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Physicochemical Characterization of Broiler Poultry Litter from Commercial Broiler Poultry Operation in Semiarid Tropics of India

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Abstract: This study aimed to characterize the physicochemical properties of broiler poultry litter (BPL) produced from intensively reared commercial broiler farming areas in tropical zone of Tamil Nadu, India. The BPL samples were collected from 110 commercial poultry farms at the end of the production cycle (6th week), further 20 samples were collected from the point of utility. The dry matter (DM), moisture, ash, organic matter (OM), and organic carbon (OC) from the manure samples were 83.04 ± 0.77, 16.96 ± 0.77, 27.08 ± 1.18, 72.92 ± 1.18 and 42.39 ± 0.69 per cent respectively. The pH, Electrical conductivity (EC) (ds m^{-1}), and Kjeldahl Nitrogen (N) were 8.43 ± 0.06, 5.74 ± 0.13, and 24.2 ± 0.84 g kg-1 respectively. The BPL from the cement floor had higher levels of P and K (12.74 and 13.28) than the mud floor (10.88 and 10.96). According to the findings of this study, BPL as such at the end of the production cycle is rich in OM, nitrogen, macro and micro minerals at the same time at the point of utility there was a loss of OM, N, and concentration of minerals was noticed, which advocate proper storage and composting process.

Keywords: physicochemical properties; broiler; manure; poultry litter

1. Introduction

The Indian poultry industry consists of broiler and egg-type chicken worth of INR 1905 billion in 2022 with an average growth rate of 10.18 per cent and the projected value for the year 2028 is INR 3477 billion [1]. More than 80 per cent of India's chicken output is produced by contract farming under the organized sector mainly by vertical integration by major companies which comprise approximately 60-70 per cent of the total chicken production [2,3]. India is the 6th largest producer in the world [4] and about 331.51 million chicks are being slaughtered annually in India [5].

Broiler production is mainly concentrated in the states of Maharashtra (0.726 million tons), West Bengal (0.649 million tons), Haryana (0.619 million tons), Andhra Pradesh (0.592 million tons), Tamil Nadu (0.50 million tons) and Telangana (0.482 million tons) with the total annual production of 4.9 million tons. Tamil Nadu state is the 5th leading state in poultry meat production which accounts for 10.01 per cent of the poultry meat produced in the country [5].

The major broiler production zone in Tamil Nadu falls under the tropical semiarid zone and the average farm size ranges between 5000 and 20,000 broilers and the production cycle lasts for 5 to 6 weeks. Coconut cultivation is one of the major agricultural activities in the major broiler production belt (Tirupur, Coimbatore, and Erode districts) and most of the farmers utilize coconut pith waste [6] as bedding material in broiler farming. This is an effective way of recycling agricultural waste by the farmers. Most of the farmers utilize the used litter as a soil amendment after storing it for a short period [6].

One of the challenges facing livestock and poultry industries worldwide is manure management. Improper management and utilization of manure can contribute to environmental degradation, and ultimately be detrimental to human and animal populations. The disposal of raw poultry manure without further treatment poses serious environmental problems such as obnoxious odour, leaching of toxic elements such as heavy metals [7], methane emissions, eutrophication of waterways, and nutrient imbalances when applied to soil, phytotoxicity and dissemination of pathogens and weeds [8], broiler poultry litter adversely affects plant growth and seed germination [9], due to production of phytotoxic substances such as phenolic and volatile fatty acids during partial OM decomposition as they have wide C:N ratio. The broiler litter consists of bedding material mixed with droppings, feathers, and feed waste, which is rich in major plant nutrients. The average daily fresh manure production by broiler chicken is about 43 kg per 1000 kg live weight. On a dry weight basis, poultry litter production ranges from 0.7 to 2.0 tons per 1000 broilers per flock. In Tamil Nadu, it was estimated that broiler chicken litter production per year is about 5.2 lakh MT/year [10]. The research data regarding the physicochemical properties of broiler litter from commercial broiler farms and loss of nutrients during storage and further handling is limited.

In this study, broiler litter samples were collected from different poultry farms utilizing various bedding materials and were subjected to laboratory analysis of their physicochemical properties, manure samples were also collected from the end user level and the variability in the physicochemical properties is documented, and the management factor influencing the BPL quality, correlation between the physiochemical properties and loss of plant nutrient during the process of storage had been studied.

