

Development of eco-friendly bio-fertilizer using feather compost

Sreenivasa Nayaka¹ and GM Vidyasagar^{2*}

Department of Botany, Gulbarga University, Gulbarga - 585 106, Karnataka, India

Received for publication: April 06, 2013; Accepted: May 13, 2013.

Abstract: The present study, focused on preparation of feather compost, characterization and effect of feather compost in fields. During the study period, *Streptomyces albus* was used to degrade the feather material. The degradation of chicken feathers was observed through morphological and microscopic level changes at regular intervals. During the compost preparation the temperature were recorded on 8th day (51.1^oC) and decreased trend was observed up to 14th day (29.5^oC) respectively, while increase trend in pH was noticed up to 8th day (8.2) and low pH was observed on 14th day (7.34). The moisture content was also shown wide fluctuation during the compost preparation. The highest moisture content on 10th day (61%) and sudden decreased moisture content in feather compost at 14th day (29.5%). The nutrient composition of feather compost results indicate that C (43.26%), N (6.94%), H (6.72%), P (0.063%), Fe (3.74%), Mn (0.95%), Ca (0.42%), SO₄ (0.084%), and Mg (0.007%) respectively. The field experiments were conducted with up to 90 days with comparison of different composts on growth of plants. The results indicate that the impact of feather compost treated plants showed maximum growth than the mulberry, control, cow dung, and urea. Therefore, the obtained value-feather compost showed macro and micronutrients in C, N, H, P, Fe, Mn, Ca, SO₄ and Mg could be used for effective for preparation of feather compost or soil amendments, in growth of the plants. To our knowledge, this is first report of using eco-friendly bio fertilizer feather compost. The proposed ecologically safe method is simple and economically viable thus applicable on agricultural fields.

Keywords: Feather degradation, *Streptomyces albus*, Compost, Bio fertilizer.

Introduction

Keratin as structural component of the integument of most birds, mammals, reptiles and amphibians, occurs commonly in nature and hence arises as a waste product in variety of ways. The disposal of large quantities of keratinous wastes from leather industries, agricultural industry or from a slaughterhouse by dumping piles of unusable animal hides in natural biological zone may lead to a severe environmental impact. The growing concern for environmental production coupled with the urgent search for potentially useful materials has led to the development of a number of technologies for the bioconversion of keratinous waste into recoverable products [1-2]. Biodegradation of intensively formed animal waste is now viewed as an alternative avenue for creating a viable end product with visible benefits to the primary producers in environmental and economic management strategies [3]. A combination of specific waste products and process producers via biological methods would lead not only to an improved consumable product, but also to consumer confidence in waste management practices.

Considering their high content of useful compounds, animal wastes could have a great potential for many applications. For this purpose, destruction of the rigid keratin structure is necessary. Degradation of keratin wastes a material is usually achieved by thermal hydrolysis in dilute acid or base, or enzymatic digestion by specific keratinases [4]. At present, the poultry industry manages waste (carcass, feather, hair and manure) through several disposal methods. Carcass waste is generally rendered in to bone and meat meal [5]. Feather waste is also rendered by either steam or chemical treatment to produce feather meal [6]. The manure is stockpiled to be solid in either untreated or treated forms to consumers as fertilizer or disposed as landfill. Disposal pits and trench burial incineration are also common methods used for disposal of disease mortality [5]. In each of these processes, however, the outcome has limitations with respect to quality, cost efficiency as well as environmental management [3]. The hair, feather and sheep wool contain approximately 90% keratin and are used in composting. It is

*Corresponding Author:

Dr. G.M. Vidyasagar,

Professor, Department of Botany,

Gulbarga University, Gulbarga, Karnataka, India.

gmvidyasagar@gmail.com, sreenivas.n6@gmail.com

one of the more economical and environmentally safe methods of recycling the feather [7]. The actinomycetes act as natural scavenger in nature play an important role in degrading keratinous waste and the production of keratinase. Actinomycetes are widely distributed in nature and have major role in the degradation of organic matters. Investigation of feather degradation began in 1950s on alpha keratin using keratinolytic *Bacillus* sp. and *Microsporium canis* [8] and also actinomycetes reported to break down feathers such as *streptomyces pactum* and *streptomyces albidoflavus* [9-10]. Therefore, the present study is aimed to develop an eco-friendly process of feather composting using indigenous actinomycetes to replace the currently used environmentally hazardous ones.

