International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:10, No:8, 2016

Co-Composting of Poultry Manure with Different Organic Amendments

M. E. Silva, I. Brás

***Abstract*—**To study the influence of different organic amendments on the quality of poultry manure compost, three pilot composting trials were carried out with different mixes: poultry manure/carcasse meal/ashes/grape pomace (Pile 1), poultry manure/ cellulosic sludge (Pile 2) and poultry manure (Pile 3). For all piles, wood chips were applied as bulking agent. The process was monitored, over time, by evaluating standard physical and chemical parameters, such as, pH, electric conductivity, moisture, organic matter and ash content, total carbon and total nitrogen content, carbon/nitrogen ratio (C/N) and content in mineral elements. Piles 1 and 2 reached a thermophilic phase, however having different trends. Pile 1 reached this phase earlier than Pile 2. For both, the pH showed a slight alkaline character and the electric conductivity was lower than 2 mS/cm. Also, the initial C/N value was 22 and reached values lower than 15 at the end of composting process. The total N content of the Pile 1 increased slightly during composting, in contrast with the others piles. At the end of composting process, the phosphorus content ranged between 54 and 236 mg/kg dry matter, for Pile 2 and 3, respectively. Generally, the Piles 1 and 3 exhibited similar heavy metals content. This study showed that organic amendments can be used as carbon source, given that the final composts presented parameters within the range of those recommended in the 2nd Draft of EU regulation proposal (DG Env.A.2 2001) for compost quality.

***Keywords*—**Co-composting, compost quality, organic amendments, poultry manure.

I. Introduction

THE environmental problems associated with raw poultry manure treatment and valorization could be mitigated by its composting before disposal in agricultural soils. However, to obtain high quality composts it is necessary to evaluate the effect of several key factors during the composting process, such as raw materials, temperature, aeration, moisture content and carbon/nitrogen ratio. In fact, it is recommended to maintain the C/N ratio between 20-40 in order to achieve a good process development and a stabilized compost [1]. Poultry manure is usually rich in nitrogen but poor in carbon, showing low C/N ratio which limits the composting process. In order to obtain the optimum C/N ratio, poultry manure can be composted with different organic amendments that behave as carbon source. The major disadvantage of the process is the large quantity of carbon-rich materials necessary to accomplish the C/N ratio recommended values.

In the present study was assessed the feasibility of using a co-composting process to stabilize poultry manure, a nitrogen-rich organic waste, with different rich organic carbon amendments, as carbon sources, and wood chips as the bulking agent.

II. Methodology

A. Composting Trials and Sampling

Poultry manure, carcasse meal, ashes, grape pomace, cellulosic sludge were used as raw materials and wood chips as bulking agent. Three cone-shaped composting piles were made with 1.5 m high and 2 m base diameter. Pile 1 contained poultry manure, carcasse meal, ashes, grape pomace and wood chips. Pile 2 had poultry manure, cellulosic sludge and wood chips. Pile 3 had only poultry manure and wood chips and it was used as control. The proportions of raw materials were chosen according their C/N ratio (Table I). The composting piles were manually turned every 3 days until the end of the thermophilic phase (active phase), in order to homogenize the biomass, to minimize the formation of anaerobic pockets and to prevent excessively high temperature in the piles. The moisture content was initially adjusted to approximately 50–60%, and maintained during the composting through the addition of water. Temperature was measured daily with a probe (HI 762PWL; Hanna Instruments) at depths of 15, 75 and 140 cm from the top of the piles. Samples of about 3 kg were collected from the top to the bottom of each pile with a sampling pipe, and homogenized by mixing. Approximately 2 kg of the sample was returned to the pile and the remaining part was stored at 4 °C for further analysis.

