samples were collected after an interval of 15 days until 90 days for the determination of organic C, macro- (N, P and K) contents. The results depicted significant successive reduction of organic C contents / C:N ratio and improvement in macro- and micro-nutrient concentration in the processed PL with increased storage time both under composting and un-composting conditions. Among the storage methods, PL composted under plastic cover resulted to highest nutrient contents and the lowest C:N ratio; while shed storage without composting gave the poorest results. Finally, the lowest values of C:N were found under in-pit and lined-floor storage which differed significantly from under-shed storage with maximum value. Therefore from this study it is concluded that composting of poultry litter along with plastic sheet cover provides the best storage condition to conserve nutrients.

Key words: C:N ratio, decomposition, nitrogen, phosphorus, potassium

INTRODUCTION

With the expansion of poultry industry, generation of poultry litter has increased tremendously. Worldwide, the poultry growers are facing a big concern for its utilization or disposal that could be safe for the environment. Owing to its high content of plant nutrients, poultry litter is considered the most valuable organic resource for fertilizing purpose (Singh *et al*., 2004). Its fertilizing value is higher than the traditional farmyard manure. In addition to the benefits for crop production in the form of nutrients, it helps build soil organic matter and improves structural stability (Deksissa *et al*., 2008). Recycling of organic wastes in agriculture adds much needed organic and mineral matter to the soil (Khan *et al*., 2003). Poultry litter can be applied to agricultural land either fresh or after composting (Singh *et al*., 2004). However, the fresh poultry litter may have inappropriate C:N ratio, imbalanced amount of plant nutrients, pathogens and nuisance odors. Proper recycling of this organic waste as a source of plant nutrients is need of the day because of rising cost of chemical fertilizers, deteriorating soil fertility due to soil erosion and /or very low soil organic matter. The best way of recycling and reducing the volume of organic wastes is through composting, and then that can be applied beneficially to cultivated lands (Ahmad *et al*., 2007). Composted organic materials are not only a source of macro and micro-nutrients, but they also improve the soil characteristics like aeration, water holding capacity, bulk density, aggregation, cation exchange capacity and activity of beneficial microflora (Jilani *et al*., 2007). Moreover, compost would also provide a stabilized form of organic matter that imparts longer lasting residual effects to soil than that obtained from the addition of un-composted raw material (Preusch *et al*., 2002).

Farmers are not handling the poultry litter properly; after removal from the sheds, it is stockpiled in open-air. Usually, the heap is left up to one year to subside burning effect of fresh litter on crop seed germination. It encourages nitrogen (N) losses through ammonia volatilization and nitrate leaching which respectively cause odor and water quality problems (Mukhtar *et al*., 2004). Moreover, farmers have to wait long for its application to the crops.

Composting is a natural biological process by which organic material is broken down and decomposed to stable humus. Use of composted organic waste as a fertilizer and soil amendment not only brings economic benefits to the farmers, but also reduces pollution because of reduced nutrient run-off and N leaching (Nyamangara *et al*., 2003). Carbon losses as CO_2 are continuously decreased during composting and dropped to an almost constant value after 81 days (Marta *et al*., 2003). Poultry litter is widely used by the farmers yet no significant research work has been done for its proper storage and composting. Keeping this in view, an experiment was conducted to achieve the safe level of C:N ratio and to study the plant nutrients dynamics in poultry litter under different storage conditions and composting.

MATERIALS AND METHODS

Experimental Procedure: Fresh poultry litter was collected from broiler sheds. It was mixed to make uniform in composition, and divided into as many lots of 500 kg each as the number of treatments. Five storage methods were employed separately as treatments, and each method was further studied under composting and un-composting (farmers' practice) conditions. Two-factor factorial completely randomized design with three replications was followed. The size of each heap / pit was 2 m × 2 m × 1 m (length × width × height or depth) and the quantity of poultry litter in each one was 500 kg.
Detail of treatments is as follows:

Factor 1 Storage methods: SM1 Under-shed heap storage (poultry litter was piled on bare ground surface under the shed)

SM2 Covered heap storage (poultry litter was stored on bare ground surface as a pile and covered with plastic sheet)

SM3 Open-air heap storage (poultry litter was stored on bare ground surface and kept open i.e. without any cover / shed over the pile)

SM4 In-pit storage (poultry litter was dumped in pits without any covering / shed)

SM5 Lined-floor heap storage (poultry litter was stored on concrete cemented ground surface and kept open i.e. without any cover / shed over the pile)

Factor 2 Storage conditions: SC1 Composting (At two weeks interval, the heap / pit material was turned, mixed and re-piled after adjusting back moisture at 40 %)

SC2 Un-composting as control (throughout, material in the pile / pit was kept undisturbed, and no water addition except from rains)

Experiment was continued for 90 days, and temperature of stockpiles was recorded twice a week during this period.