Materials and Methods

Preparation of feather compost:

Chicken feather was washed with tap water and detergent followed by defatting (Chloroform: methanol) [11]. After making them fat free, the solvent was evaporated, washed three to four times with distilled water and air-dried. In the preparation of feather compost the slight changes, wheat husk was used and mixed uniformly with small pieces of feather in 1:1 ratio (wheat husk: feather) [12] then, it was placed in a plastic bin. This mixture was autoclaved at 120°C for 15 min. The preparation was then inoculated with 50 ml aqueous spore suspension (7×10^7 spore/ml) of *Streptomyces albus* prepared from 7 days old culture grown on SCA medium. Feather compost preparations were kept for degradation for 14 days, respectively. The pots were covered with polythene bag to avoid contamination and were regularly moistened with sterilized water to maintain the moisture content of about 60%. The degradation of feather was examined at regular intervals.

Light microscopy:

The growth of *Streptomyces albus* on feather during composting was carefully observed under light microscope with every 2 days of intervals for about 14 days. For microscopic observation, whole feather pieces were selected and stained with silver staining and examined under 45X resolution.

Physico-chemical analysis of feather compost:

In the plastic bin of feather compost sample was taken and recorded the temperature, pH and moisture content at 2 days intervals.

Temperature and pH determination:

The temperature was continuously monitored by a Salmoiraghi Co. thermometer (Model 17506). Process temperature was determined every two days intervals by inserting the thermometer 25 cm deep in three different locations into the composting feather materials in the plastic bin. The determination of pH was performed at every two days intervals by taking samples from 3 different locations of composting material with the help of long forceps [13]. The samples were suspended in water (w/v, 1:10) and shaken for 30 min on rotary shaker and the pH of the supernatant was determined using a pH meter (Scientific Instrument Co, model 900/3).

Moisture content:

The moisture content was expressed based on wet weight, which gives the percentage of original wet weight sample containing water [14]. Here initial weight of the compost was measured and final weight of the compost after drying is also determined, there by water loss can be calculated, which indicates the original moisture content of the compost. The moisture content was determined based on wet or dry weight by the following formula.

$$\text{Moisture content (\% wet basis)} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight} - \text{container}} \times 100$$

Determination of total Nutritional composition of composts:

The Carbon, Hydrogen and Nitrogen present in the feather compost were analyzed with the help of FLASH EA 111 SERIES CHN (Hyderabad). The total percentage of both micro and macro nutrients such as, P, K, Ca, Mn, SO₄, Zn, Cu, Mo, Fe, Bo, Cl and Mg were determined (Biogenic Lab, Hubli). Further, electrical conductivity and salinity of the samples were also determined [15].

Effect of feather compost on growth:

In the present investigation assess the effectiveness of feather compost and compared to three types of composts were taken and analyzed. These were Mulberry,

cow dung and urea fertilizer and control without fertilizer. The compost samples were collected in polythene bags and were brought to the laboratory for investigation. The soil aggregates were broken up for grinding with pestle and the mortar and the samples were spread for drying. After drying, the soils were passed through 2mm stainless steel or plastic sieve. 5 kg of soil per pot was supplemented with 500gm feather compost, green manure of mulberry and cow dung 50 g [16], composts separately along with urea (70 mg/kg) in one pot as a chemical fertilizer [17]. *C. roseus* seeds were collected from the Botanical Garden of Gulbarga University premises and surface sterilized with 0.01% mercuric chloride (HgCl₂) solution for 5 min with frequent shaking and then thoroughly washed with de-ionised water. 5 seeds were sown per pot including control pot, where no compost was supplemented. The pots were watered every day to keep water-holding capacity of soil up to 60%. The Further investigation was carried in the plants were grown in the green house, Department of Botany, Gulbarga University, Gulbarga. The growth was measured at 15 days intervals from 7th day to 90th day. To assess the effectiveness of feather compost in pot experiments were carried out in triplicate.