B. Physicochemical Analyses

Moisture content was evaluated from the weight loss after sample drying 105 °C for 24 h [2]. The organic matter and ashes contents were determined by loss-on-ignition, at 550 °C for 8 h [3]. Electrical conductivity (EC) and pH measurements were performed by electrometric determination in aqueous extracts (1:5, w/v) of the samples. Total carbon was estimated as the product of the organic matter content and the empirical coefficient 0.5 [4]. The Kjeldahl digestion method was followed to evaluate the total nitrogen content [5] while the phosphorus content was determined by the colorimetric ascorbic acid method [6]. The heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) were quantified using a Perkin Elmer atomic absorption spectrophotometer after digestion of dried samples with aqua regia for 16 h at room temperature, followed by

M. E. Silva is with the Departamento de Ambiente, Escola Superior de Tecnologia e Gestão de Viseu, Campus Politécnico, 3504-510 Viseu and CI&DETS, Instituto Politécnico de Viseu, 3504-510 Viseu, Portugal (corresponding author; phone: 351-232-480-500; fax: 351-232-424-651; e-mail: beta@estv.ipv.pt).

I. Brás is with the Departamento de Ambiente, Escola Superior de Tecnologia e Gestão de Viseu, Campus Politécnico, 3504-510 Viseu and CI&DETS, Instituto Politécnico de Viseu, 3504-510 Viseu, Portugal (e-mail: ipbras@estv.ipv.pt).

ebullition for 2 h and filtration [7]. All analyses were performed in triplicate.

III. Results and Discussion

A. Raw Materials Characterization

The physicochemical characteristics of the raw materials used are presented in Table I. All the raw materials tested were non-acidic wastes. The poultry manure had higher moisture content and electrical conductivity (3.8 mS/cm) than the others raw materials.

TABLE I
RAW MATERIALS' PHYSICOCHEMICAL CHARACTERIZATION

Parameters	Poultry manure	Carcass meal	Ashes	Grape pomace	Cellulosic sludge
Moisture (%)	74.4	25.4	42.6	67.0	47.7
pH	7.5	7.1	9.1	8.3	7.4
EC (mS/cm)	3.8	0.7	0.4	0.1	1.1
OM (%)	70.0	90.6	17.2	83.2	85.9
Ashes (%)	30.0	9.4	82.8	16.8	14.1
TOC (%)	35.0	45.3	8.6	41.6	41.2
TN (%)	4.25	1.55	0.09	0.63	0.57
C/N ratio	8.2	29.2	98.7	66.2	215
P (mg/kg dm)	275	123	383	251	30
Cd (mg/kg dm)	<LD	<LD	<LD	<LD	<LD
Cr (mg/kg dm)	<LD	<LD	<LD	2.74	16.4
Cu (mg/kg dm)	16.3	29.9	120	265	59
Ni (mg/kg dm)	7.2	0.8	2.73	<LD	52
Pb (mg/kg dm)	<LD	<LD	<LD	<LD	<LD
Zn (mg/kg dm)	137	133	395	54.7	21.4

EC = Electric Conductivity; OM – Organic Matter; TOC = Total Organic Carbon, TN = Total Nitrogen; dm = dry matter; LD, limit of detection (Zn: 1.3 mg/kg, Cu: 2.0 mg/ kg, Ni: 0.3 mg/kg, Cr: 2.3 mg/kg, Cd: 0.3 mg/kg, Pb: 3.7 mg/kg).

Previous studies have reported high values of electrical conductivity for poultry manure [8]–[9]. The high electrical conductivity was due to the fact that the solid and liquid fractions were mixed, contributing to the existence of soluble chemical species such as potassium, sodium and chlorine. The total nitrogen (TN) content of poultry manure was 3–49 times higher than in the others raw materials. On the other hand, the total carbon (C) content of carcass meal was 1.3 higher than in poultry manure. Thus, the C/N ratio of poultry manure was very low (approximately 8) when compared with those of cellulosic sludge and ashes (approximately 215 and 99, respectively).

Heavy metals such as lead and cadmium were not detected in the raw materials. The highest concentrations of heavy metals were, copper that was found in grape pomace at concentrations of 265 mg/kg dry matter, and zinc was registered in concentration of 395 mg/kg dry matter in ashes. The levels of heavy metals found in poultry manure were in the range of those reported before by Nicholson et al. [10]. The heavy metal contents in animal manures are correlated with their concentration in the feed consumed and with the efficiency of feed conversion by animals [10].

B. Composting Characterization

According to Mondini et al. [11], poultry manure is a good fertilizer due to its high content of C and N and the low C/N ratio. It is also known that fresh poultry manure cannot be applied to crops due to caustic effects on the foliage [11]. In this study, poultry manure was co-composted with organic carbon-rich materials because they behave as conditioning agents, allowing the C/N ratio increase, but also the reduction of the initial moisture content. As control, poultry manure was composted only with the addition of wood chips. The extent of the process was established considering that periods between 60–80 days and 120–150 days are necessary to convert manure into stabilized compost by windrow composting with manual turning [12].

