Production and evaluation of Bokashi compost from Poultry by-products

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Abstract

Poultry waste poses serious environmental concerns, necessitating sustainable management strategies. The present study evaluated bokashi composting as a rapid method for converting poultry wastes, including cage litter, deep litter, and poultry offals, into nutrient-rich organic manure. Sixteen airtight bokashi bins were arranged into four treatment groups: G1 (cage litter + premix), G2 (poultry offals + premix), G3 (deep litter + premix), and G4 (combined wastes + premix), and composted anaerobically for five weeks. Significant ($P \leq 0.05$) physical changes occurred during composting. The highest weight reduction (10.13%) and volume reduction (27.97%) were recorded in G2, followed by G4 (7.20% and 25.76%, respectively). Moisture content declined markedly in G1 and G4, reaching 33.50% and 34.25%, respectively, while G2 retained the highest final moisture (66.55%). Compost fermentation resulted in a significant ($P \leq 0.05$) decline in pH, with the lowest final values observed in G1 (4.27) and G2 (3.95), accompanied by an increase in electrical conductivity, particularly in G2 (0.56 mS/cm), indicating enhanced nutrient solubilisation. Total organic matter and total organic carbon decreased across all treatments, with the greatest reductions observed in G2. In contrast, nutrient enrichment occurred during composting, with the highest final nitrogen recorded in G4 (2.06%), phosphorus in G2 (4.58%), and potassium in G3 (2.09%). Microbial analysis revealed increased lactic acid bacteria counts, highest in G1 (6.07 log cfu/g), along with reduced coliform populations in all groups. Application of bokashi compost improved soil fertility, with the highest soil nitrogen in G2 (1.33%) and the highest phosphorus (0.47%) and potassium (1.29%) in G4. Spinach seed germination was highest in G1 (91.25%), whereas G3 showed comparatively lower germination (66.88%). Overall, bokashi composting proved to be a rapid, nutrient-conserving, and environmentally sustainable approach for transforming poultry by-products and wastes into organic manure suitable for agriculture.

Keywords: Bokashi composting, Poultry waste, Poultry offals, Organic manure

Introduction

Worldwide poultry numbers exceed 33 billion, producing more than 90 million tonnes of waste each year (FAO, 2023). Improper disposal of this manure emits potent greenhouse gases, chiefly methane and nitrous oxide, both with high global warming potential, and also creates issues such as foul odours, pathogen spread, and nutrient leaching (IPCC, 2021). The rapid growth of poultry production combined with insufficient waste treatment infrastructure makes it urgent to adopt sustainable management practices that reduce pollution and recover nutrients (Hemavarshini *et al.*, 2025). India is currently generating approximately 3.30 million tonnes of poultry waste annually (Das *et al.*, 2025). Poultry abattoirs generate large quantities of waste, with around 32.5-37.0% of live chicken weight becoming waste after slaughter (Roy et al., 2025). The waste typically comprises 57.37% feathers and skin, 20.35% intestines, 14.8% legs, and less than 1% other parts (Mozhiarasi and Natarajan, 2022). Feathers alone constitute about 5-10% of the live weight of a chicken, representing a significant keratin-rich by-product requiring proper disposal (Safari *et al.*, 2024). Poultry waste contains high levels of nitrogen, phosphorus, potassium, calcium, and organic carbon that enhance microbial activity and soil fertility, but inadequate decomposition results in nutrient loss and odor generation (Poojitha et al., 2024, Das *et al.*, 2025). Due to high moisture and a low C:N ratio, poultry waste readily undergoes anaerobic decomposition and ammonia emission when poorly managed. Traditional poultry waste disposal methods, including landfilling and incineration, are environmentally unsustainable, as landfilling promotes leachate formation and methane release, whereas incineration is costly and may emit hazardous gases such as dioxins and furans (Zhang *et al.*, 2023). These limitations necessitate sustainable approaches such as bokashi composting that enable efficient waste stabilisation and nutrient recovery. Bokashi differs from conventional composting mainly because it is a fermentation based process carried out under anaerobic conditions, using beneficial microorganisms such as lactic acid bacteria and yeasts, whereas conventional composting mainly depends on aerobic microbial decomposition in the presence of oxygen (Lew *et al.*, 2021). Bokashi is also generally faster and helps in retaining nutrients in the fermented material. Bokashi composting has emerged as an effective approach for managing poultry by-products such as feathers, bones, and offals through fermentation using Effective Microorganisms (EM), a consortium of beneficial microbes including lactic acid bacteria, yeasts, and phototrophic bacteria (Saputra *et al.*, 2025). Bokashi composting involves anaerobic fermentation of organic waste with inoculated bran for two to three weeks (Lew *et al.*, 2021). Lactic acid bacteria dominate bokashi fermentation and produce organic acids that lower pH, while bokashi fermentation can also reduce gaseous nitrogen losses, particularly ammonia emissions (Kujala and Kinnunen, 2026). Despite its success with plant-based wastes, bokashi composting remains less explored for poultry by-products, which demand specialized microbial adaptation owing to their high protein and lipid content. Considering the limited work on bokashi composting for poultry waste, the present study was designed to evaluate its potential for efficient disposal and utilization of poultry by-products.

Material and methods

Location of the study The present study was carried out at Poultry unit of the Division of Livestock Production and Management (LPM), Faculty of Veterinary Sciences and Animal Husbandry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Shuhama (Jammu and Kashmir).

Experimental materials

Poultry litter and poultry offals Poultry waste substrates, including cage litter, deep litter, and poultry offals, were utilized for bokashi composting. Cage and deep litter were obtained from the poultry farm of the Division of LPM (SKUAST-K), and poultry offals were sourced from local poultry slaughter outlets.

Composting containers Bokashi composting was carried out in airtight bokashi bins with a capacity of 15 litres.