Results and Discussion

Preparation of feather compost:

During composting process the keratinous materials were observed under light microscope for morphological changes occurred due to the colonization of *Streptomyces albus* on feather and depicted in (Fig 1) respectively.

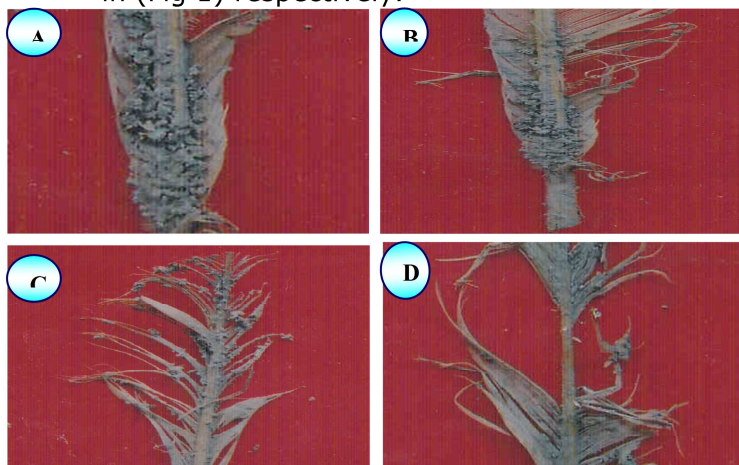


Fig.1: Association of *Streptomyces albus* with feather material in the inoculated vessel. The figure shows feather structures were extremely pliable (A to D).

Streptomyces albus gradually eroded feather surface indicating that the keratin molecule was being digested and shows growth of the feather unit. Damage to feathers including delaminating of the rachis was evident on 8th day and *Streptomyces* sp was tightly associated with the feather in the inoculated vessel (Fig 2).