The temperature profile during the composting process is correlated with parameters such as C/N ratio, pH, total carbon, NH_4-nitrogen, NOx-nitrogen, ash, cation exchange capacity and with microbial activity. The temperature profiles obtained with the average values registered in the piles top, middle and bottom throughout the composting process are shown in Fig. 1. The periodic short-term decays in temperature were caused by the cooling effect induced by turning the piles. Is interesting to notice that the temperature in pile 1 and 2 immediately increased from the beginning, reaching thermophilic temperature (> 45 ºC) in the day 25 and 20, respectively. In the pile 2, the average temperatures above 45 ºC were sustained until day 57. Pile 3 (only poultry manure) did not show a thermophilic phase, reaching a maximum of 41 ºC in days 57 and 58. Similar results have been obtained by other authors. Tiquia and Tam [13] measured the temperature in the bottom, middle, top and surface of piles for poultry litter composting and observed a maximum average temperature of 56 ºC, whereas Guerra-Rodrigues et al. [14] and Charest and Beauchamp [15] registered values of 60 ºC within 2 weeks in the co-composting of poultry manure with barley waste and with deinking paper sludge, respectively.

The pH and EC variation during composting are represented in Fig. 2. All the piles showed similar trend in the case of pH variation. Overall, the pH values showed a slight alkaline character, except at the beginning of the process for pile 1 that exhibited neutral pH (7). These piles did not follow the typical variation for this parameter. As the compost process develops, the NH_3 volatilization in the thermophilic phase and the gradually intensified nitrification decreased the pH [16]. Nevertheless, the final pH values of the composts in the composting piles were within the optimum range of 6–9, except for pile 2 that reached pH 10.

Pile 3 registered the highest EC values, ranged between 8 and 4 mS/cm. In contrast pile 1 and 2 showed EC lower than 4 mS/cm at the end of the process. The EC variation during the composting is the expected. The increase in the EC could be caused by the release of mineral salts and ammonium ions from the decomposition of organic matter. As the composting process continued, the volatilization of ammonia and precipitation of mineral salts make the EC to decrease [17].