Sampling: During the storage period of poultry litter, composite samples consisting of three sub samples each from top, center and bottom of the pile / pit were collected at 15 days interval viz 15, 30, 45, 60, 75 and 90 days after the start of experiment. Samples were dried in forced draft oven at 65 ºC for 24 hours and ground by Willey machine. They were stored in plastic bottles at room temperature till their analysis for C, N, P and K contents.

Analytical Procedures: Poultry litter was analyzed for various elements through respective methods as described here: For organic carbon 1.0 g sample was taken into silica porcelain crucible and dry-ashed in Muffle furnace at 500 °C for 4 hours. Weight of ash was recorded, and organic C content in the sample was calculated by using the formula as given below (Brake, 1992):

$$\text{Organic C (\%)} = \frac{100 - (\text{Ash \%})}{1.8}$$

Where, factor 1.8 is for converting total organic matter into organic carbon.For total N, 1.0 g dried compost sample was weighed into a micro Kjeldahl flask, then 20 ml concentrated H_2SO_4 and 3.0 g digestion mixture were added. Flask was heated until the digest was clear. Nitrogen was determined by distillation followed by titration against 0.01 N H_2SO_4 (van Schouwenberg and Walinge, 1973).

Phosphorus and potassium were determined after wet digestion (Ryan *et al.*, 2001). For P determination, color was developed in the digest and its absorbance was measured using a Spectronic 21 at 430 nm (Anderson and Ingram, 1993). Potassium was estimated by placing 1.0 ml extract into a test tube and adding 5 ml distilled water and 4 ml of lithium chloride solution. The tube was shaken and potassium was determined using a flame analyzer (Winkleman *et al*., 1986).

Data Analysis: Data recoded for various elements in the stocked / composted poultry litter were passed through two way analysis of variance (ANOVA) with Complete Randomized Design (CRD). Statistical difference among the data mean values of various factorial treatments was found through least significant difference (*lsd*) at $P \leq 0.05$ (Sokal and Rohlf, 1997).

RESULTS AND DISCUSSION

Temperature: The variation in temperature over a period of 90 days as recorded twice a week is given in Figure 1. Temperature remained almost within the mesophillic range (40-50°C) during the initial and last two weeks of storage period. The high temperatures in the processed poultry litter were mainly due to hot summer weather. After a month it entered into high thermophillic range (60°C) and remained so for about 45 days, especially in composting treatment in which it reached up to a maximum of 68°C on 50th day. On the completion of the composting process, temperature in the heaps / pits of poultry litter was around 50°C, which was mainly due to hot summer weather. The comparison between composted and un-composted poultry litter revealed a very small difference of temperature in the beginning and at the end of the experiment. However, in the mid period there was 5-10°C higher temperature in the composted as compared to un-composted poultry litter. Among various methods, the in-pit and covered storage attained the highest temperature exceeding 60°C. The lowest temperature was recorded for under-shed method that was mainly due to permanent shade over the heap and low moisture content in the material.

From the result it was obvious that temperature measurement is among the important parameters for monitoring the composting process. Goyal *et al*. (2005) described that initial temperatures of 28-30°C were recorded at the start of composting process and the highest temperature was observed at thermophilic stage, up to 46°C during composting of organic wastes. High temperature is essential for several biological processes, and to reduce the pathogens. The internal temperatures of piles recorded at very first day of composting were not significantly different from one another. Raj and Antil (2011) also found that compost pile maintained the thermophilic temperatures. It was quite clear from the data that temperature increased with the passage of time but not at uniform speed. This suggested that composting process was going to end and most of the matter had been decomposed.

