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End Product Maturity of Poultry Waste Compost in Terms of Different Chemical Changes

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ABSTRACT

The current study was performed in the Division of Livestock Production and Management, (FVSc and AH SKUAST- Kashmir) to assess the change in different chemical parameters of composting poultry farm waste under the temperate climatic conditions of Kashmir Valley. Poultry waste in the form of poultry carcass and liter manure was used for this study.Four treatment groups with four replicates each were formulated as : G_1 : poultry carcass; liter manure, G_2 : poultry carcass; liter manure; paddy straw, G_3 : poultry carcass ; liter manure ; effective microbes and G_4 : poultry carcass ; liter manure ; paddy straw; effective microbes. The overall lowest TOM value of 38.13% was observed in G_2 group in which paddy straw was added as an additional carbon source. The overall lowest TOC value of 22.33% was observed in G_2 group in which paddy straw was added as carbon source. The overall highest nitrogen content of 2.43% was observed in G_4 group in which paddy straw and effective microbes were added. The overall lowest C : N ratio of 10.26 was observed in G_4 group having paddy straw and effective microbes. The overall highest total ash content of 46.15% was also observed in G_2 group where paddy straw was added as a source of carbon. The overall highest pH of 9.01 was observed in G_1 the control group. The overall highest TDS value of 2.26 ppt was recorded in G_1 (control group). The overall highest EC value of 3.16 mS/cm was recorded in G_1 group. It was concluded that significant changes in different chemical parameters were observed in poultry waste during composting in terms of a final product maturity.

Keywords Composting, Dead birds, Poultry liter, Bio-minerals, Seasons.

INTRODUCTION

Poultry sector in India has recently progressed with an immense annual growth rate which has resulted

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Table 1. Different group combinations for composting.

Groups	Description
G_1	Dead birds + Poultry litter (Control)
G_2	Dead birds + Poultry litter + Paddy straw
G_3	Dead birds + Poultry litter + Effective microbes
G_4	Dead birds + Poultry litter +Paddy straw + Effective microbes

in increase of both per capita availability and consumption of poultry products (Anonymous 2021). Due to commercialization and involvement of highly intensive and concentrated inputs in modern livestock farming there is also generation of large volumes of waste (Gwyther *et al.* 2012). Economically viable and practically feasible waste management method is needed for such waste to be effectively and eco-friendly disposed in order to avoid different harmful effects of such waste when left as such on environment, society and animals (Bolan 2010). Composting in this regard is one of the eco-friendly, modern and novel methods of utilizing the animal waste effectively besides fetching a valuable final product called compost with a high bio-mineral value (Hutchinson and Seekins 2008). The final maturity of end product due to composting determines its shelf-life, applicability and usability (Sivakumar *et al.* 2007). The mature end product will show highest degree of organic matter decomposition with resistance to further decomposition and steady values of a number of indices like organic matter content, carbon nitrogen ratio and storage temperature, total dissolved salts, electrical conductivity (Sivakumar *et al.* 2008).

MATERIALS AND METHODS

Poultry waste selected for the study was in the form of dead birds (carcass) and deep liter manure. Four compost recipe groups (with four replicates in each group) were formulated with addition of effective microbial culture (*Lactobacillus plantarum*, *Lactobacillus casei*, *Saccharomyces cerevisiae* and *Rhodopseudomonas palustris*) in two groups (Table 1). Composting was done in wooden boxes (Mini composter) with dimensions of 3 feet length × 3 feet width × 3 feet height designed (Donald *et al.* 1996). The study was conducted during two different seasons viz., summer and winter. Compost samples were collected at the end of both primary and secondary stage. In each stage samples were gathered from different locations to get a representative sample and stored in an air tight polythene bag and transferred immediately for moisture estimation. Respective samples were also collected in sterile plastic bags and sealed to air tight for further examinations. The following chemical properties of the compost samples were estimated on DM basis.An aqueous solution of 1/10 (w/v compost-water extract) was used to measure the parameters like; pH, electrical conductivity and TDS (Tiquia and Tam 2002). Total ash (Allison 1965 , APHA 1995),total organic matter (Navarro *et al.* 1993), Kjedal nitrogen (AOAC 2005)), total organic carbon (Allison 1965, Navarro *et al.* 1993, Lawson and Keeling 1999) and carbon nitrogen ratio (Zhu *et al.* 2004) were also estimated at the end of pri-

Table 2. Per cent total organic matter during different stages and seasons of composting (Mean±SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly ($p<0.05$).