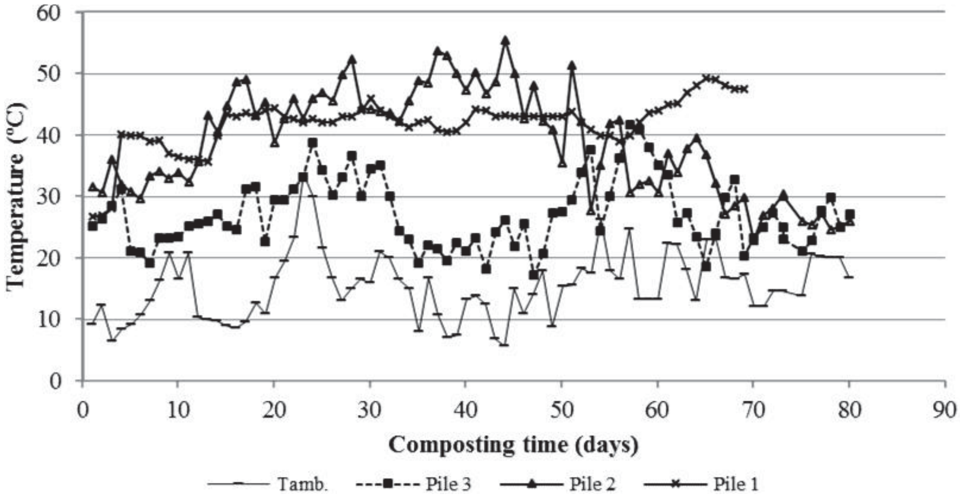

Fig. 1 Temperature profile of the composting processes

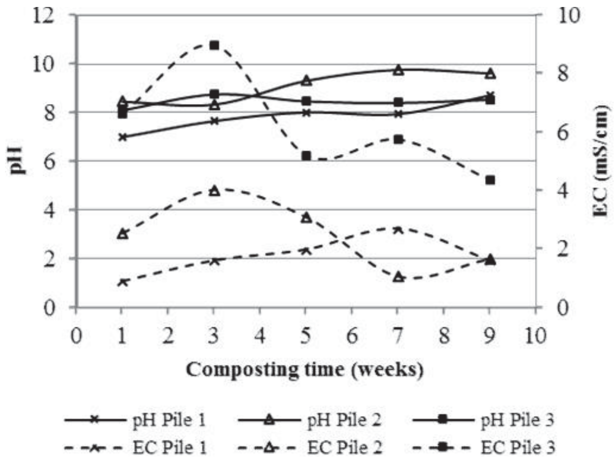

Fig. 2 pH and electric conductivity (EC) during the composting process

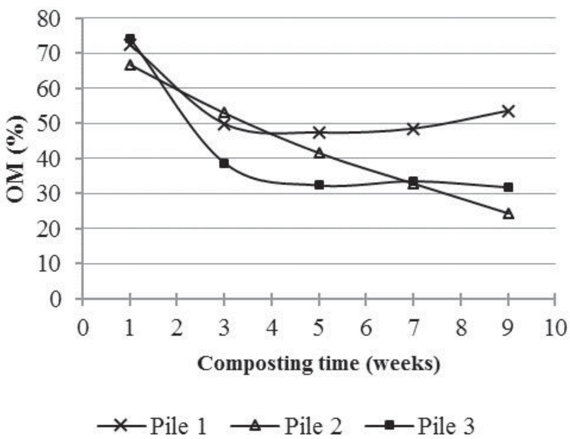

Fig. 3 Organic matter (OM) evolution during the composting process

The OM content decreased during the composting process from approximately 67–74% to 54%, 25% and 32% in piles 1, 2 and 3, respectively, indicating removal of organic matter through microbial activity and/or abiotic losses (Fig. 3).

According to the proportional mix of the different materials, in the beginning of composting, the total nitrogen content of the piles varied from 1.5% (pile 2) to 3.6% (pile 3) (data not shown). These values decreased to approximately 1.4% and 1.1% in piles 2 and 3, respectively. However, in pile 1 this value increased reaching 3.8% at the final of composting process (data not shown). Pile 3, with a high content of poultry manure, showed a decrease in total carbon and nitrogen content in the first 20 days. But in piles 1 and 2 the decrease of these elements was gradual. Carbon and nitrogen consumption by present microorganisms and/or abiotic compounds losses throughout the active composting process resulted in changes in the C/N ratio of the piles. In pile 3, the C/N ratio increased, respectively, from 10 to 14, while in piles 1 and 2 (which had the highest initial C/N ratio - 22), this parameter decreased, reaching C/N of 7 and 9, respectively (Fig. 4).

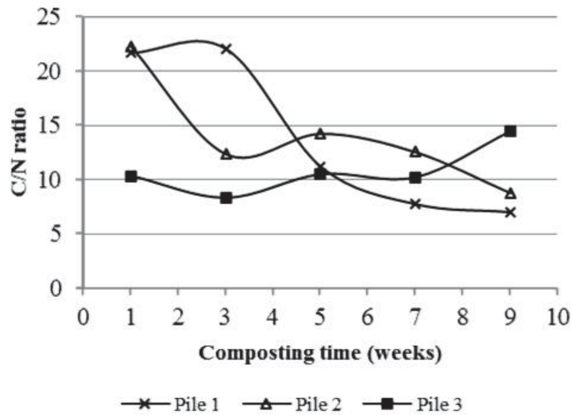

Fig. 4 C/N ratio evolution during the composting process

The major decrease in the percentages of total carbon, organic matter and nitrogen were observed in pile 3. However, the microbial activity was not sufficient to heat the pile above 45 ºC, suggesting that the C- and N-compounds or their proportion in poultry manure do not support good microbial growth. In contrast, the presence of additional C-compounds from the organic amendments, in piles 1 and 2, permitted the achievement of thermophilic phases in both piles, suggesting good microbial growth.

C. Compost Characterization

The composts physicochemical characterization is presented in Table II. All final composts presented lower contents of moisture, total carbon and total nitrogen, and higher content of ash than raw poultry manure (Tables I and II), indicative of mineralization of organic matter.