Experimental design A total of sixteen (16) plastic bokashi bins (Fig. 1) were used in the experiment, with four (4) replicates assigned to each treatment group. Poultry waste (cage litter, deep litter, and offals) was mixed and placed in bokashi bins in successive layers, each uniformly sprinkled with 100 grams of bokashi bran (it is bran inoculated with Effective Microorganisms, molasses and water, used to initiate fermentation of organic waste), which were arranged according to the treatment plan described in Table 1 (Fig. 2 and 3). The mixing process was repeated until the bins were filled (total 12 kg), and liquid effluent was drained every 2-3 days during fermentation. Initial moisture content was maintained at approximately 40-50%. Bokashi composting was carried out under anaerobic conditions in the bokashi bins for a period of 5 weeks.

Sample collection Compost samples were collected at the initial and final stages of bokashi composting. Representative samples were obtained from different locations within each bin. Samples for moisture analysis were stored in airtight polythene bags and immediately transported for analysis, while additional sterile samples were sealed for further laboratory examinations.

Parameters studied

Physical parameters

Weight reduction (%) The total weight of composting substrates was measured before and after the composting process. Weight reduction (%) was determined based on the difference between initial and final weights.

Volume reduction (%) The volume of the composting material was recorded at the beginning and end of the composting process. Percentage volume reduction was calculated based on the difference between initial and final volumes.

Moisture reduction (%) To measure moisture content, composting samples were dried at 100ºC in a hot air oven for 24 hours (AOAC 2005). At initial and final stages, samples were promptly weighed, and the placed inside hot air oven to determine moisture levels.

Chemical parameters

pH: It was calculated by dipping the digital pH meter into an aqueous solution of 1/10 (w/v compost-water extract) following the procedure outlined by Tiquia and Tam (2002).

Electrical conductivity (Sm^{-1}): It was determined using a 1:10 (w/v) compost-water extract. The extract was measured with a digital electrical conductivity meter following the method described by Tiquia and Tam (2002).

Total dissolved salts (TDS, %): It was measured by dipping digital TDS meter inside an aqueous solution of 1/10 (w/v compost-water extract). Measurement was done using the method of (Tiquia and Tam, 2002).

Total organic matter (TOM, %): It was determined using the loss-on-ignition method described by Navarro *et al.* (1993). Samples were first oven dried at 105°C to constant weight and subsequently combusted in a muffle furnace at 430°C for 24 hours. It was calculated based on the percentage weight loss after ignition.

Total organic carbon (TOC, %): It was estimated following the method described by Allison (1965). Assuming organic matter contains 58% carbon; TOC (%) was calculated by dividing total organic matter by 1.724 or multiplying total organic matter by 0.58.

Total ash (%): It was determined according to the AOAC (2005) method. Samples were incinerated in a muffle furnace at 550-600°C for 1-5 hours until complete combustion of organic matter, leaving inorganic mineral residue. Total ash (%) was calculated based on loss on ignition, following the procedures described by Allison (1965).

Total nitrogen (%): AOAC (2005) was used for estimation of Nitrogen content at initial and final stage of composting.

End product maturity

Nitrogen (%): It was calculated at initial and final stages of experiment by using the method suggested by Jackson (1973).

Phosphorus (%): It was calculated at initial and final stages of experiment by using the method suggested by Jackson (1973).

Potassium (%): It was calculated at initial and final stages of experiment by using the method suggested by Jackson (1973).

Microbial analysis

Preparation of sample: On day 42, compost samples from each treatment were aseptically collected for microbial enumeration. One millilitre of sample was homogenized in 9 ml sterile normal saline, followed by serial ten-fold dilutions using 0.1 ml inoculums in 0.9 ml saline. All procedures were performed under a Class II bio-safety cabinet to ensure aseptic conditions.

Total coliform count: Total coliforms were enumerated using MacConkey agar. One millilitre of appropriate serial dilution was aseptically plated in sterile 100 mm Petri dishes, followed by addition of 10-15 ml molten MacConkey agar (45°C). After solidification, plates were incubated inverted at 37°C for 24-48 hours. Typical red-pink colonies were counted on plates containing 30-300 colonies, and results were expressed as $\log_{10}$ CFU/g after applying the dilution factor.

Lactic acid bacteria count: It was enumerated using De Man, Rogosa, and Sharpe (MRS) agar. Serial dilutions of the compost sample were prepared in sterile diluents. From the selected dilution, 1 ml was transferred to a sterile 100 mm petridish, and 10-15 ml of melted, cooled (45°C) MRS agar was poured and mixed by gentle rotation. After solidification, plates were incubated inverted at 37°C for 48-72 hours under anaerobic conditions. Creamy white colonies (0.5-2.0 mm) were counted on plates showing 30-300 colonies. The average colony count was multiplied by the dilution factor and expressed as $\log_{10}$ cfu/g.

Seed germination and vegetation: A seed germination and vegetation study was conducted using a 3:1 soil-to-bokashi compost ratio to assess its effect on soil fertility and plant growth, evaluating soil quality, germination rate, and vegetative growth compared to untreated soil.

Soil analysis: Soil samples from bokashi-treated and control plots were collected at the start and end of the experiment to assess changes in soil properties. The following parameters were recorded, such as, pH, organic matter content (%), nitrogen (%), phosphorus (%), and potassium (%).
Seed material: Spinach (*Spinacia oleracea*) seeds were used for the study.
Seed germination (%): Germination rate was determined by counting the number of seeds germinated at 7 and 14 days after sowing, and expressed as a percentage of the total seeds sown.
Statistical analysis: Statistical analysis was performed using one way analysis of variance (ANOVA) in IBM SPSS Statistics, and differences among group means were considered significant at the 5% probability level ($P \leq 0.05$) (version 30.0 IBM Corp., Armonk, NY, USA, 2023).