Results from the release of all micro and macro nutrient also suggests that maximum decomposition took place between 60 to 90 days of composting as maximum reading for all the micro and macro nutrients were recorded during this period. (Gaung *et al*., 2010) found that increase in temperature during composting was due to biological and biochemical degradation of organic materials by microorganisms. During composting, the initial organic matter is decomposed and humified through various biological processes. Similar results during composting were observed by Ogunwande *et al*. (2008) that pile temperatures were 28 and 71°C. Hachicha *et al*. (2009) also proved that, composting mixtures rapidly achieved thermophillic temperatures (>45°C) and maximum temperature reached during composting was 62°C.

C: N Ratio: The C: N ratios of poultry litter under composting versus un-composted condition stored through different methods are shown in Figure 2. There was a decreasing trend in the C:N ratio of poultry litter over time, and a significant difference ($P \leq 0.01$) was found at 30 d interval. Significant difference between composted litter and un-composted litter was from 45 d onward till 90 days of storage, being the lowest C:N ratio of 10 at 90 d with composting (Figure 2 a). It revealed that proper moisture and aeration conditions provided under composting treatment enhanced the mineralization of organic materials. Finally, as the temperature of decomposed litter approached to air temperature, the material became softer and finer, C:N ratio was stable, its color changed to dark brown, and malodors were no longer detectable. Through composting of different organic materials, C:N ratio was highly reduced at the end of composting (Adediran *et al.*, 2003; Filippi *et al.,* 2002) During the composting process C:N ratio of organic materials decreased until in a fairly stable 20:1 range (Sharif *et al.,* 2003).

Different among various storage methods for C:N of poultry litter at various stages is presented in Figure 2 b. Data elucidated that at 90 days significantly lower C:N ratio was with lined-floor and in-pit storage as compared to under-shed method. This was mainly due to the reason that under lined-floor and in-pit methods, the manually added water and rain water was not lost through peculation and evaporation, respectively. Proper moisture conditions favoured the rapid mineralization of carbon through decomposition of organic materials. So, the increased nitrogen and decreased carbon contents, resulted into lowering the C:N ratio of compost. Mixture of swine manure and straw, first composted for 10 days then packed into bags and composted for 40 days was found to have lower C:N ratio than that in unpacked composted material (Liao *et al*., 2003). Inoculation of a mixture of household organics and shredded wood with inocula from the active phase of composting enhanced mineralization of organic matter and yielded biologically stabilized product with a more favorable C:N ratio (Bolta *et al.*, 2003). Similarly Adhikari *et al*. (2008) revealed that carbon and nitrogen ratio was high in all the treatments at initial and decreased with the passage of time.

Nitrogen contents: Figure 3 shows that storage methods differed significantly ($P \leq 0.05$) for nitrogen concentration over time in both the composted and un-composted poultry litter. Difference between composted and un-composted poultry litter was non significant except at 90 d with higher value from composting (2.32 % N). An increasing trends in nitrogen concentration was observed over time especially after 60 days (Figure 3 a). Hachicha *et al*. (2009) also reported that total N was between 1.8-2.2 mg kg^{-1} in initially composted raw poultry litter and for vegetables waste, it was confirmed from the investigations of (Jadia and Fulekar, 2008) that the mixture of vegetables waste has initial TN concentration in the range of 1-1.06 mg kg^{-1}.

Storage with plastic sheet covered and lined-floor methods gave statistically higher nitrogen concentration as compared to other methods. The highest concentration of nitrogen was found under covered storage method after 90 days. It was due to the reason that with plastic sheet cover, nitrogen losses through ammonia volatilization were minimized, whereas, in open heaps the mineralized nitrogen was lost freely. Leaching losses of nitrate-N were higher with pit-dump stockpiled poultry litter in both natural as well as composting conditions, and it increased over time (Chaudhry *et al*., 2009). The in-house composting of layer manure results into a friable and nutrient-rich product, and a high-rise house conditions improve N retention in the prepared compost. In this way fertilizer value of compost is improved and ammonia emission is reduced from the stock-house. Composting provides environmentally sustainable solution of waste recycling and control of NH_3 emissions (Ahmad *et al.*, 2008).