In all piles, a slight decrease in the percentage of total carbon was observed during the maturation phase. Consequently, final C/N ratios of around 7 and 11 were registered for piles 1, 2 and 3 composts, respectively. A final C/N ratio of 20 or less indicates a mature compost [18]. The final C/N ratio values of composts from piles 2 and 3 were similar to those found for final co-composts of rice straw, oilseed rape cake and poultry manure [19].

The phosphorus content initially present in poultry manure, decreased in all the composts (Table I and II) and it concentration in piles 1 and 2 composts was similar. The heavy metals concentration in all composts was lower than those found in other poultry manure composts [20] and did not exceed the limits proposed by European guidelines [21] for a class 1 compost.

TABLE II
COMPOST PHYSICOCHEMICAL CHARACTERIZATION

Parameters	Pile 1	Pile 2	Pile 3
Moisture (%)	48.7	41.4	35.9
pH	8.7	9.5	9.2
EC (mS/cm)	1.9	1.8	4.4
OM (%)	53.6	25.4	21.5
Ashes (%)	46.4	74.6	78.5
TOC (%)	26.8	12.7	10.7
TN (%)	3.8	1.1	1.0
C/N ratio	7.0	11.2	11.2
P (mg/kg dm)	141	54.1	236
Cd (mg/kg dm)	<LD	<LD	<LD
Cr (mg/kg dm)	<LD	14.4	<LD
Cu (mg/kg dm)	48.2	86	62.8
Ni (mg/kg dm)	2	33.0	16.2
Pb (mg/kg dm)	<LD	<LD	<LD
Zn (mg/kg dm)	148	42	200

EC = Electric Conductivity; OM = Organic Matter; TOC = Total Organic Carbon. TN = Total Nitrogen; dm = dry matter; LD. limit of detection (Zn: 1.3 mg/kg, Cu: 2.0 mg/kg, Ni: 0.3 mg/kg, Cr: 2.3 mg/kg, Cd: 0.3 mg/kg, Pb: 3.7 mg/kg).

The absence of harmful concentrations of heavy metals and the presence of nutrients in compost are advantageous if it is to be further used as organic amendment for agricultural soils. However, the release of mineral salts through decomposition of organic matter, and the concentration effect due to net loss of dry mass, leads to an increase in the values of electrical conductivity. This parameter reflects the degree of salinity in the compost, indicating its possible phytotoxicity if applied to soil. The highest value was found in pile 3 (4.4 mS/cm) followed by pile 1 compost (1.9 mS/cm) and pile 2 compost (1.8 mS/cm) (Table II). The compost from pile 3 had higher electrical conductivity than the raw poultry manure and also than 4 mS/cm, the higher limit considered tolerable by plants of medium sensitivity [22].

IV. CONCLUSION

The co-composting processes studied showed more benefits than the composting of poultry manure alone, accomplishing final co-composts of higher quality. The results of our study support the conclusion that the addition of organic ammendments materials that are rich in carbon to poultry manure improve the biodegradation and allows the resulting compost to meet most of the criteria of the 2nd Draft proposal for compost quality.

ACKNOWLEDGMENT

The authors would like to express their gratitude to Instituto Politécnico de Viseu, the Center for Studies in Education, Technologies and Health (CI&DETS) and the Portuguese Foundation for Science and Technology (FCT).

REFERENCES

[1] G. Vallini, "Il Compostaggio," in: *La protezione dell'ambiente in Italia*, I. Bertini., R. Cipollini and P. Tundo, Eds., Consiglio Nazionale delle Richerche. Società Chimica Italiana e Consorzio Interuniversitario Chimica per l'Ambiente, Bologna, 1995, pp. 83–134.

[2] EN 13040, *Soil Improvers and Growing Media – Sample preparation for chemical and physical tests, determination of dry matter content, moisture content and laboratory compacted bulk density*. European Committee for Standardization, Technical Committee CEN/TC 223, 1999.

[3] EN 13039, *Soil Improvers and Growing Media – Determination of organic matter content and ash*. European Committee for Standardization. Technical Committee CEN/TC 223, 1999.