Results

Chemical properties of different ingredients used: Chemical properties of different ingredients used in the study are depicted in Table 2. The chemical composition of cage litter, deep litter, and poultry offals used for bokashi composting varied considerably. Moisture content was highest in poultry offals (76.06%) and lowest in deep litter (65.00%), while pH ranged from slightly acidic in poultry offals (6.86) to highly alkaline in deep litter (9.13). Electrical conductivity and total dissolved solids were generally low across all the ingredients. Poultry offals had the highest total organic matter (69.19%) and total organic carbon (40.90%), whereas deep litter had the highest total ash (34.50%). The C:N ratio was highest in cage litter (17.70) and lowest in poultry offals (13.08). Nitrogen content was slightly higher in deep litter (1.68%), phosphorus was highest in deep litter (3.70%), and potassium levels were relatively similar across all ingredients, indicating that each component contributes differently to the nutrient profile of bokashi compost.
Changes in weight and volume during composting: Weight and volume reductions during bokashi composting varied significantly ($P \leq 0.05$) among the different treatment groups as shown in Table 3. The highest weight reduction (%) was observed in G2 (10.13), followed by G4 (7.20), while G1 and G3 showed minimal reduction (~2.3). Volume reduction (%) was also greatest in G2 (27.97) and G4 (25.76), whereas G1 and G3 had lower reductions (14.60 and 13.49, respectively), indicating that poultry offals contributed most to physical breakdown during composting.
Moisture content, pH and electrical conductivity (EC) changes during composting: Moisture content of bokashi compost ingredients decreased significantly ($P \leq 0.05$) during composting, as shown in Table 3. G2 retained the highest final moisture (66.55%), while G1 and G4 showed the greatest reduction, reaching 33.50% and 34.25%, respectively. G3 decreased to 41.00%. These results indicate that cage litter and deep litter lost more moisture during composting compared to poultry offals. pH of all the bokashi compost groups decreased significantly ($P \leq 0.05$) during composting, while electrical conductivity (EC) increased significantly ($P \leq 0.05$), as presented in Table 3. G1 and G2 attained the lowest final pH values (4.27 and 3.95), whereas comparatively higher final pH was observed in other groups, indicating effective acidification during the fermentation process. Simultaneously, EC values increased across all groups, with the highest value recorded in G2 (0.56 mS/cm), showing increased ionic concentration and improved nutrient availability as composting progressed.
Changes in total dissolved solids (TDS), total organic matter (TOM) and total organic carbon (TOC) during composting: TDS increased significantly ($P \leq 0.05$), whereas TOM and TOC decreased significantly ($P \leq 0.05$) in all the bokashi compost groups during composting, as presented in Table 4. TDS increased with the highest final value observed in G2 (2.59 ppt), demonstrating enhanced nutrient solubilisation. In contrast, TOM and TOC showed marked reductions, with the greatest decline recorded in G2 (35.71% TOM and 21.93% TOC), due to microbial decomposition of organics and carbon mineralization during composting.
Changes in total ash and Kjeldahl nitrogen during composting: Total ash (%) and Kjeldahl nitrogen (%) increased significantly ($P \leq 0.05$) in all bokashi compost groups during composting, as presented in Table 5. G3 recorded the highest final ash content (53.00%), indicating mineral concentration during decomposition, while Kjeldahl nitrogen increased across groups, with the highest value observed in G4 (2.06%). These findings show progressive mineral enrichment and improved nitrogen availability during composting.
Changes in microbial populations during composting: Lactic acid bacteria (LAB) counts increased significantly ($P \leq 0.05$), while coliform counts decreased in all bokashi compost groups during composting, as shown in Table 5. G1 recorded the highest final LAB (6.07 log cfu/g), whereas the greatest reduction in coliforms occurred in G4 (5.86 → 5.41 log cfu/g). These results signify enhanced beneficial microbial activity, improving fermentation of the compost.
Assessment of end-product maturity of bokashi compost: The maturity of the bokashi compost was assessed

Table 1: Experimental plan

Treatment	Cage litter	Offals	Deep litter	Premix
T1	✓	×	×	✓
T2	×	✓	×	✓
T3	×	×	✓	✓
T4	✓	✓	✓	✓
Each treatment had four replicates				

Table 2: Chemical properties of different ingredients used for bokashi composting (Mean±SE)

Ingredients	Moisture (%)	pH	EC (mS/cm)	TDS (ppt)	Total organic matter (%)	Total organic carbon (%)	Total ash (%)	C:N ratio	Nitrogen (%)	Phosphorous (%)	Potassium (%)
Cage litter	68.50± 0.96	8.49± 0.044	0.29± 0.006	2.33± 0.054	56.92± 1.16	33.39± 0.68	28.50± 1.71	17.70± 0.041	1.59± 0.016	3.13± 0.045	0.98± 0.012
Deep litter	65.00± 0.58	9.13± 0.012	0.16± 0.010	1.31± 0.024	47.84± 0.39	27.86± 0.23	34.50± 4.86	17.68± 0.026	1.68± 0.030	3.70± 0.174	1.27± 0.029
Poultry offals	76.06± 1.62	6.86± 0.074	0.41± 0.008	0.51± 0.017	69.19± 1.94	40.90± 1.11	21.00± 0.91	13.08± 0.025	1.38± 0.029	3.53± 0.068	1.05± 0.026

Table 3: Weight reduction (%), volume reduction (%), moisture change (%), pH change and electrical conductivity change (EC, mS/cm) during bokashi composting between different groups (Mean±SE)