Phosphorus contents: The phosphorus concentrations in the composted and uncomposted poultry litter stored through various methods had statistically significant difference. Composting resulted in to significantly higher phosphorus contents over un-composting from 60 days onward (Figure 4 a). This difference was due to enhanced mineralization of organic matter under composting conditions. It reduced the volume and weight of raw poultry litter, so produced a condensed material which was having higher amount of mineral elements concentrated into the compost. Composted dairy manures could contain high level of phosphorus relative to the initial concentration due to the volume reduction of the organic fraction (Zibliske, 1987). Regular turning of the piles facilitated composting within the layer house, resulting in a 39 % reduction in manure weight and a 37 % reduction in manure volume over that of deep stacked raw manure (Thompson *et al*., 2001) Also, the compost had decreased moisture content, improved handling properties, and less odor than raw manure. The composted product containing poultry litter was found to have higher levels of plant nutrients such as P, K, and many of the other micronutrients than the product without poultry litter (Das *et al.*, 2003). However, reported that phosphorus concentration in ensilaged poultry litter decreased slightly during post fermentation (Owoigbe *et al*., 1997)

The storage methods differed significantly ($P \leq 0.05$) from 15 d through 90 d, with the highest contents under covered storage (1.96 %) and the lowest in open-air (1.86 %) and under-shed method (1.84 %) at 90 d (Figure 4 b). The lower phosphorus contents could be attributed to leaching of mineralized phosphorus from the open-air heaps and slow decomposition in the under-shed storage. Whereas, the higher phosphorus contents in covered storage were due to protection from excessive rainwater causing leaching, and faster mineralization under optimum moisture conserved by plastic sheet cover.

An increase in the phosphorus concentration was also found in vermin-composting of poultry litter (Ghosh *et al.*, 2004). Results in the current study are also similar to the findings of Cooperband *et al.* (2002) who found higher P values in the poultry litter after composting process as compared to its mixtures with other wastes. The findings are not similar with that obtained by Guerra-Rodriguez *et al.* (2001) from co-composting of chestnut burr or leaf litter with poultry litter showing 0.71-0.12% P reductions with co-composting. Preusch *et al.* (2002) found enhanced N and P contents in composted vs. un-composted poultry litter.

Potassium: It was observed that different storage methods resulted in variable potassium concentration in composted and uncomposted poultry litter at various stages (Figure 5). Data indicated that potassium concentration was increased with increasing storage time both under composting and uncomposting conditions (Figure 5 a). Higher potassium concentration was found in the composted poultry litter as compared with uncomposted after 60 d, and the difference was significant only at 90 d. Hatchery waste co-composted with poultry litter maintained higher temperatures resulted in higher dry matter and volatile solids, and it had higher levels of P, K, and micronutrients than the product without poultry litter (Das *et al*., 2003).

Rodriguez *et al.* (2001) found an increase in K concentration (2.82-3.26%) during co-composting which is accordance to the findings. The increase of K in the co-compost due to mineralization, and decrease of K concentration was due to the fixation process. Clark (2000) found the similar value of potassium in the food waste composting and observed that K release increased from the initial to final day of composting by the action of microbes. Storage under in-pit method resulted in to highest potassium concentration of poultry litter (13.6 g kg^{-1}) which differed significantly with the under-shed and open-air methods. Shamsi *et al.* (2008) found that potassium and cadmium behaved antagonistically; so the potassium could be a candidate for cadmium detoxification in crops cultivated under polluted environments.

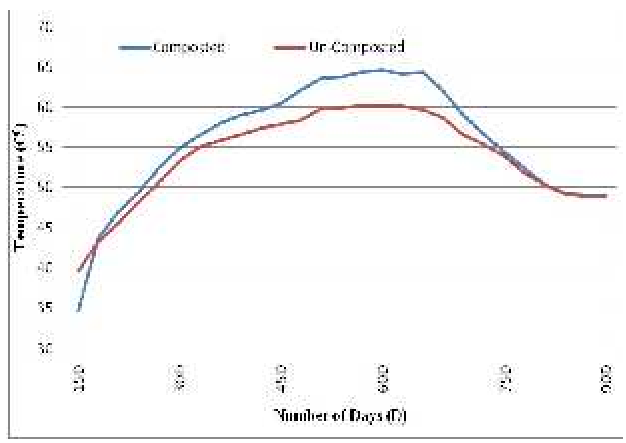

Figure 1 a. Temperature of poultry litter as composted and uncopmosted at various stages

Storage under in-pit method resulted in to highest potassium concentration of poultry litter (1.36 %) which differed significantly with the under-shed and open-air methods. This was because of the reason that in-pit method received more water required for the decomposition of organic matter, so it mineralized higher amount of potassium. Although open-air and lined-floor methods also received the same quantity of water, but from the heaps of these methods the excess water carrying soluble potassium would have percolated down or flowed around.