2. Materials and Methods

2.1. Study Area

This study was carried out in the Western Agro-climatic zone of Tamil Nadu, India, specifically in the districts of Coimbatore, Tiruppur, and Erode, which have the highest concentration of broiler population. The study area is located between 10°36′ and 11°58′ N latitude; 76°49′ and 77°58′ E longitude with the mean sea level ranging between 177 to 411 meters. The selected districts have the

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highest annual growth rate in broiler population and the greatest number of broiler integrators, broiler parental breeding farms, broiler hatcheries, commercial broiler farms, a small number of chicken processing plants, poultry input dealers, and service providers, all of which contribute to a favorable environment for commercial broiler ventures. They are located in a semi-arid tropical climate, with temperatures ranging from 18 to 40 ^{0}C. The annual rainfall was approximately 700 mm. The soil is predominantly red sand and gravel, with some red loam and black loam, loamy soil, and clay soil thrown in for good measure.

2.2. Sample Collection

The BPL samples were collected following the point sample method [11]. In the current study, to collect a representative in-house litter sample, samples were collected from each of 110 commercial broiler houses located across the three selected districts of the western agro-climatic zone between March and September 2017 at the end of the production cycle (5 to 7 weeks). To understand the physicochemical properties of BPL at the point of utility, 20 samples were collected from various composting yards (static composting for a period of 4-6 months) and analyzed. A representative BPL sample was carefully collected from various areas proportionately in the production house, and a total of 15 to 20 samples were randomly collected with the spade from the litter pack down to the depth of the litter. After placing the samples in a plastic pail and vigorously mixing them with a spade to break up large clumps, the manure was separated into four pieces. Two opposite pieces of the four were discarded. The remaining two parts were blended and mixed. The above method was repeated until the remaining amount of material (about 0.5 kg) was sufficient for analysis. The well-mixed sub-sample was placed in a plastic bag that was half to two-thirds full. The bag was closed and sealed when the extra air was squeezed out. The date, time, farm name, and number were all labeled on the bags. The samples were immediately used in the laboratory.

2.3. Physicochemical Analysis

The collected BPL samples were homogenized and oven-dried at 105°C for 24 hours to determine the moisture content [12,13]. The pH and EC were determined in 1:10 (w/v) aqueous extracts of the BPL sample using a digital pH and EC meter [14,15]. The total ash content was determined as the difference between the DM content and the gravimetric loss-on-ignition produced by the previously dried samples at 550 °C for 5 hr. in a muffle furnace and expressed as a %age of residues after combustion [12,16]. The total OM /Total volatile solids content was calculated with the formula i.e., Total OM = [100 – Ash %]. Total OC analysis was done by dry combustion method with “Van Bemelem Factor” of 1.8 using the formula Total OC (%) = [100-Ash %] / 1.8, [16–19]. Total Kjeldahl Nitrogen was estimated by digesting the air-dried compost samples in concentrated sulphuric acid at 500°C and by distillation and trapping the NH_3 in 0.1 N H_2SO_4 titrated against standard 0.1 N NaOH solutions [20]. The C/N ratio was computed based on the concentration of total OC and Total Kjeldahl Nitrogen [14,21]. The major plant nutrients viz., total P, Ca, and Mg were analyzed as per [10], and the total potassium was analyzed using a Flame photometer [10]. The micronutrients, viz., Cu, Zn, Fe, and Mn using atomic absorption photometer [20].

2.4. Statistical Analysis

The physicochemical properties were statistically analyzed as they were influenced by factors such as geographical location, commercial broiler integrating company, and other management factors such as floor type, roof type, feeding method, litter material used, form of feed, watering devices used, and population size. The correlation of physicochemical attributes was also performed. Descriptive statistics consisting of mean, range, standard deviation, standard error, and coefficient of variation were computed for all the traits studied by adopting conventional procedures as described by Snedecor and Cochran [22]. The least-squares analysis of variance was made using SPSS software (Version 17.0) as well as using Sigmaplot for Windows (version 11.0) of Systat Software Inc.

2.5. Ethical Approval

In this experiment, no animal or human intervention investigations were conducted.

3. Results

3.1. Dry Matter

The mean ± SE (Table 1) of DM (%) in BPL collected from the surveyed geographical area was 83.04 ± 0.77 (57.85 to 94.59). The DM content of BPL was found to be significantly (P<0.05) affected the type of drinkers provided in the broiler farm (Table 2). The DM level was found to be positively correlated (P<0.05) with the electrical conductivity of BPL and found to have a highly significant negative (P<0.01) correlation with moisture, pH, Mg, and Cu contents (Table 3).

Table 1. Mean (± SE) Physicochemical Characteristics of BPL in Commercial Broiler Farms (n = 110).