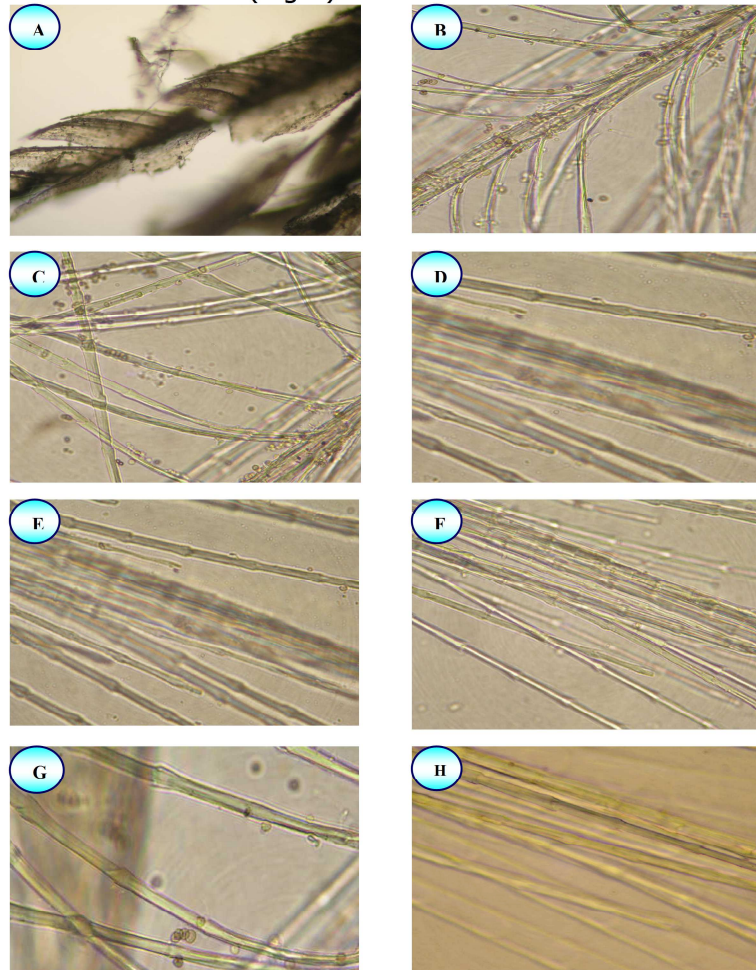


Fig.2: Daily examination under light microscope shows entire damage of feathers including of the delamination of the rachis and *Streptomyces albus* tightly associated with the feather structure up to 14th day (A to H)



Fig.3: The final compost of feather

The feather residue had putty-like consistency and any recognizable feather structures were extremely pliable. The microscopic observations of the inoculated feathers showed an extensive degradation of keratin. The final compost obtained after degradation is represented in (Fig 3).

The practical use of keratinase producing microorganisms is being explored in applied microbiology where there is great need for active degraders of feather keratin. Composting trials demonstrated that bioreactors of compost materials of straw, chicken feathers and poultry litter will, when inoculated with active feather degrading bacteria, enhance keratin utilization [18]. Composting of residual feather seems to require the presence of a co-substrate for composting and nitrogen conservation. Recent works have been published on the biodegradation of animal wastes using specific microbial populations [19-20] obtained 50% carbon conversion when composting the wastes from poultry industry with high nitrogen content. This indicated high biodegradability of protein of animal origin under composting conditions. However, in the present work specific actinomycetes used in enhancing the keratin degradation and it was very effective.

Physico-chemical analysis of feather compost:

Change in Temperature: A wide range of temperature was found to be essential during the process of feather compost were carefully monitored and change in temperature was noticed as shown in (Fig 4) respectively. In feather compost, there was a peak attainment in composting temperature of about 51.1°C on 8th day, remains stabilized until 10th day and there is a quick drop in temperature on 10th day of about 42.8°C as available carbon was utilized. This peak temperature remained/stabilized up to 8th day and on 10th day there was a quick drop in temperature indicating the depleting level of organic matters and enzyme production by *Streptomyces albus*. This gradual decrease in temperature continued and on 14th day the final temperature recorded in the compost was 29.5°C. The nature and population size of microorganism in feather composting depend on number of factors, one of which is temperature. Similar variations in temperature levels were found during keratin degrading experiments, carried

out in composting piles for the development of environmental friendly bio-fertilizer [12] Lyndall *et al.*, 2004). Composting process is usually carried out within the thermophilic range of temperature permitting the disinfection of the final product [21].