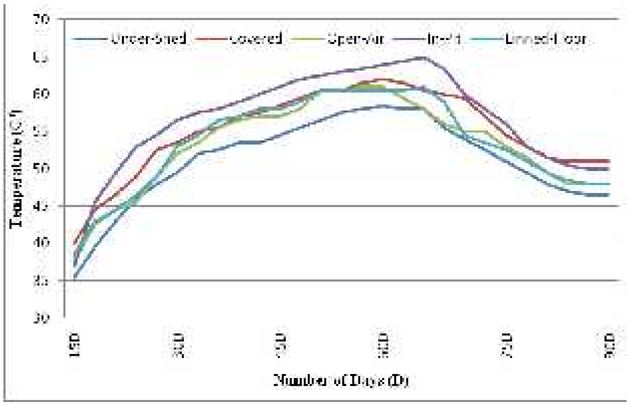

Figure 1 b. Temperature of poultry litter under different storage methods at various stages

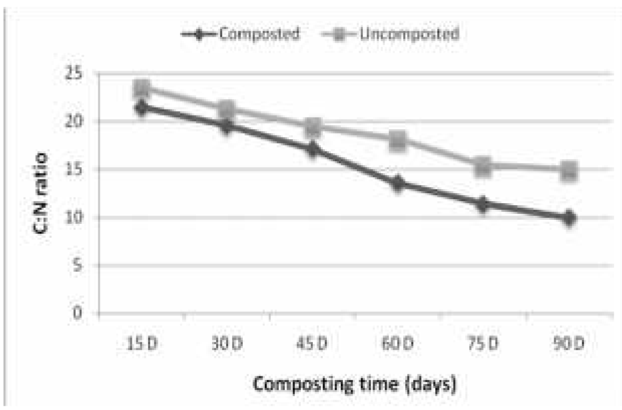

Figure 2 a. Ratio of C:N in poultry litter as composted and uncopmosted at various stages

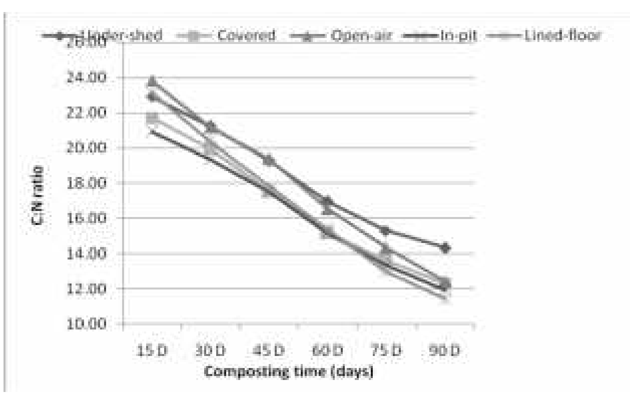

Figure 2 b. Ratio of C:N in poultry litter under different storage methods at various stages

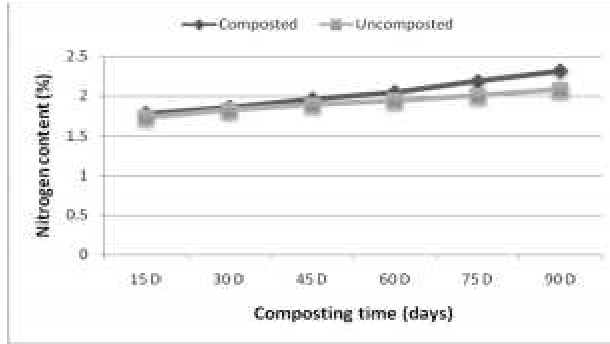

Figure 3 a. Nitogen content in poultry litter as composted and uncopmosted at various stages

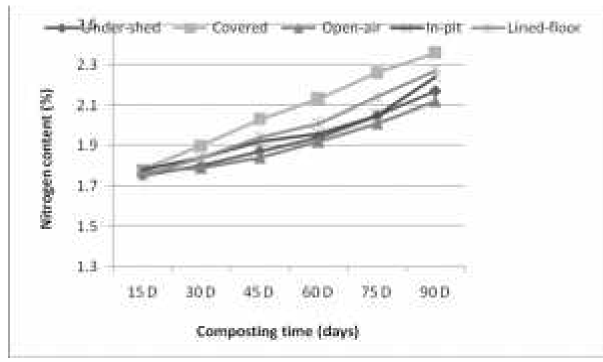

Figure 3 b. Nitogen content under different storage methods of poultry litter at various stages