Sl. No	Character	Minimum	Maximum	Mean (± SE)
1	Dry matter (%)	57.85	94.59	83.04 ± 0.77
2	Moisture (%)	5.41	42.15	16.96 ± 0.77
3	Ash (%)	6.25	77.21	27.08 ± 1.18
4	Organic matter (%)	22.79	93.75	72.92 ± 1.18
5	Organic carbon (%)	13.25	54.51	42.39 ± 0.69
6	pH	7.01	9.60	8.43 ± 0.06
7	EC (ds m^{-1})	1.47	10.05	5.74 ± 0.13
8	N (g kg-1)	4.5	36.6	24.2 ± 0.84
9	C : N ratio	7.54	79.74	21.42 ± 1.24
10	Calcium (g kg-1)	10.9	47.9	22.2 ± 0.72
11	Phosphorous (g kg^{-1})	4.4	31.5	11.3 ± 0.49
12	Potassium (g kg^{-1})	5.8	78.0	14.9 ± 1.17
13	Magnesium (g kg^{-1})	10.1	16.6	11.6 ± 0.12
14	Zinc (mg kg^{-1})	17.00	1908.26	276.61 ± 26.50
15	Copper (mg kg^{-1})	1.43	135.82	25.01 ± 2.05
16	Manganese (mg kg^{-1})	70.27	330.87	200.34 ± 6.004
17	Iron (mg kg^{-1})	716.28	4937.62	2371.72 ± 98.99

Table 2. Mean (± SE) of DM, Moisture, Ash and Organic Matter at Different Management Conditions.

Effect	n	DM (%)	Moisture (%)	Ash (%)	OM (%)
		Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)
Overall mean	**110**	**84.58 ± 2.56**	**15.42 ± 2.56**	**36.84 ± 3.11**	**63.16 ± 3.11**
Geographical location					
Coimbatore	55	84.23 ± 2.44	15.77 ± 2.44	37.65 ± 2.96	62.35 ± 2.96
Erode and Tirupur	55	84.93 ± 2.98	15.07 ± 2.98	36.03 ± 3.63	63.97 ± 3.63
Integrator				*	*
Others	10	89.12 ± 3.93	10.89 ± 3.93	41.88 ± 4.77^{b}	58.13 ± 4.77^{a}
Shanthi	68	84.79 ± 3.14	15.21 ± 3.13	32.05 ± 3.81^{a}	67.95 ± 3.81^{b}
RMP	32	79.84 ± 2.64	20.16 ± 2.64	36.59 ± 3.21^{b}	63.41 ± 3.21^{b}
Floor				**	**
Cement	56	83.78 ± 2.63	16.22 ± 2.63	32.58 ± 3.20	67.42 ± 3.20^{b}
Mud	54	85.38 ± 2.82	14.62 ± 2.82	41.10 ± 3.43	58.90 ± 3.43^{a}
Roof					
Tiles	75	85.06 ± 2.94	14.94 ± 2.94	36.96 ± 3.57	63.04 ± 3.57
Asbestos	14	85.18 ± 3.24	14.82 ± 3.24	40.59 ± 3.94	59.41 ± 3.94
Metal	21	83.51 ± 2.83	16.50 ± 2.83	32.97 ± 3.44	67.03 ± 3.44
Extra feeding				**	**

No	95	84.55 ± 2.47	15.45 ± 2.47	32.07 ± 3.00[a]	67.93 ± 3.00[b]
Yes	15	84.62 ± 3.13	15.39 ± 3.13	41.61 ± 3.81[b]	58.39 ± 3.81[a]
Littering					
Coir pith	105	83.51 ± 1.64	16.49 ± 1.64	34.31 ± 1.99	65.69 ± 1.99
Rice husk	5	85.65 ± 4.60	14.35 ± 4.60	39.37 ± 5.59	60.63 ± 5.59
Type of feed					
Mash	33	84.65 ± 3.21	15.35 ± 3.21	39.69 ± 3.91	60.31 ± 3.91
Crumble	77	84.52 ± 2.83	15.48 ± 2.83	33.99 ± 3.44	66.01 ± 3.44
Watering		*	*		
Automatic	77	86.97 ± 2.92[b]	13.03 ± 2.92[a]	35.98 ± 3.55	64.02 ± 3.55
Nipple	33	82.19 ± 2.60[a]	17.81 ± 2.60[b]	37.70 ± 3.16	62.30 ± 3.16
Population size					
< 9000	80	83.35 ± 2.41	16.65 ± 2.41	37.28 ± 2.93	62.72 ± 2.93
9001-16800	18	83.49 ± 3.20	16.51 ± 3.20	37.77 ± 3.89	62.23 ± 3.89
>16800	12	86.90 ± 3.61	13.10 ± 3.61	35.46 ± 4.39	64.54 ± 4.39

*P<0.05; **P<0.01.