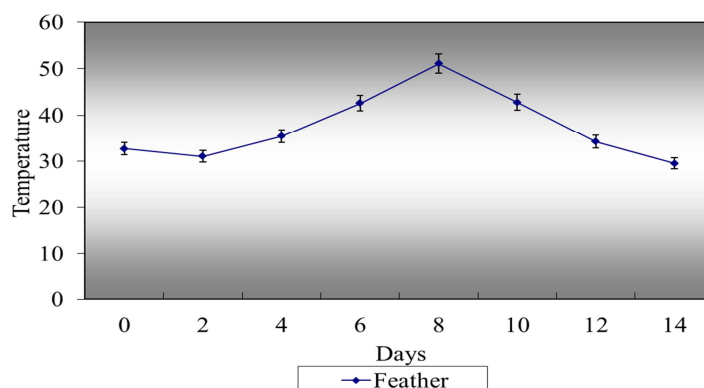


Fig.4: Final temperature in feather compost

Change in pH: The pH value in feather compost was decreased slightly in alkaline range during the processing period (Fig 5). Initial pH value in feather compost was neutral (pH 7.0). There was a peak attainment of pH 8.2 on 8th day indicates the optimum pH for composting activity by *Streptomyces albus*. It was also observed that there was a gradual decrease in pH after peak attainment. Interestingly during the process of composting, a wide range of pH changes. This is due to *Streptomyces albus* getting rid of excess nitrogen by intensive delamination and ammonia production. Any further increase in pH is limited by volatility of ammonia, which escapes in the form of gas [22]. Similar observations are noticed [12], who have composted chest nut burr/ leaf litter and poultry manure. Same findings are agreeable with have conducted studies on the digestion of keratinaceous waste [9].

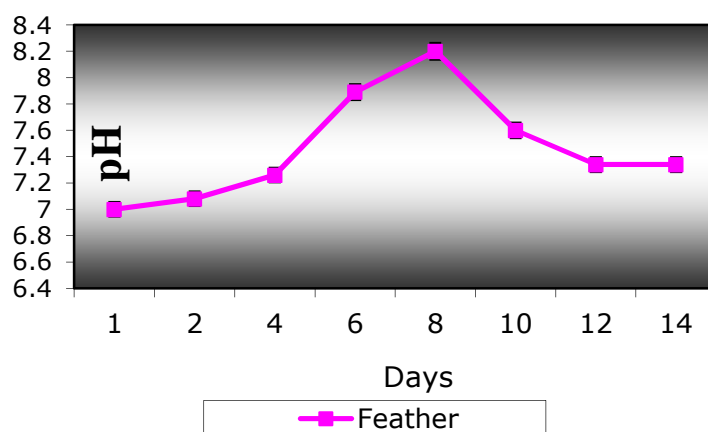


Fig.5: The final pH of feather compost

Change in Moisture Content:

The moisture content of the compost was recorded during the process of composting and variation in the moisture content was observed at every sampling. The moisture content of feather composting was less, which indicated rapid loss in moisture during feather degradation. During initial phases of composting (39.5%) and next two days the moisture was raised (57.5%) by nearly 18% and dropped in next two days. It went up by 23% again in 2 days and drastically lost 33% of moisture from 12th day onwards (Fig 6). Throughout the composting process of feather, the moisture loss were observed, mainly due to metabolic activity of organisms that generates heat energy or due to environmental conditions such as, over ventilation, [23]. The end of composting in feather observed decrease in moisture content of about 46%, [24] reported similar findings on the removal of 0.78 g water/g dry weight of starting material. Compost samples with normal non-moisture content may be biologically impaired, low moisture reduces respiration whereas, high moisture content increases anaerobic condition [25]. It was also reported that drop in moisture content below 30% slowed down the biological reactions. So, 50-60% of moisture content is the optimum range for the process of composting [26].