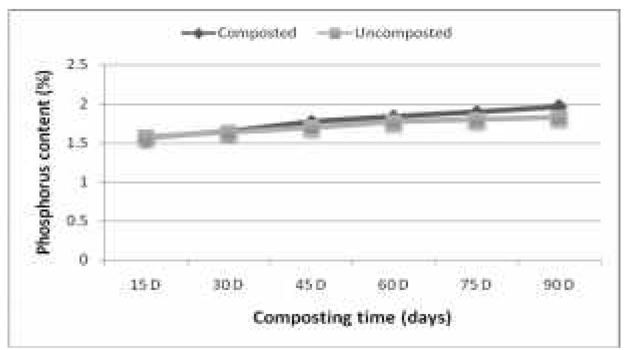

Figure 4 a. Phosphorus content in poultry litter as composted and uncopmosted at various stages

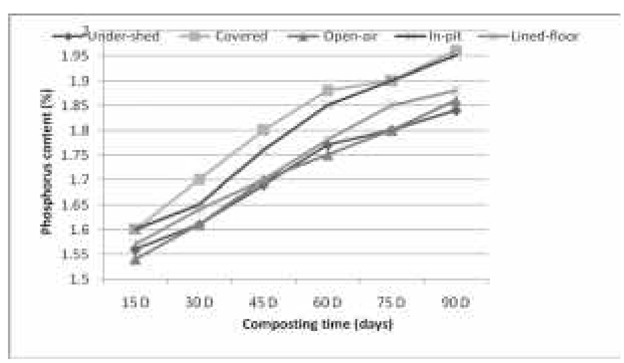

Figure 4 b. Phosphorus content in poultry litter under different storage methods at various stages

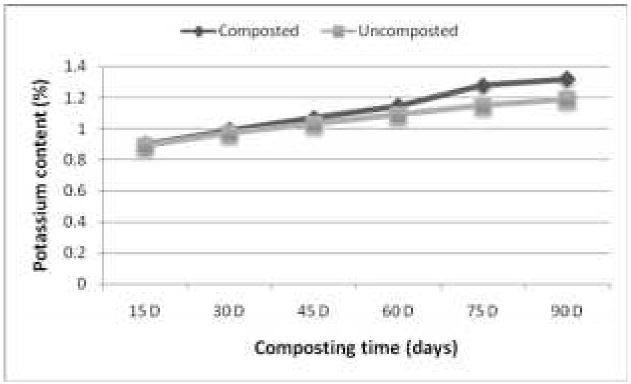

Figure 5 a. Potassium content in poultry litter as composted and uncopmosted at various stages

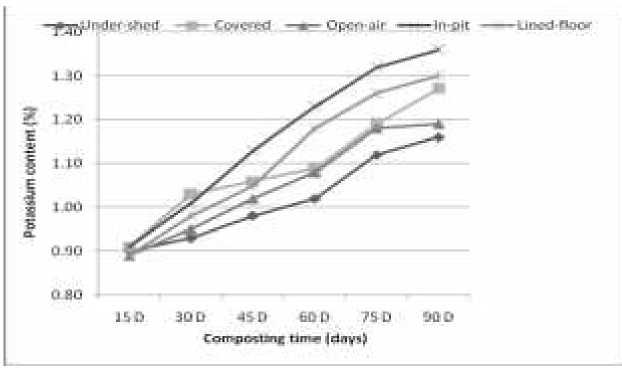

Figure 5 b. Potassium content in poultry litter under different storage methods at various stages

Conclusions and applications: Composting of poultry litter is useful in many ways: converting poultry litter free of malodors, less in weight, easier to transport for land application. Composting narrows down the C:N ratio earlier than in uncomposted poultry litter, making it ready for soil application in shorter time. Composting also elevates the N, P and K contents in the poultry litter as compared to that in uncomposted material. Poultry litter processed through covered and pit storage methods was generally found better than other methods, for its nutrients composition.

Acknowledgment: This study was supported by Pakistan Agriculture Research Council, Islamabad, Pakistan under project "Recycling of Organic Wastes For Sustainable Productivity - ALP Umbrella Project (Arid Agri. Univ., Rawalpindi, Component-II)".