Group	Primary stage Winter	Primary stage Summer	Primary stage Overall	Secondary stage Winter	Secondary stage Summer	Secondary stage Overall
G_1	$^{BC}52.82±1.28$	$^{AB}54.75±1.06$	53.78±1.69	$^{A}48.73±2.43^{a}$	$^{BC}45.45±2.92^{b}$	47.09±1.25
G_2 (Paddy straw)	$^{A}43.54±1.15^{a}$	$^{A}51.59±0.75^{b}$	47.56±0.43	$^{A}39.29±0.66^{a}$	$^{A}36.97±0.58^{b}$	38.13±0.64
G_3 (Effective microbes)	$^{C}54.75±0.97^{a}$	$^{B}58.18±1.43^{b}$	56.46±3.40	$^{A}41.94±5.88^{a}$	$^{C}48.36±1.86^{b}$	45.15±1.30
G_4 (Paddy straw+ effective microbes	$^{B}48.51±2.20$	$^{A}51.03±1.06$	49.77±1.21	$^{A}44.05±0.69$	$^{AB}41.78±0.88$	42.91±0.97

Table 3. Per cent total organic carbon during different stages and seasons of composting (Mean ± SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly ($p<0.05$).

Group	Primary stage Winter	Summer	Overall	Secondary stage Winter	Summer	Overall
G_1	$^{B}30.75\pm0.72^{a}$	$^{B}38.57\pm0.78^{b}$	34.66±1.03	$^{C}28.05\pm1.61$	$^{BC}27.31\pm0.93$	27.68±0.18
G_2 (Paddy straw)	$^{A}26.84\pm2.20^{a}$	$^{A}33.26\pm3.16^{b}$	30.05±2.25	$^{B}23.48\pm0.39^{a}$	$^{A}21.18\pm0.56^{b}$	22.33±1.86
G_3 (Effective microbes)	$^{B}31.18\pm0.90^{a}$	$^{B}37.74\pm2.99^{b}$	34.46±1.76	$^{A}25.87\pm2.81^{a}$	$^{C}28.03\pm1.10^{b}$	26.95±2.14
G_4 (Paddy straw+ effective microbes)	$^{B}29.78\pm2.74^{a}$	$^{A}34.23\pm1.77^{b}$	32.0±1.21	$^{A}25.08\pm0.60$	$^{B}24.80\pm0.82$	24.94±0.79

mary and final stage. The data collected was analyzed as per the standard statistical procedures suggested by Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

Total organic matter

The total organic matter (TOM) or total volatile solids reflect the quantity of organic matter lost through oxidation process. The overall results (Table 2) showed a considerable reduction in total organic matter from primary (47.56 to 56.46%) to secondary stages (38.13 to 47.09%) of composting. At primary stage the significantly ($p<0.05$) lowest TOM (highest reduction)of 43.54 % was observed in G_2 group during winter season and 51.03% in G_4 group during summer season. At secondary stage the lowest TOM (highest reduction) was observed in G_2 (39.29 and 36.97 % respectively) during winter and summer seasons. In both the groups addition of paddy straw as an additional carbon source lead to highest reduction in TOM indicating a higher microbial degradation and stabilization of compost (Cekmecelloglu *et al.* 2004, Das *et al.* 2002, Abdelhamid *et al.* 2004, Taquia and Tam 2002, Sivakumar *et al.* 2007).

Total organic carbon

TOC at primary stage of composting ranged between 26.84% (G_2) and 31.18% (G_3) during winter and 33.26% (G_2)and 38.57% (G_1) during summer (Table 3). At secondary stage TOC ranged between

Table 4. Per cent nitrogen content (Kjeldal) during different stages and seasons of composting (Mean±SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly ($p<0.05$).

Group	Primary stage Winter	Summer	Overall	Secondary stage Winter	Summer	Overall
G_1	$^{A}0.84\pm0.07$	$^{B}0.95\pm0.05$	0.89±0.05	$^{A}1.86\pm0.07$	$^{A}1.84\pm0.09$	1.85±0.04
G_2 (Paddy straw)	$^{A}0.73\pm0.05$	$^{A}0.76\pm0.08$	0.74±0.05	$^{A}1.63\pm0.06$	$^{A}1.55\pm0.08$	1.59±0.05
G_3 (Effective microbes)	$^{A}0.81\pm0.03$	$^{AB}0.79\pm0.02$	0.8±0.04	$^{A}1.50\pm0.05^{a}$	$^{A}1.65\pm0.04^{b}$	1.57±0.02
G_4 (Paddy Straw+ effective microbes)	$^{B}1.09\pm0.03^{a}$	$^{C}1.29\pm0.04^{b}$	1.19±0.14	$^{B}2.39\pm0.20$	$^{B}2.47\pm0.31$	2.43±0.14

Table 5. Carbon nitrogen ratio during different stages and seasons of composting (Mean±SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly (p<0.05).