Groups	Weight reduction (%)	Volume reduction (%)	Moisture change (%)		pH		EC (mS/cm)	
			Initial	Final	Initial	Final	Initial	Final
G1 (Cage litter + premix)	2.37^{a}±0.20	14.60^{a} ±2.07	68.50^{aA} ±0.96	33.50^{aB} ±0.65	8.49^{bA}± 0.044	4.27^{aB} ±0.043	0.29^{bA} ±0.006	0.41^{B} ±0.038
G2 (Poultry offals + premix)	10.13^{c}±2.71	27.97^{b} ±2.98	76.06^{bA} ±1.62	66.55^{cB} ±3.30	6.86^{aA}± 0.074	3.95^{aB} ±0.044	0.41^{dA} ±0.008	0.56^{B} ±0.023
G3 (Deep litter + premix)	2.29^{a}±0.26	13.49^{a} ±1.88	65.00^{aA} ±0.58	41.00^{bB}±2.68	9.13^{cA}± 0.012	5.81^{bB} ±0.243	0.16^{aA} ±0.010	0.46^{B} ±0.125
G4 (Cage litter + deep litter + poultry offals + premix)	7.20^{b}±0.99	25.76^{b} ±1.27	69.00^{aA} ±1.73	34.25^{abB}±1.31	6.99^{aA}± 0.092	5.59^{bB} ±0.205	0.36^{cA} ±0.007	0.51^{B} ±0.029

Means with different small superscripts column wise and capital superscripts row wise differ significantly (P≤0.05)

Table 4: Total dissolved solids (TDS, ppt), **total organic matter (TOM, %) and total organic carbon (TOC, %)** change during bokashi composting between different groups (Mean±SE)

Groups	TDS (ppt)		TOM (%)		TOC (%)	
	Initial	Final	Initial	Final	Initial	Final
G1 (Cage litter + premix)	2.33^{cA}± 0.054	3.78^{cB}± 0.069	56.92^{bA}± 1.16	49.67^{bB}± 1.23	33.39^{bA}± 0.68	29.21^{bcB}± 0.54
G2 (Poultry offals + premix)	0.51^{aA}± 0.017	2.59^{bB}± 0.223	69.19^{cA}± 1.94	35.71^{aB}± 5.45	40.90^{cA}± 1.11	21.93^{abB}± 3.32
G3 (Deep litter + premix)	1.31^{bA}± 0.024	1.84^{aB}± 0.197	47.84^{aA}± 0.39	27.09^{aB}± 6.47	27.86^{aA}± 0.23	15.78^{aB}± 3.78
G4 (Cage litter + deep litter + poultry offals + premix)	1.20^{bA}± 0.048	2.23^{abB}± 0.139	53.78^{bA}± 2.26	51.01^{bB}± 2.88	31.33^{bA}± 1.33	30.59^{cB}± 1.65

Means with different small superscripts column wise and capital superscripts row wise differ significantly (P≤0.05)

Table 5: Total ash, Kjeldahl nitrogen**,** Lactic acid bacteria and coliform change during bokashi composting

Groups	Total ash (%)		Kjeldhal nitrogen (%)		LAB (cfu/g)		Coliform (cfu/g)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
G1 (Cage litter + premix)	28.50^{abA}± 1.71	48.00^{bcB} ±7.35	1.59^{bA}±0.016	1.85^{aB}±0.020	5.75^{bA} ±0.008	6.07^{bB}± 0.007	5.85^{bA}± 0.013	5.45^{aB}± 0.021
G2 (Poultry offals + premix)	21.00^{aA}± 0.91	26.75^{aB} ±0.85	1.38^{aA}±0.029	1.96^{abB}±0.021	5.65^{aA} ±0.034	6.02^{aB}± 0.022	5.86^{bA}± 0.012	5.43^{aB}± 0.045
G3 (Deep litter + premix)	34.50^{bA}± 4.86	53.00^{cB} ±7.23	1.68^{bA}±0.030	2.03^{abB}±0.085	5.86^{cA} ±0.007	6.06^{abB} ±0.011	5.79^{aA}± 0.010	5.40^{aB}± 0.015
G4 (Cage litter + deep litter + poultry offals + premix)	22.48^{aA}± 1.86	31.23^{abB} ±3.96	1.82^{cA}±0.044	2.06^{bB}±0.086	5.82^{cA} ±0.010	6.06^{bB}± 0.006	5.86^{bA}± 0.008	5.41^{aB}± 0.019

Means with different small superscripts column wise and capital superscripts row wise differ significantly (P≤0.05)

Table 6: Total nitrogen, total phosphorous, total potassium during bokashi composting (Mean±SE)

Groups	**Total nitrogen (%)**		**Total phosphorous (%)**		**Total potassium (%)**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**
G1 (Cage litter + premix)	$1.59^{Ab}\pm$ 0.016	$1.85^{aB}\pm$ 0.020	$3.13^{bA}\pm$ 0.045	$4.10^{bB}\pm$ 0.046	$0.98^{aA}\pm$ 0.012	$1.22^{aB}\pm$ 0.049
G2 (Poultry offals + premix)	$1.38^{Aa}\pm$ 0.029	$1.96^{abB}\pm$ 0.021	$3.53^{cA}\pm$ 0.068	$4.58^{cB}\pm$ 0.028	$1.05^{aA}\pm$ 0.026	$1.52^{bB}\pm$ 0.041
G3 (Deep litter + premix)	$1.68^{Ab}\pm$ 0.030	$2.03^{abB}\pm$ 0.085	$3.70^{cA}\pm$ 0.174	$4.12^{bB}\pm$ 0.045	$1.27^{bA}\pm$ 0.029	$2.09^{cB}\pm$ 0.043
G4 (Cage litter + deep litter + poultry offals + premix)	$1.82^{Ac}\pm$ 0.044	$2.06^{bB}\pm$ 0.086	$2.15^{aA}\pm$ 0.025	$3.15^{aB}\pm$ 0.068	$1.02^{aA}\pm$ 0.064	$1.48^{bB}\pm$ 0.029

Means with different small superscripts column wise and capital superscripts row wise differ significantly (P≤0.05)