[4] F. Zucconi and M. De Bertoldi, "Compost specifications for the production and characterization of compost from municipal solid waste." in: *Compost: production, quality and use*, M. De Bertoldi, M. P. Ferranti, P. L'Hermite, F. Zucconi, Eds., Elsevier Applied Science Publishers Ltd, Essex, 1987, pp. 30-50.

[5] EN 13654-1, *Soil Improvers and Growing Media – Determination of Nitrogen – Part 1: Modified Kjeldahl Method*. European Committee for Standardization, Technical Committee CEN/TC 223, 2001.

[6] APHA (American Public Health Association). *Standard Methods for Examination of Water and Wastewater*. American Public Health Association, 21st ed, Washington D.C., 2005.

[7] EN 13650, *Soil Improvers and Growing Media – Extraction of aqua regia soluble elements.* European Committee for Standardization, Technical Committee CEN/TC 223, 2001.

[8] S. M. Tiquia, "Evolution of extracellular enzyme activities during manure composting," *Journal of Applied Microbiology* 92, 764-775, 2002.

[9] J. C. Tang, Y. Inoue, T. Yasuta, S. Yoshida, A. Katayama, "Chemical and microbial properties of various compost products," *Soil Science and Plant Nutrition* 49, 273–280, 2003.

[10] F. Nicholson, B. Chambers, B. Allowayd, A. Hird, S. Smith, C. Carlton-Smith," An inventory of heavy metals inputs to agricultural soils in England and Wales," in: *Proceedings of the 16th World Congress of Soil Science.* Montpellier, France, 1998.

[11] C. Mondini, R. Chiumenti, F. Borso, L. Leita, M. De Nobili, "Changes during processing in the organic matter of composted and air-dried poultry manure," *Bioresource Technology* 55, 243-249, 1996.
[12] S. M. Tiquia, J. H. C. Wan, N. F.Y. Tam, "Extracellular enzyme profiles during co-composting of poultry manure and yard trimmings," *Process Biochemistry* 36, 813-820, 2001.
[13] S. M. Tiquia and N. F. Y. Tam, "Characterization and composting of poultry litter in forced-aeration piles," *Process Biochemistry* 37, 869-880, 2002.
[14] E. Guerra-Rodríguez, M. Vázquez, M. Díaz-Raviña, "Co-composting of barley wastes and solid poultry manure," *Bioresource Technology* 75, 223-225, 2000.
[15] M. H. Charest, C. J. Beauchamp, "Composting of de-inking paper sludge with poultry manure at three nitrogen levels using mechanical turning: behavior of physico-chemical parameters," *Bioresource Technology* 81, 7-17, 2002.
[16] S. M. Tiquia and N. Tam, "Fafe of nitrogen during composting of chicken litter," *Environ. Pollut*. 110, 535–541, 2000.
[17] M. Gao, B. Li, A. Yu, F. Liang, L. Yang, Y. Sun, "The effect of aeration rate on forced-aeration composting of chicken manure and sawdust," *Bioresource Technology* 101, 1899–1903, 2010.
[18] T. Nolan, S. M. Troy, M. G. Healy, W. Kwapinski, J. J. Leahy, P. G. Lawlor, "Characterization of compost produced from separated pig manure and a variety of bulking agents at low initial C/N ratios," *Bioresource Technology* 102, 7131–7138, 2011.
[19] M. T. Abdelhamid, T. Horiuchi, S. Oba, "Composting of rice straw with oilseed rape cake and poultry manure and its effects on faba bean (*Vicia faba* L.) growth and soil properties," *Bioresource Technology* 13, 183-189, 2004.
[20] E. Guerra-Rodríguez, J. Alonso, M. J. Melgar, M. Vázquez, "Evaluation of heavy metal contents in co-composts of poultry manure with barley wastes or chestnut burr/leaf litter," *Chemosphere*, 65(10), 1801-1805, 2006.
[21] DG Env.A.2, *Working Document of Biological Treatment of Biowaste 2nd draft. Directorate-General Environment*, Brussels, 12th February, ENV.A.2 - Sustainable Resources, 2001.
[22] K. Lasaridi, I. Protopapa, M. Kotsou, G. Pilidis, T. Manios, A. Kyriacou, "Quality assessment of composts in the Greek market: The need for standards and quality assurance," *J. of Environ. Manage*. 80, 58-65, 2006.