Group	Primary stage Winter	Primary stage Summer	Primary stage Overall	Secondary stage Winter	Secondary stage Summer	Secondary stage Overall
G_1	$^{B}36.45\pm4.12^{a}$	$^{B}40.60\pm1.61^{b}$	38.45±2.43	$^{B}15.05\pm1.21$	$^{B}14.78\pm0.50$	14.91±0.90
G_2 (Paddy straw)	$^{B}36.59\pm1.29^{a}$	$^{B}43.76\pm8.0^{b}$	40.17±0.9	$^{BC}14.39\pm0.60$	$^{B}13.66\pm1.01$	14.02±4.22
G_3 (Effective microbes)	$^{B}38.33\pm2.20^{a}$	$^{B}47.61\pm2.64^{b}$	42.97±2.37	$^{C}17.21\pm2.55$	$^{B}16.91\pm1.04$	17.06±1.84
G_4 (Paddy straw +effective microbes)	$^{A}27.27\pm2.72$	$^{A}26.46\pm2.11$	26.86±1.91	$^{A}10.48\pm1.12$	$^{A}10.04\pm1.57$	10.26±0.80

25.08 % (T_4) and 28.05 % (G_1) during winter and 21.18 % (G_2) during summer. More significant (p<0.05) reduction in TOC was observed at secondary stage of composting when compared to primary stage. The loss of organic carbon was due to addition of optimum moisture, aeration and presence of sufficient C:N ratio which improved the microbial degradation process. Results were comparable with the findings of Cummins *et al.* (1993), Lawson and Keeling (1999). The reduction in the TOC was mainly due to the loss of organic matter through microbial degradation and loss carbon in the form of CO_2 as (Kumar *et al*. 2007, Sivakumar *et al.* 2007).

Kjeldal nitrogen

Composting reduces the nitrogen loss by NH_3 volatilization and conserves N by favoring its mineralization. At primary stage group G_4 recorded highest N content of 1.09 and 2.39 % during winter and summer seasons respectively (Table 4) and similarly at secondary stage G_4 had highest nitrogen content of 1.29 and 2.47% during winter and summer seasons respectively. Similar results were for dead bird were also reported by Donald *et al.* (1996), Barton and Benz (1990), Murphy and Carr (1991), Cummins *et al.* (1993). The better results obtained was due to addition of carbon sources (paddy straw) and effective microbial culture (Vuorinen and Saharinen 1997). Tiquia *et al*. (1998), Huang *et al.* (2004) also observed same type of results in spent litter swine manure and saw dust. Bharathy *et al.* (2012) recorded comparatively lower nitrogen in compost of broiler slaughter waste.

Carbon nitrogen ratio

Maintaining a proper carbon nitrogen ration (20-40:

Table 6. Per cent ash content during different stages and seasons of composting (Mean±SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly (p<0.05).

Group	Primary stage Winter	Primary stage Summer	Primary stage Overall	Secondary stage Winter	Secondary stage Summer	Secondary stage Overall
G_1	$^{C}33.92\pm1.03^{a}$	$^{C}33.10\pm1.40^{b}$	33.51±1.41	$^{C}36.16\pm0.82^{a}$	$^{C}31.60\pm1.34^{b}$	33.89±1.32
G_2 (Paddy straw)	$^{C}43.34\pm0.83^{a}$	$^{B}32.97\pm0.94^{b}$	38.15±1.62	$^{C}45.76\pm0.45$	$^{D}46.55\pm3.32$	46.15±1.03
G_3 (Effective microbes)	$^{A}28.30\pm0.59^{a}$	$^{BC}33.72\pm1.07^{b}$	31.01±1.06	$^{A}31.42\pm0.59^{a}$	$^{B}48.73\pm0.47^{b}$	40.07±0.97
G_4 (Paddy straw+ effective microbes)	$^{B}34.97\pm0.28^{a}$	$^{A}33.80\pm0.28^{b}$	34.38±1.11	$^{B}37.17\pm0.32^{a}$	$^{A}39.88\pm1.75^{b}$	38.52±2.01

Table 7. pH during different stages and seasons of composting (Mean±SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly ($p<0.05$).