Table 7: Total nitrogen, total phosphorus, total potassium, pH and total organic matter changes of soil-bokashi compost (Mean±SE)

Groups	**Total nitrogen (%)**		**Total phosphorous (%)**		**Total potassium (%)**		**pH**		**TOM (%)**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
G1 (Cage litter + premix)	$0.91^{bA}\pm$ 0.009	1.21^{bB} ±0.01	$0.27^{bA}\pm$ 0.003	$0.39^{bB}\pm$ 0.010	$0.79^{bA}\pm$ 0.009	$1.09^{bB}\pm$ 0.006	$6.01^{bA}\pm$ 0.021	$6.40^{bB}\pm$ 0.017	66.92^{A} ±1.16	52.17^{cB} ±2.40
G2 (Poultry offals + premix)	$1.09^{dA}\pm$ 0.010	1.33^{cB} ± 0.012	$0.31^{bA}\pm$ 0.007	$0.44^{bcB}\pm$ 0.011	$0.94^{dA}\pm$ 0.011	$1.26^{cB}\pm$ 0.010	$5.78^{aA}\pm$ 0.009	$6.11^{aB}\pm$ 0.010	65.69^{A} ±3.06	41.96^{abB} ±2.94
G3 (Deep litter + premix)	$0.72^{aA}\pm$ 0.006	0.92^{aB} ± 0.005	$0.23^{aA}\pm$ 0.004	$0.32^{aB}\pm$ 0.022	$0.69^{aA}\pm$ 0.004	$0.96^{aB}\pm$ 0.007	$6.48^{dA}\pm$ 0.010	$6.69^{dB}\pm$ 0.011	58.83^{A} ±1.26	38.34^{aB} ±3.31
G4 (Cage litter + deep litter + poultry offals + premix)	$0.96^{cA}\pm$ 0.005	1.32^{cB} ± 0.004	$0.29^{bA}\pm$ 0.005	$0.47^{cB}\pm$ 0.013	$0.86^{cA}\pm$ 0.005	$1.29^{cB}\pm$ 0.008	$6.12^{cA}\pm$ 0.011	$6.52^{cB}\pm$ 0.006	60.03^{A} ±3.92	47.76^{bcB} ±1.40

Means with different small superscripts column wise and capital superscripts row wise differ significantly (P≤0.05)

Table 8: Spinach seed germination (%) during bokashi composting between different groups (Mean±SE)

Groups	**7th Day**	**14th Day**
G1 (Cage litter + premix)	$83.75^{b}\pm2.45$	$91.25^{b}\pm2.65$
G2 (Poultry offals + premix)	$79.69^{b}\pm1.07$	$87.19^{b}\pm1.07$
G3 (Deep litter + premix)	$58.44^{a}\pm6.13$	$66.88^{a}\pm6.70$
G4 (Cage litter + deep litter + poultry offals + premix)	$76.25^{b}\pm1.84$	$85.00^{b}\pm1.84$

Means with different superscripts differ significantly (P≤0.05)

based on the stabilisation of nutrient parameters, particularly total nitrogen (%), total phosphorus (%), and total potassium (%) as represented in Table 6, which are key indicators of compost stability and agronomic value and significant (P≤0.05) differences were observed among the groups. Total nitrogen increased in all groups, with the highest final value in G4 (2.06%), indicating enhanced nitrogen retention. Total phosphorus also increased, with G2 reaching the highest final content (4.58%), showing improved nutrient enrichment. Total potassium showed the greatest accumulation in G3 (2.09%), suggesting effective mineral stabilisation.

Changes in soil pH and total organic matter (TOM) following bokashi compost application: Soil pH increased significantly (P≤0.05) in all bokashi-treated groups, while TOM decreased, as shown in Table 7. G3 recorded the highest final pH (6.69) and the greatest reduction in organic matter (38.34%), whereas G1 retained higher organic matter (52.17%). These results imply a slight rise in soil pH alongside active decomposition and mineralisation of organic substrates after bokashi application.

Changes in soil macronutrient status following bokashi compost application: The influence of soil-bokashi compost application on soil nutrient status was evaluated based on total nitrogen, total phosphorus, and total potassium as presented in Table 7, which serve as important indicators of soil fertility improvement. Total nitrogen content increased significantly (P≤0.05) in all treatment groups after compost application, with the highest final values recorded in G2 (1.33%) and G4 (1.32%). Similarly, total phosphorus showed a significant (P≤0.05) increase across all the groups, with maximum accumulation observed in G4 (0.47%). Total potassium also increased significantly (P≤0.05), reaching the highest levels in G4 (1.29%) and G2 (1.26%). Overall, these results support that application of bokashi compost enhanced soil macronutrient status.

Seed germination response of spinach to bokashi compost application: Seed germination of spinach varied significantly (P≤0.05) among the different treatments, as represented in Table 8. Germination increased from about 83.75% to 91.25% in G1, while G3 recorded lower values (58.44%-66.88%). G2 and G4 showed intermediate germination (≈76-87%). These results show that bokashi compost application improved the germination and early establishment of seeds.

Discussion

Cage litter showed elevated moisture and mildly alkaline pH, which are typical characteristics of poultry litter due to uric acid breakdown and the accumulation of alkaline compounds during storage (Maruthamuthu *et al.*, 2024). The moderate EC and TDS indicated suitable salinity levels for composting. Its considerable N, P and K contents, along with high organic matter and organic carbon, indicate its nutrient-rich nature and suitability as a substrate for composting and soil amendment. The ash content may support the presence of minerals derived from bedding and feed residues.

The deep litter in this study exhibited high moisture and a strongly alkaline pH, typical of poultry litter due to prolonged microbial activity and ammonia accumulation during uric acid breakdown, consistent with findings by Oliveira *et al.* (2021). Low EC and TDS values indicate moderate salinity suitable for composting.