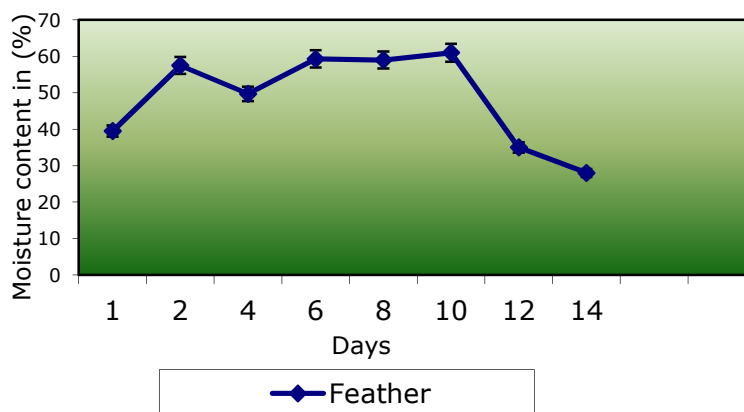


Fig.6: The analysis of Moisture content in Feather compost

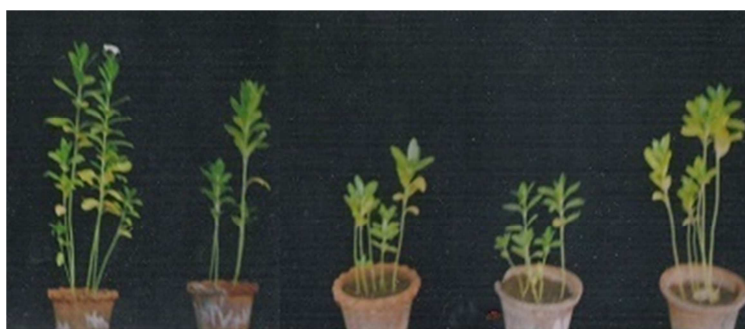
Determination of total nutritional composition of feather compost:

The end products of feather composting were analyzed and percentage of macro and micro nutrients such as, C, H, N, P, K, Ca, Mn, SO₄, Zn, Cu, Mo, Fe, Bo, Cl, Mg and electrical conductivity contents were determined (Tabl 1). The feather compost

showed macro and micronutrients in C (43.26%), N (6.94%), H (6.72%), P (0.063%), Fe (3.74%), Mn (0.95%), Ca (0.42%), SO₄ (0.084), and Mg (0.007%) order. The end product analysis of feather compost revealed the presence of all kinds of primary, secondary and trace or micro-nutrients in varying proportions. Nitrogen is one of the important primary nutrient, serves as an essential component of amino acid, the basic structural units of proteins. As a component of nucleic acids, it is required for plant cell division and reproduction. In the present investigation, reduction in the total nitrogen content from 8.37% to 6.94% was observed; this indicates the free available nitrogen for the growth of plants. Here the significant decrease in the nitrogen content of the compost was resultant of ammonification (NH⁴⁺) process, which converted a fraction of organic nitrogen in to NH₃ and NH⁴⁺ ions [27]). Phosphorus, an important primary nutrient supplies energy for growth and maintenance. It serves as an integral component of cell membranes, their by involved in selective permeability of cell membrane and also a part of plant's energy transfer mechanism (high energy phosphate ATP) [28]. In the current study, feather compost contains 0.063% of phosphorus. The processing of compost results in slight increase in pH. In such alkaline conditions, the availability of phosphorus to plants gets increased. Potassium as primary nutrient activates certain enzymes in plants and regulates the opening and closing of stomata, which regulates airflow and in water transpiration out of the leaves. In the present study, feather composts contain 6 ppm of exchangeable potassium in the form of K⁺ attached to molecules of the compost [28]. Wool and hair wastes has nutrient source (N, P, K and S) for crops and evaluate their potential to improve soil biology and chemical properties [6]. Though, the micronutrients are required in very negligible amounts, they surely affect the growth. Most of the micronutrients are present either in ionic forms as chelated EDTA in their metabolism [28]. In the current study, micronutrients such as, Zn, Fe, Mn and Cl were present in negligible amounts, whereas Cu, Bo, were totally absent. Based on this view, feather compost was considered as important compost for agriculture fields.

Table.1: Some physico-chemical properties of feather compost

Parameters	Feather compost
Total C %	43.26
Total N%	6.94
Total pH	8.20
Electrical conductivity	5.82
C/N ratio	6.54
Salinity	2.87
Phosphorous (P)	0.063%
Potassium (K)	6.00ppm
Calcium (Ca)	4026 %
Manganase (Mn)	0.95 %
Sulphate (SO ₄)	0.084%
Zinc (Zn)	< 0.1%
Copper (Cu)	NIL
Molybdenium (Mo)	NIL
Iron (Fe)	3.74%
Boron (Bo)	NIL
Chlorine (Cl)	0.42%
Magnesium (Mg)	0.007 %

**Fig.8:** Growth of *C. roseus* on 90th day in different composts formulations.

(A) Feather compost; (B) Mulberry compost; (C) Cow dung compost; (D) Urea compost and (E) Control.