Group	Primary stage			Secondary stage		
	Winter	Summer	Overall	Winter	Summer	Overall
G_1	7.66±0.06	7.10±0.14	7.38±0.05	9.53±0.06 ^{a}	^{B}8.50±0.32 ^{b}	9.01±0.23
G_2 (Paddy straw)	7.53±0.20	7.60±0.70	7.56±0.28	9.30±0.40 ^{a}	^{AB}8.23±0.54 ^{b}	8.76±0.61
G_3 (Effective microbes)	7.56±0.20	7.36±0.23	7.46±0.15	9.26±0.43 ^{a}	^{A}7.50±0.05 ^{b}	8.38±0.08
G_4 (Paddy straw+ effective microbes)	7.52±0.23	7.33±0.29	7.43±0.26	9.20±0.30 ^{a}	^{AB}8.10±0.05 ^{b}	8.65±0.16

1) is prerequisite for compost making. Carbon is a source of energy for microbial growth. Nitrogen is used for the synthesis of cellular material, amino acids and proteins and is continuously recycled through the cellular material of the microorganisms (USDA-NRCS 2003). A significant ($p<0.05$) reduction in C:N ratio (Table 5) from primary to secondary stage of composting (Cekmecelloglu *et al.* 2004). The highest and lowest C: N ratio at the end of secondary stage was 17.21 in G_3 and 10.48 in G_4 during winter and 16.91 in G_3 and 10.04 in G_4 during summer season (Hirai *et al.* 1983). An overall highest reduction of C:N ration observed in T_4 was due to effective utilization and consumption of organic carbon by effective microbes. Moreover paddy straw provided an extra source of carbon for increased microbial activity (Cummins *et al.* 1993, Leon 2006). Contrary results were also observed by Tiquia and Tam (2002). The C:N ratio of end product in the range of 20 :1 indicates the maturity of the compost (Sivakumar *et al.* 2007).

Ash

At the end of secondary stage G_1 (45.76) and G_3 (31.42) groups during winter and G_2 (46.55) and G_1 (31.60) during summer season observed the highest and the lowest values respectively. The overall results suggested that there was significant ($p<0.05$) increase in the per cent ash content at the end secondary stage of composting when compared with primary stage

Table 8. Total dissolved solids (ppt) during different stages and seasons of composting (Mean±SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly ($p<0.05$).

Group	Primary stage			Secondary stage		
	Winter	Summer	Overall	Winter	Summer	Overall
G_1	^{A}1.20±0.03^{a}	^{C}2.29±0.02^{b}	1.74±0.03	^{A}1.71±0.04^{a}	^{C}2.82±0.03^{b}	2.26±0.02
G_2 (Paddy straw)	^{BC}1.53±0.04^{a}	^{B}1.70±0.02^{b}	1.61±0.03	^{A}2.04±0.03^{a}	^{B}1.80±0.01^{b}	1.92±0.02
G_3 (Effective microbes)	^{C}1.60±0.03^{a}	^{A}1.43±0.05^{b}	1.51±0.02	^{C}2.12±0.02	^{A}1.62±0.01	1.87±0.02
G_4 (Paddy straw+ effective microbes)	^{B}1.42±0.02	^{A}1.50±0.06	1.46±0.02	^{B}1.91±0.02	^{A}1.69±0.01	1.80±0.03

Table 9. Electrical conductivity (mS/cm) during different stages and seasons of composting (Mean±SE). Figures with different small superscripts row wise and capital superscripts column wise differ significantly (p<0.05).

Group	Primary stage Winter	Primary stage Summer	Primary stage Overall	Secondary stage Winter	Secondary stage Summer	Secondary stage Overall
G_1	$^{A}1.77±0.06^{a}$	$^{C}3.38±0.05^{b}$	2.57±0.06	$^{A}2.26±0.06^{a}$	$^{B}4.07±0.05^{b}$	3.16±0.05
G_2 (Paddy straw)	$^{C}2.34±0.04^{a}$	$^{B}2.55±0.03^{b}$	2.44±0.04	$^{C}2.86±0.04$	$^{A}2.71±0.01$	2.78±0.02
G_3 (Effective microbes	$^{C}2.43±0.03$	$^{A}2.39±0.03$	2.41±0.04	$^{C}2.89±0.05$	$^{A}2.78±0.05$	2.83±0.01
G_4 (Paddy straw+ effective microbes)	$^{B}2.10±0.05^{a}$	$^{B}2.51±0.03^{b}$	2.30±0.03	$^{B}2.66±0.04$	$^{A}2.76±0.07$	2.71±0.02

of composting (Table 6). Comparable ash content in dead bird compost was also reported by Cummins *et al.* (1993), McCaskey (1994). However Cekmecelloglu *et al.* (2004), Abdelhamid *et al.* (2004) reported higher total ash contentin composting food waste. Henry and White (1993) also reported an increase total ash content from initial to final stages of composting.