Poultry offals showed the highest moisture content and a near-neutral pH, favouring microbial activity and biodegradation. Their elevated EC and TDS indicated the presence of soluble nutrients, while the higher N, P and K contents reflected their nutrient rich nature. High organic matter and carbon contents further support their suitability as a composting substrate (Sharma *et al.*, 2017).

Weight reduction differed significantly (P≤0.05) among groups and increased with fermentation time, with the relatively low loss being typical of anaerobic bokashi fermentation. Baba *et al.* (2018) reported only 4.72% weight reduction in poultry waste compared with 35.52% under aerobic composting. Volume reduction also differed significantly (P≤0.05) among groups, mainly due to organic matter decomposition during composting (Alarefee *et al.*, 2023). Moisture content decreased significantly (P≤0.05) in all the treatments of bokashi composting. This reduction may be attributed to microbial utilization of water during organic matter degradation, absorption by fermentative microbes, and limited moisture loss during the fermentation process (Yang *et al.*, 2024).

The significant (P≤0.05) decline in pH may be due to the production of lactic and other organic acids by effective microorganisms under anaerobic conditions, as observed by Gebiola *et al.* (2023). In contrast, EC increased significantly (P≤0.05) across all groups, possibly because of the release and concentration of soluble salts and mineral ions during organic matter decomposition, similar to the findings of Rizzo *et al.* (2013).

Bharathy *et al.* (2012) reported changes in TDS during poultry waste composting, which may be associated with the breakdown of organic matter and release of soluble salts and organic acids. In the present study, TDS increased significantly (P≤0.05) across all groups during fermentation.

The significant (P≤0.05) differences in TOM reduction may be due to substrate composition. Greater reductions in G2 and G3 were associated with higher degradable organic content, while bulking agents in G4 may have slowed organic matter loss. Similar reductions have been reported during poultry and livestock waste composting (Wang *et al.*, 2015; Onwosi *et al.*, 2017).

Total organic carbon (TOC) decreased significantly (P≤0.05) across all groups, indicating effective carbon mineralization during bokashi composting. This reduction results from microbial decomposition and CO_2 production during fermentation, as also reported by Huang *et al.* (2020).

Total ash (%) increased significantly (P≤0.05) across all groups, possibly due to organic matter mineralisation and accumulation of inorganic residues during bokashi maturation, as observed by Iqbal *et al.* (2018). Kjeldahl nitrogen also increased significantly (P≤0.05) during composting, which may be linked to microbial mineralisation and weight reduction, similar to the findings of Awasthi *et al.* (2014).

The significant (P≤0.05) increase in total nitrogen across all groups may be attributed to carbon loss and concentration of nitrogen during fermentation, as also reported by Baba *et al.* (2022) in poultry waste composting. Total phosphorus content also increased significantly (P≤0.05) from the initial to final stages, which may be associated with dry matter loss and nutrient concentration, consistent with the findings of Xu *et al.* (2025) in animal waste composting. Likewise, potassium content increased significantly (P≤0.05), possibly due to the release of water soluble potassium salts and reduction in compost weight, similar to the trend reported by Zhen *et al.* (2019).

LAB counts differed significantly (P≤0.05) among groups, with higher counts associated with anaerobic fermentation and readily fermentable substrates. LAB dominance during bokashi fermentation was also reported by Kujala and Kinnunen (2026). The coliform counts decreased significantly (P≤0.05) in all the groups; this reduction indicated effective suppression of pathogenic and indicator organisms during the composting process. Sadeghi *et al.*

(2022) reported that organic acid production and competitive exclusion by beneficial microbes play a key role in reducing coliform populations during composting. pH increased significantly (P≤0.05) across groups, likely due to the decomposition of organic acids during compost maturation. Similar increases in pH during poultry waste composting were reported by Baba *et al.* (2022).

Fig. 1: Bokashi bin used for the preparation of bokashi compost.

Fig. 2: Experimental setup showing multiple bins used for poultry waste based bokashi composting

Fig. 3: Addition and mixing of bokashi bran during compost preparation

The significant (P≤0.05) decrease in TOM across groups may be due to microbial degradation and CO_2 loss during composting. Similar organic matter degradation in poultry waste composting was reported by Liu *et al*. (2022). Total nitrogen increased significantly (P≤0.05) in all groups, possibly due to nitrogen concentration as organic matter decomposed, similar to the findings of Feng *et al.* (2023). Total phosphorus also increased significantly (P≤0.05), with higher values in the poultry-offal treatments, probably due to their higher phosphorus content, as observed by Lew *et al.* (2021). Total potassium showed a significant (P≤0.05) increase as well, which may be due to the release of soluble K and loss of organic matter during composting, in agreement with Gao *et al.* (2023).

Spinach seed germination increased from day 7 to 14 across all groups, indicating progressive compost stabilisation. Higher early germination in G1, G2 and G4 suggested lower phytotoxicity, while the lower germination in G3 indicated slower stabilisation. Seed germination index is a useful indicator of compost maturity and phytotoxicity (Yang *et al.*, 2021).

Conclusion

The present study demonstrated that bokashi composting is an effective and sustainable approach for the management and utilisation of poultry wastes, including cage litter, deep litter, and poultry offals. Significant reductions in organic matter, moisture, and carbon content, along with increased nutrient concentrations (N, P and K), confirmed efficient decomposition and compost stabilisation under anaerobic fermentation. The rise in beneficial lactic acid bacteria and reduction in coliform counts indicated improved microbial quality and hygienic safety of the compost. Application of the matured bokashi compost enhanced the soil fertility by improving macronutrient status, which was further supported by higher spinach seed germination, showing improved compost maturity. Therefore, bokashi composting proved to be a environmentally friendly, and nutrient conserving method for converting poultry by-products cum wastes into value added organic manure suitable for sustainable agricultural application.