REFERENCES

Adediran, J. A., L. B. Taiwo and R. A. Sobult (2003). Effect of organic wastes and method of composting on compost maturity nutrient composition of compost and yield of two vegetable crops. J. Sust. Agric. 22(4):95-109.

Adhikari, B. K., S. Barrington, J. Martinez and S. King (2008). Characterization of food waste and bulking agents for composting. Waste Manage. 28: 795–804.

Ahmad, R., G. Jilani, M. Arshad, Z. A. Zahir and A. Khalid (2007). Bio-conversion of organic wastes for their recycling in agriculture: An overview of perspectives and prospects. Ann. Microbiol. 57(4):471-479.

Ahmad, R., M. Naveed, M. Aslam, Z.A. Zahir, M. Arshad and G. Jilani. (2008). Economizing the use of nitrogen fertilizer in wheat production through enriched compost. Renew. Agric. Food Syst. 23(3): 243-249.

Anderson, J. M. and J. S. Ingram (1993). Colorimetric determination of ammonium and phosphorus. Pages 70-80 in Tropical Soil Biology and Fertility - A Hand Book of Methods. C.A.B. International, Wallingfold, U.K.

Bolta, S. V., R. Mihelic, F. Lobnik, and D. Lestan. (2003). Microbial community structure during composting with and without mass inocula. Compost Sci. Util. 11(1):6-15.

Brake, J. D. (1992). A practical guide for composting poultry litter. MAFES Bulletin 981, June, 1992. Department of Poultry Science, Mississippi State University, USA. (Vide: http://www.msstate.edu/dept/poultry/complit.htm)

Chaudhry, A. N., G. Jilani, M. A. Khan and T. Iqbal. (2009). Improved processing of poultry litter to reduce nitrate leaching and enhance its fertilizer quality. Asian J. Chem., 21: 4997-5003.

Clark, S., (2000). Development of a Biologically Integrated Food Waste Composting System. Berea College, Kentucky, USA.

Cooperband, L., G. Bollero and F. Coale. (2002). Effect of poultry litter and its compost on soil nitrogen and phosphorous availability and corn production. Nutr. Cycl. Agroecosyst., 6(2): 185-194.

Das, K. C., M. Y. Minkara, N. D. Melear and E. W. Tollner. (2002). Effect of poultry litter amendment on hatchery waste composting. J. Appl. Poult. Res. 11:282-290.

Deksissa, T., G. S. Wyche-Moore and W. W. Hare (2007). Occurrence, fate and transport of 17beta-estradiol and testosterone in the environment. In: Proc. of 2007 AWRA Summer Specialty Conf., Vail, CO, June 25-27, 2007.

Filippi, C., S. Bedini, R. Levi-Minzi, R. Cardelli and A. Saviozzi. (2002). Co-composting of olive oil mill by-products: Chemical and microbiological evaluation. Compost Sci. Util. 10(1):63-71.

Ghosh, P. K., P. Ramesh, K. K. Bandyopadhyay, A. K. Tripathi, K. M. Hati, A. K. Misra and C. L. Acharya (2004). Comparative effectiveness of cattle manure, poultry manure, phosphocompost and fertilizer-NPK on three cropping systems in vertisols of semi-arid tropics. I. Crop yields and system performance. Bioresour. Technol., 95: 77-83.

Goyal, S., S. K. Dhull and K. K. Kapoor (2005). Chemical and biological changes during composting of different organic wastes and assessment of compost maturity. Bioresour. Technol., 1584-1591.

Guang, K. Chao, Lai. Ya, L. and Shang, Y. (2010). Inoculation of food waste with the thermo-tolerant lipolytic actinomycete *Thermoactinomyces vulgaris* A31 and maturity evaluation of the compost J. Biores. Technol., 101: 7424-7431.

Hachicha, R., S. Hachicha, I. Trabelsi, S. Woodward and T. Mechichi (2009). Evolution of the fatty fraction during co-composting of olive industry wastes with animal manure: Maturity assessment of the end product. J. Chemos., 75: 1382-1386.

Jadia, C. D. and M. H. Fulekar (2008). Vermicomposting of vegetables waste: A bio-physicochemical process based on hydro-operating bioreactor. J. Afri. Biotecnol. 7: 3723-3730.