Effect of feather compost on growth:

The effect of compost on plant growth was clearly established as a significant difference in the growth was observed among control and Composts treated Plants (Fig 8). We observe day by day a gradual increase feather compost potted plant, growth in all the pots containing different compost amended soil. The effect of different compost on the growth of the plant was observed in significantly different. The trend was observed feather compost > mulberry > control > cow dung > urea. This could have resulted in enhanced decomposition of the organic forms of N and P, hence increased availability of N and P. similar resulted were reported by [29-30] and observed that poultry manure had highest effect of on soil available levels of N and P compared to other animal manures. Comparative effectiveness of animal manures on soil chemical properties, yield and root growth of *Amaranthus* (*Amaranthus cruentus* L.) [15], though, the micronutrients are

required in very negligible amounts, they surely affect the growth [12]. Most of the micronutrients are present either in ionic forms as chelated EDTA in their metabolism.

Conclusion

The method used in this study might present an alternative to on farm composting to produce a community orientated and environmentally friendly facility. This study is useful in rapid removal of the recalcitrant feather content with the release of valuable by products acceptable in land use applications. Reduction in the number of pathogenic bacteria and fungi is another significant achievement of the feather composting. Feather was successfully composted if the right conditions are found, as in case of mixture with husk treatments adequate initial microbial population or inoculums. And also co-composting of feather: husk mixtures produced stable and crude products with high nitrogen content. These characteristics increase the value of feather waste in agriculture fields.

References

1. Shih JCH, Recent development in poultry waste digestion and feather utilization a review, Poultry Science, 1993, 72: 1617-1620.
2. Matsumoto T, Fungal diseases in dermatology. In principal and practice of clinical mycology (Eds.). Kibbler, CC, Mackenzie, DW, Odds, FCJ, New York: J. Wiley and Sons Ltd.1996, 103-129.
3. Kim WK, Patterson PH, Nutritional value of enzyme- or sodium hydroxide-treated feathers from dead hens, Poultry, Sci, 2000, 79: 528-534.
4. Jou CJG, Chen YS, Wang HP, Lin KS, Tai HS, Hydrolytic dissociation of hog-hair by microwave radiation, Bioresource, Technology, 1999, 70: 111-113.
5. Environmental protection agency: Review on farm disposed treatment risks and the potential for recycling of wastes produced form commercial chicken farms and process. Consolation draft. Produced for the environment protection. Agency by PPK, Environment and Infra structure pvt Ltd. 1999.
6. Valtcho D, Zheljazkov, Assessment of wool waste and hair waste as soil amendment and nutrient source, J, Environ, Qual, 2005, 34: 2310-2317.
7. Ichida JM, Krizova L, Lefevre CA, Keener HM, Elwell, DL, Burt EH, Bacterial inoculum enhances keratin degradation and biofilm formation in poultry compost, J, Microbiol, Methods, 2001, 47(2): 199-208.
8. Daniels, G, The digestion of human hair keratin by *Microsporium canis Bodin*, J, Gen, Microbiol, 1953, 8:289-294.