References

1) Alarefee, H. A., Ishak, C. F., Othman, R., Karam, D. S. (2023). Effectiveness of mixing poultry litter compost with rice husk biochar in mitigating ammonia volatilization and carbon dioxide emission. Journal of environmental management, **329**: 117051. https://doi.org/10.1016/j.jenvman.2022.117051

2) Allison, L. E. (1965). Organic carbon. In Methods of soil analysis: Part 2. Chemical and microbiological properties (pp. 1367–1378). American Society of Agronomy.

3) AOAC. (2005). Official methods of analysis (18th ed.). Association of Official Analytical Chemists, Washington, DC.

4) Baba, I. A., Banday, M. T., Khan, H. M., Khan, A. A., Sheikh, I. U. D., Patoo, R. A., Anjum, Z. (2022). Feasibility and product maturity of compost developed from poultry waste in temperate agroclimate of Kashmir region. International Journal of Environment and Climate Change, **12**(5): 41-49. https://doi.org/10.9734/ijecc/2022/v12i530673

5) Baba, I. A., Banday, M. T., Khan, H. M., Khan, A. A., Untoo, M. (2018). Economics of composting of poultry farm waste. Journal of Entomology and Zoology Studies, **6**(2): 2925–2928. Available at: https://www.entomoljournal.com/archives/?year=2018andvol=6andissue=2andArticleId=3499

6) Bharathy, N., Sakthivadivu, R., Sivakumar, K., Saravanakumar, V. (2012). Disposal and utilization of broiler slaughter waste by composting. Veterinary World, 5(6), 359–361. https://doi.org/10.5455/vetworld.2012.359-361

7) Das, A. R., Raj, S. K., Pillai, S. P., Anith, K. N., Jacob, D., Vandanadevi, V. S., Aparna S., Meenakshi, R. P. (2025). Composting- a viable option for converting poultry manure into a nutrient rich manure. World's Poultry Science Journal, **81**(4): 1259–1284. https://doi.org/10.1080/00439339.2025.2541249

8) Feng, M., Wu, X., Qiu, X., Wang, H. (2023). Influence of peat and biochar on gas emissions and microbial metabolism during co-composting of chicken manure and maize straw. Waste and Biomass Valorization, **14**: 197–208. https://doi.org/10.1007/s12649-022-01857-z

9) Food and Agriculture Organization of the United Nations (FAO) (2023). FAOSTAT statistical database. FAO. Available at: https://www.fao.org/faostat/

10) Gao, Y., Wang, S., Tan, W., Xi, B. (2023). Dynamics of nutrient elements and potentially toxic elements during composting with different organic wastes. Frontiers in Sustainable Food Systems, **7**: 1181392. https://doi.org/10.3389/fsufs.2023.1181392

11) Gebiola, M., Rodriguez, M. V., Garcia, A., Garnica, A., Tomberlin, J. K., Hopkins, F. M., Mauck, K. E. (2023). Bokashi fermentation of brewery's spent grains positively affects larval performance of the black soldier fly Hermetia illucens while reducing gaseous nitrogen losses. Waste management, **171**: 411–420. https://doi.org/10.1016/j.wasman.2023.09.033

12) Hemavarshini, M. P., Thiyageshwari, S., Selvi, D., Anandham, R., Thirunavukkarasu, M., Sivasubramanian, K., Jegadeeswari, D. (2025). Sustainable Management of Chicken Waste: Exploring Conversion Technologies for Environmental Benefits. Frontiers in bioscience (Elite edition), **17**(2): 25930. https://doi.org/10.31083/FBE25930

13) Hwang, H. Y., Kim, S. H., Kim, M. S., Park, S. J., Lee, C. H. (2020). Co-composting of chicken manure with organic wastes: characterization of gases emissions and compost quality. Applied Biological Chemistry, **63**(3). https://doi.org/10.1186/s13765-019-0483-8