pH

At the end of secondary stage the pH values ranged between 9.20 in group G_4 and 9.53 in group G_1 during winter and 7.5 in group G_3 and 8.5 in treatment group G_1 during summer (Table 7). Season was having significant (p<0.05) effect on pH at the end of secondary stage of composting during winter and summer seasons due to a significant increase in the pH values from primary to secondary stage of composting. The increase in pH was due to production of ammonium salt and bicarbonates with the progress of composting as (Caceres *et al*. 2005, USDA-NRCS 2003, Langston *et al.* 2002). pH of final compost of was higher (8.38–9.0) which indicate the high rate of ammonium salt formation (Rodriguez *et al.* 2003). Comparable result were also recorded by other workers (McCaskey 1994, Lawson and Keeling 1999, Ahamed *et al.* 2016, Mahimairaja *et al.* 1994) with gradual increase in pH from initial to final stages and stabilization at 9 in aerobic composting due to decomposition and release of NH_3.

Total dissolved salts

TDS at final stage ranged between 1.71 (G_1) and 2.04 (G_2) ppt during winter season and 1.62 (G_3) and 2.82 (G_1) during summer season (Table 8). TDS varied significantly (p<0.05) between different seasons and stages of composting (Kumar *et al*. 2007). There was a steady increase in TDS from primary to secondary stage of composting (Zhang and He 2006). Bharathy *et al.* (2012), Sakthivadivu *et al.* (2015) observed a significant (p<0.05) increase in the TDS content in the finished compost.

Electrical conductivity

The presence of different ions of calcium, magnesium, sulfur, sodium, chlorine determines its electrical conductivity (EC). At the end of secondary stage the EC recorded was 2.89 (G_3) and 2.26 (G_1) mS/cm during winter and 4.07 (G_1) and 2.71 (G_2) mS/cm during summer seasons (Table 9). Significant effect of seasons on EC was observed in treatment group G_1. The overall values suggested that the EC was significantly (p<0.05) reduced from primary to secondary stages of composting. The acceptable EC level for compost is >4.0 mS/cm (Rao and Pandey 1996). EC levels were within the range during both the seasons as (1.77 to 2.43 during winter and 2.39 to 2.55 during summer season) at primary stage and 2.26 to 2.89 during winter and 2.76 to 4.07 during summer season at the end of secondary stage. Comparable EC value of 2.2 mS/cm in dead bird compost was reported by Lawson and Keeling (1999), 3.5 mS/cm in fish offal compost by Laos *et al.* (2002), 3-4 mS/m in cattle slurry compost by Caceres *et al*. (2005) 1.27 to 3.62 mS/cm in poultry manure compost by Prasanthrajan (2004).

CONCLUSION

It was concluded that considerable chemical stability and maturity in the final product of compost developed from poultry waste was attained for its further utilization as bio-manure. However no individual effect of different group combinations was observed in the composting process.

REFERENCES

Abdelhamid MT, Horiuchi T, Oba S (2004) Composting of rice straw with oil seed rape cake and poultry manure and its effect on Faba bean (*Viciafaba*) growth and soil properties. *Bioresour Technol* 91 (2) : 183—189.

Allison LE (1965) Organic carbon : In : Black CA, Evans DD, White JL, Ensiminger LE, Clark FE, Dinauer RC (eds). Methods of soil analysis, Part 2 : Chemical and microbiological properties. SSSA, Madison, WI, pp 367—378.

Anonymous (2021) Annual Report of Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Govt of India, pp 14.

AOAC (2005) Official Methods of Analysis, Association of Official Analytical Chemists, 15th ed. Washington, DC.

APHA (American Public Health Association) (1995) Standard methods for the examination of water and waste water. 19th edn. APHA, Washington, DC, USA.

Bharathy N, Sakthivadivu R, Sivakumar K, Kumar RS V (2012) Disposal and utilization of broiler slaughter waste by composting. *Vet World* 5 (6) : 359—361.