9. Ignatova Z, Gousterova A, Spassov G, Nedkov P, Isolation and partial characterization of extracellular keratinase from wool degrading thermophilic actinomycetes strain *Thermoactinomyces candidus*, Can, J, Microbiol, 1999, 45: 217-222.
10. Bressollier P, Letourneau F, Urdaci M, Verneuil B, Purification and characterization of a keratinolytic serine proteinase from *Streptomyces albidoflavus*, J, Applied and Environmental Microbiology, 1999, 65: 2570-6.
11. Sangeeta Lal, Ram C, Rahak, Suresh K, Hasiju, In vitro degradation of keratin by 2 sps of *Bacillus*, J, Appl, Microbiol, 1999,48: 283-287.
12. Lyndall M, Pettett, Ipek, Kurtboke, D, Development of an environmentally friendly biofertilizer with keratin degrading and antibiotic producing actinomycetes, Actinomycetologia, 2004, 18: 34-42.
13. Taiwo, Oso, Manure sampling for nutrient analysis: variability and sampling efficiency, J, Environ, Qual, 2004, 30: 1432-1437.
14. National engineering hand book, United States Department of Agricultural National Resources Conservation Service (210-VI-NEH), 2000, 85-109.
15. Maerere AP, Kimbi GG, Nonga DLM, Comparative effectiveness of animal manures on soil chemical properties yield and root growth of amaranthus (*Amaranthus cruentus* L.) AJST, 2001, 1:14-21.
16. Muhammad S, Amusa NA, In-vitro inhibition of growth of some seedling blight inducing pathogens by compost-inhabiting microbes, African Journal of Biotechnology, 2003, 2(6): 161-164.
17. Wu P, Zong-wen L, Study on structural characteristics of pillared clay modified phosphate fertilizers and its increase efficiency mechanism, Bulletin of Mineralogy petrology and geochemistry, 2004, 6(3): 195-201.
18. Ichidia JM, Krizova L, Lefevre CA, Keener HM, Elwell, DL, Burttt EH, Bacterial inoculum enhances keratin degradation and biofilm formation in poultry compost, J, Microbiol, Methods, 2001, 47(2): 199-208.
19. Gushterova A, Braikova, D, Goshev, I, Christov, P, Tishinov, K, Vasileva-Tonkova, E, Haertle, T, Nedkov, P, Degradation of keratin and collagen containing wasted by newly isolated thermoactinomycetes by alkaline hydrolysis, Letters, Appl. Microbiol, 2005, 40: 335-340.
20. Tiquia SM, Ichida JM, Keener HM, Elwell DL, Burttt EH, Michel FC, Bacterial community profiles on feathers during composting as determined by terminal restriction fragment length polymorphism analysis of 16S rDNA genes, Appl, Microbiol, Biotechnology, 2005, 67: 412-419.
21. Salter C, Cuyler A, Pathogen reduction in food residuals composting, Biocycle, 2003, 44: 42-50.
22. Kunert J, Biochemical mechanism of keratin degradation by the actinomycetes *Strptomycetes*, J, Basic Microbiol, 2000, 21: 314-316.
23. Hogan JA, Miller FC, Finstein MS, Physical modeling of the composting ecosystem, Appli, Environ, Microbiol, 1989, 55: 1082-1092.
24. Hayashida SN, Nanri Y, Teramoto T, Nishimoto K, Ohta Miyaguchi M, Identification and characteristics of actinomycetes useful for semicontinuous treatment of domestic animal faeces, Appl, Environ, Microbiol, 1988, 54: 2058-2063.
25. Brinton WF, Compost quality standards and guidelines, Wood End Research laboratory. Inc, New York State Association of Recyclers, 2000, (<http://compost.css.cornell.edu/Brinton.pdf>).
26. Villacastillo, Josi, Inoculation composted pink bark with beneficial organisms to make a disease suppressive compost for container production in Mexican for forest nurseries, J, Native Plant, 2004, 3: 181-185.
27. Tiquia SM, Evaluation of organic matter and nutrient composition of partially decomposed and composed and composted spent pig litter, Environ, Technol, 2002, 24: 97-107.
28. McWilliams D, Identifying nutrient deficiencies for efficient plant growth and water use.co-operative extensive services college of agriculture and home economics (www.cahe.nmsu.edu), 2003.
29. Bomke AA, Lavkulich LM, Composition of poultry manure and effect of heavy application on soil chemical properties and plant nutrition. British Colombia, Canada, In: Managing Livestock Wastes, 1975, 611-617.
30. Schegel AJ, Effect of composted manure on soil chemical properties and nitrogen use by grain sorghum, Journal of Production Agriculture, 1992, 5:153-157.

Source of support: Nil

Conflict of interest: None Declared