Jilani, G., A. Akram, R. M. Ali, F. Y. Hafeez, I. H. Shamsi, A. N. Chaudhry and A. G. Chaudhry (2007). Enhancing crop growth, nutrients availability, economics and beneficial rhizosphere microflora through organic and biofertilizers. Ann. Microbiol. 57(2):177- 183.

Khan, M. A., M. Rahim and S. Ali (2003). Sewage sludge effect on soil fertility of maize as compared to poultry litter, farmyard manure and chemical fertilizer. Pakistan J .Agri. 6(2):69- 77.

Liao, X. D., Y. B. Wu, Z. S. Wang, M. Dai, Z. Z. Qian and X. D. Liao (2003). Effects of pile size and packaging on swine manure composting. Trans. Chinese Soc. Agric. Engg. 19(4):287-290.

Marta, Y., J. Y. Zhang, and M. H. Wong. (2003). Microbial activity during composting of anthracene-contaminated soil. Chemosphere 52(9):1505-1513.

Moore Jr., P. A., T. C. Daniel, D. R. Edwards and D. M. Miller (1995). Effect of chemical amendments on ammonia volatilization from poultry litter. J. Environ. Qual. 26:23-26.

Mukhtar, S., J. L. Ullman, J. B Carey and R. E. Lacey (2004). A review of literature concerning odors, ammonia, and dust from broiler production facilities: 3. Land application, processing, and storage of broiler litter. J. Appl. Poult. Res. 13:514-520.

Nyamangara, J., L. F. Bergstorm, M. I. Piha and K. E. Giller (2003). Fertilizer use efficiency and nitrate leaching in tropical sandy soil. J. Environ. Qual. 32:599-606.

Ogunwande, G. A., J. A. Osunade, K. O. Adekalu and L. A. O. Ogunjimi (2008). Nitrogen loss in chicken litter compost as affected by carbon to nitrogen ratio and turning frequency. J. Biores. Technol., 99: 7495-7503.

Owoigbe, G. A., P. Bartko., P. Mudren., V. Vajda and E. Pilipeinec (1997). Fermented broiler poultry litter - its composition and nutritional use. Folia Veterin., 41(1-2): 37-40.

Parr, J. F. and S. B. Hornich. (1989). Rehabilitation of degraded agricultural soils with organic wastes. Pages 278-87 in Proc. Workshop Rainfed Agriculture in the Near East Region, Amman, Jordan, Gov. Print. Office, Washington, D.C. Jan. 18-23, 1986. U.S.

Preusch, P. L., P. R. Adler., L. J. Sikora and T. J. Tworkoski (2002). Nitrogen and phosphorus availability in composted and uncomposted poultry litter. J. Environ. Qual. 31:2051-2077.

Raj, D. and R. S. Antil (2011). Evaluation of maturity and stability parameters of composts prepared from agro-industrial wastes. Bioresource Technology, 102: 2868–2873.

Rodriguez, G. E., M. Vazquezand and M. D. Ravina (2001). Co-composting of Chestnut burr and leaf litter with solid poultry manure. J. Biores. Tech., 78: 107-109.

Ryan, J., G. Estefan, and A. Rashid. (2001). Soil and Plant Analysis Lab Manual. 2nd ed. International Centre for Agricultural Research in Dry Areas, Aleppo, Syria. Shamsi, I.H.,G. Jilani, G.P. Zhang and W. Kang. (2008). Cadmium stress tolerance through potassium nutrition in soybean. Asian Journal of Chemistry 20(2): 1099-1108.

Thompson, S. A., P. M. Ndegwa, W. C. Merka and A.B. Webster (2001). Reduction in manure weight and volume using an in-house layer manure composting system under field conditions. J. Appl. Poult. Res., 10: 255–261.

Van Schouwenberg, J. C. H and I. Walinge (1973). Methods of Analysis for Plant Material. Agric. Univ., Wageningen, The Netherlands.

Winkleman, G. E., R. Amine, W. A. Rice and M. B. Tahir (1986). Potassium in plant. *In:* Methods Manual Soils Laboratory. Barani Agric. Res. and Dev. Project. National Agricultural Research Centre, Islamabad, Pakistan. pp. 39-40.

Zibilske, L. M. (1987). Dynamics of nitrogen and carbon in soil during paper mill sludge decomposition. Soil Sci. J., 143: 26-33.