Bolan NS, Szogi AA, Chuasavathi TB, Seshadri MJ, Rothrock JR, Panneerselvam P (2010) Uses and management of poultry litter. *World's Poul Sci J* 66 (4) : 673—698.

Caceres R, Flotats X, Marfa O (2005) Changes in the chemical and physico-chemical properties of the solid fraction of cattle slurry during composting using different aeration strategies. *Waste Manag* 3 (2) : 212—231.

Cekmecelloglu D, Demirci A, Graves RE,Davitt NH (2004) Optimization of windrow food waste composting to inactivate pathogenic microorganisms. ASAE/CSAE Annual International Meeting, August 1-4; Fairmont Chateau Laurier, The Westin, Government Center Ottawa, Ontario, Canada.

Das KC, Minkara MY, Melear ND, Tollner EW (2002) Effect of poultry litter amendment on hatchery waste composting. *J Appl Poul Res* 11 (2) : 282—290.

Donald J, Blake JP, Tucker K, Harkins D (1996) Minicomposters in poultry production. Alabama Cooperative Extension System, ANR-804, pp 7—9.

Gwyther CL, Williams AP, Golyshin PN, Edwards-Jones G *et al.* (2012) The environmental and biosecurity characteristics of livestock carcass disposal methods : A review. *Waste Manag* 31 (4) : 767—778.

Huang GF, Wong JWC, Wu QT, Nagar BB (2004) Effect of C/N on composting of pig manure with saw dust. *Waste Manag* 24 (2) : 805—813.

Hutchinson M, Seekins B (2008) Safe Disposal of Backyard Poultry Mortalities. University of Maine Cooperative Extension, pp 21—23.

Kumar VRS, Sivakumar K, Purushothamum MR (2007) Chemical changes during composting of dead birds with cage layer manure. *J Appl Sci Res* 3 (10) : 1100—1104.

Langston J, Carman D, Van Devender K, Boles Jr, JC (2002) Disposal of swine carcasses in Arkansas (MP397-5M-9-97N). Little Rock, Arkansas: Cooperative Extension Service, University of Arkansas.

Lawson MJ, Keeling AA (1999) Production and physical characteristics of composted poultry carcasses. *British Poul Sci* 40 (3) : 706—708.

Mahimairaja S, Bolan NS, Hedley MJ, Macgregor (1994) Losses and transformation of nitrogen during composting of poultry manure with different amendments: An incubation experiment. *Bioresour Technol* 47 (2) : 265—273.

McCaskey TA (1994) Dead bird composting.Final report for contract USDA-43-2D81-1-561, Auburn University, pp 27.

Prasanthrajan (2004) Development and evaluation of poultry waste bioconversion techniques for composting and its effect on soil and crop ecosystem. PhD thesis. Submitted to Tamil Nadu Agricultural University, Coimbatore, India, pp 203.

Rodriguez EG, Vazquez M, Ravina MD (2003) Dynamic of the co-composting of barley waste with liquid poultry manure. *J Sci Food Agric* 83 (1) : 166—172.

Sakthivadivu R, Sivakumar K, Kumar VRS, Natarajan A (2015) Chemical changes during composting of poultrywaste with coirpith waste and sugarcane top. *Int J Sci Environ Technol* 4 (1) : 40 —49.

Sivakumar K, Kumar VRS, Mohamed Amanullah M (2007) Composting of poultry carcass with farm yard manure in summer. *Res J Agric Biol Sci* 3 (5) : 356—361.

Sivakumar K, Kumar VRS, Natarajan A, Ramesh V, Prakash Ananda, Singh A (2008) Effect of season on dead bird disposal by aerobic composting with farm yard manure. *Ind Vet J* 85 (1) : 963—966.

Snedecor GW, Cochran WG (1994) Statistical methods. 8th edn. Iowa State Press, Ames, Iowa, USA, pp 254—268.

Tiquia SM, Tam NFY (2002) Characterization and composting of poultry liter in forced-aeration piles. *Proc Biochem* 37 (3) : 869—880.

Tiquia SM, Tam NFY, Hodgkiss IJ (1998) Changes in chemical properties during composting of spent pig liter at different moisture contents. *Agric Ecosyst Environ* 67 (1) : 79—89.

USDA-NRCS (2003) United States Department of Agriculture, Natural Resources Conservation Service, Conservation practice standard. *Composting Facility* 317 : 21—30.

Vuorinen AH,Saharinen MH (1997) Evolution of microbiological and chemical parameters during manure and straw co-composting in a drum composting system. *Agric Ecosyst Environ* 66 (3) : 19—29.