14) Intergovernmental Panel on Climate Change (IPCC). (2021). Climate change 2021: The physical science basis. Cambridge University Press. https://doi.org/10.1017/9781009157896
15) Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.
16) Kujala, K., Kinnunen, V. (2026). Lactic acid bacteria dominate urban Bokashi: A participatory, culture-independent pilot study of microbial diversity and functional potential in household-scale food waste fermentation. FEMS Microbes, **7**: xtag018. https://doi.org/10.1093/femsmc/xtag018
17) Lew, P. S., Nik Ibrahim, N. N. L., Kamarudin, S., Thamrin, N. M., Misnan, M. F. (2021). Optimization of Bokashi-Composting Process Using Effective Microorganisms-1 in Smart Composting Bin. Sensors, **21**(8): 2847. https://doi.org/10.3390/s21082847
18) Liu, C., Zhang, X., Zhang, W., Wang, S., Fan, Y., Xie, J., Liao, W., Gao, Z. (2022). Mitigating gas emissions from poultry litter composting with waste vinegar residue. Science of the Total Environment, **842**: 156957. https://doi.org/10.1016/j.scitotenv.2022.156957
19) Maruthamuthu, T., Karuppusamy, S., Veeramalai, R., Nagarajan, M., Manika Ragavan, P., Santiago, M., Nallathambi, B., Dharmalingam, A. P. S., Radhakrishnan, K., Ramasamy, A., Ramasamy, S. R. S., Aranganoor Kannan, T. (2024). Physicochemical Characterization of Broiler Poultry Litter from Commercial Broiler Poultry Operation in Semiarid Tropics of India. Agriculture, **14**(10): 1708. https://doi.org/10.3390/agriculture14101708
20) Mozhiarasi, V., Natarajan, T. S. (2025). Slaughterhouse and poultry wastes: Management practices, feedstocks for renewable energy production, and recovery of value added products. Biomass Conversion and Biorefinery, **15**: 1705–1728. https://doi.org/10.1007/s13399-022-02352-0
21) Mushtaq, M., K. Iqbal, M., Khalid, A., A. Khan, R. (2018). Humification of poultry waste and rice husk using additives and its application. International Journal of Recycling of Organic Waste in Agriculture, **8**(1). https://doi.org/10.1007/s40093-018-0224-8
22) Navarro, A. F., Cegarra, J., Roig, A., García, D. (1993). Relationships between organic matter and carbon contents of organic wastes. Bioresource Technology, **44**(3): 203–207. https://doi.org/10.1016/0960-8524(93)90153-3
23) Oliveira, M. D., Sousa, F. C., Saraz, J. O., Calderano, A. A., Tinôco, I. F. F., Carneiro, A. P. S. (2021). Ammonia Emission in Poultry Facilities: A Review for Tropical Climate Areas. Atmosphere, **12**(9): 1091. https://doi.org/10.3390/atmos12091091
24) Onwosi, C. O., Igbokwe, V. C., Odimba, J. N., Eke, I. E., Nwankwoala, M. O., Iroh, I. N., Ezeogu, L. I. (2017). Composting technology in waste stabilisation. Journal of Environmental Management, **190**: 140-157. https://doi.org/10.1016/j.jenvman.2016.12.051
25) Pane, C., Celano, G., Piccolo, A., Villecco, D., Spaccini, R., Palese, A. M., Zaccardelli, M. (2015). Effects of on-farm composted tomato residues on soil biological activity and yields in a tomato cropping system. Chemical and Biological Technologies in Agriculture, **2**: 4. https://doi.org/10.1186/s40538-014-0026-9
26) Poojitha, S., Anusha, K., Ratna Raju, P. 2024. Issues faced by poultry farmers in post-covid scenario. Journal of Livestock Science 15: 136-140, doi. 10.33259/JLivestSci.2024.136-140
27) Rizzo, P. F., Torre, V. D., Riera, N. I., Crespo, D. E., Barrena, R., Sánchez, A. (2013). Co-composting of poultry manure with other agricultural wastes: process performance and compost horticultural use. Journal of Material Cycles and Waste Management, **17**: 42–50. https://doi.org/10.1007/s10163-013-0221-y
28) Roy, N.K., Mili, D.C., Das, A., Deka, R.J., Bora, J.R., Kalita, D.J., Kaushik, P. 2025. Carcass characteristics of crossbred Hampshire pig fed on poultry by-products. Journal of Livestock Science 16: 402-409. doi. 10.33259/JLivestSci.2025.402-409
29) Sadeghi, S., Nafez, A. H., Nikaeen, M., Mohammadi, F., Tady, D. J., Hatamzadeh, M. (2022). Microbial indicators in municipal solid waste compost and their fate after land application of compost. Journal of environmental health science and engineering, **21**: 85–92. https://doi.org/10.1007/s40201-022-00841-y
30) Safari, H., Mohit, A., Mohiti-Asli, M. (2024). Feather meal processing methods impact the production parameters, blood biochemical indices, gut function, and hepatic enzyme activity in broilers. Journal of Animal Science, **102**: skae068. https://doi.org/10.1093/jas/skae068
31) Saputra, S. A., Zain, F. N., Pratiwi, K. A. N. (2025). Valorization of chicken feather waste in West Java into Bokashi fertilizer using anaerobic fermentation to support circular agriculture: A review. Journal of Clean Technology, **2**(2): 1–15. https://doi.org/10.15294/joct.v2i2.28957
32) Sharma, A. K., Kaur, D., Sethi, A. P. S., Chandra, M., Sharma, A. (2016). Aerobic composting as a suitable alternative for efficient management of poultry farm waste. Indian Journal of Animal Production and Management, **32**(1-2): 76–84. Available at: https://www.researchgate.net/publication/355019788
33) Tiquia, S. M., Tam, N. F. Y. (2002). Characterization and composting of poultry litter in forced-aeration piles. Process Biochemistry, **37**(8): 869–880. https://doi.org/10.1016/S0032-9592(01)00274-6

34) Wang, K., He, C., You, S., Liu, W., Wang, W., Zhang, R., Qi, H., Ren, N. (2015). Transformation of organic matters in animal wastes during composting. Journal of hazardous materials, **300**: 745–753. https://doi.org/10.1016/j.jhazmat.2015.08.016
35) Xu, J., Wang, X., Feng, J., Zhang, W., Sun, J. (2025). Study of the Relationship Between Nitrogen, Phosphorus Content, and Microbial Community Changes in Deer Manure Compost with Different Conditioners. Fermentation, **11**(2): 66. https://doi.org/10.3390/fermentation11020066
36) Yang, M., Guo, Y., Yang, F., Wang, J., Gao, Y., Wang, M., Liang, X., He, S. (2024). Dynamic changes in and correlations between microbial communities and physicochemical properties during the composting of cattle manure with Penicillium oxalicum. BMC microbiology, **24**: 301. https://doi.org/10.1186/s12866-024-03449-4
37) Yang, Y., Wang, G., Li, G., Ma, R., Kong, Y., Yuan, J. (2021). Selection of sensitive seeds for evaluation of compost maturity with the seed germination index. Waste management, **136**: 238–243. https://doi.org/10.1016/j.wasman.2021.09.037
38) Zhang, L., Ren, J., Bai, W. (2023). A Review of Poultry Waste-to-Wealth: Technological Progress, Modeling and Simulation Studies, and Economic- Environmental and Social Sustainability. Sustainability, **15**(7): 5620. https://doi.org/10.3390/su15075620
39) Zhen, X., Luo, M., Dong, H.Y., Li, S.B., Li, M.C., Kang, J.J. (2021). Variations of N-P-K contents in livestock and livestock manure composting. Applied Ecology and Environmental Research, **19**(1): 249-261. https://doi.org/10.15666/aeer/1901_249261