Table 3. Correlation Between Different Physicochemical Characters of BPL.

Character	DM	Moisture	Ash	OM	C	pH	EC	N	K	P	Ca	Mg	Zn	Cu	Mn	Fe
Dry matter	1.00	-1.000**	-0.019	0.019	0.019	-0.534**	0.209*	0.025	0.015	-0.103	0.006	-0.858**	0.089	-0.248**	-0.020	-0.088
		0.000	0.843	0.843	0.843	0.000	0.028	0.794	0.879	0.286	0.950	0.000	0.356	0.009	0.836	0.360
Moisture	-1.00**	1.000	0.019	-0.019	-0.019	0.534**	-0.209*	-0.025	-0.015	0.103	-0.006	0.858**	-0.089	0.248**	0.020	0.088
	0.000		0.843	0.843	0.843	0.000	0.028	0.794	0.879	0.286	0.950	0.000	0.356	0.009	0.836	0.360
Ash	-0.019	0.019	1.000	-1.000**	-1.00**	0.199*	-0.035	-0.450**	0.297**	0.006	-0.123	0.015	-0.319**	0.175	0.182	0.144
	0.843	0.843		0.000	0.000	0.038	0.714	0.000	0.002	0.952	0.202	0.874	0.001	0.067	0.057	0.135
Organic matter	0.019	-0.019	-1.00**	1.000	1.000**	-0.199*	0.035	0.450**	-0.297**	-0.006	0.123	-0.015	0.319**	-0.175	-0.182	-0.144
	0.843	0.843	0.000		0.000	0.038	0.714	0.000	0.002	0.952	0.202	0.874	0.001	0.067	0.057	0.135
Organic carbon	0.019	-0.019	-1.00**	1.000**	1.000	-0.199*	0.035	0.450**	-0.296**	-0.006	0.123	-0.015	0.319**	-0.175	-0.182	-0.144
	0.843	0.843	0.000	0.000		0.038	0.714	0.000	0.002	0.953	0.202	0.875	0.001	0.067	0.057	0.135
pH	-0.534**	0.534**	0.199*	-0.199*	-0.199*	1.000	-0.301**	-0.322**	0.102	0.152	-0.190*	0.360**	-0.367**	0.182	0.045	0.054
	0.000	0.000	0.038	0.038	0.038		0.001	0.001	0.288	0.114	0.047	0.000	0.000	0.056	0.639	0.577
EC(MS)	0.209*	-0.209*	-0.035	0.035	0.035	-0.301**	1.000	0.071	0.175	0.168	0.197*	-0.084	0.132	-0.020	-0.232*	-0.442**
	0.028	0.028	0.714	0.714	0.714	0.001		0.464	0.068	0.079	0.039	0.385	0.168	0.834	0.015	0.000
N	0.025	-0.025	-0.450**	0.450**	0.450**	-0.322**	0.071	1.000	-0.261**	0.142	0.404**	-0.054	0.289**	-0.056	-0.058	-0.091
	0.794	0.794	0.000	0.000	0.000	0.001	0.464		0.006	0.139	0.000	0.576	0.002	0.561	0.550	0.343
K	0.015	-0.015	0.297**	-0.297**	-0.296**	0.102	0.175	-0.261**	1.000	0.340**	-0.135	0.015	-0.311**	0.052	-0.086	-0.093
	0.879	0.879	0.002	0.002	0.002	0.288	0.068	0.006		0.000	0.160	0.878	0.001	0.593	0.371	0.334
P	-0.103	0.103	0.006	-0.006	-0.006	0.152	0.168	0.142	0.340**	1.000	0.057	0.081	-0.209*	-0.068	0.050	-0.253**
	0.286	0.286	0.952	0.952	0.953	0.114	0.079	0.139	0.000		0.557	0.401	0.029	0.480	0.606	0.008
Ca	0.006	-0.006	-0.123	0.123	0.123	-0.190*	0.197*	0.404**	-0.135	0.057	1.000	-0.021	0.489**	0.034	-0.022	-0.302**
	0.950	0.950	0.202	0.202	0.202	0.047	0.039	0.000	0.160	0.557		0.826	0.000	0.728	0.821	0.001
Mg	-0.858**	0.858**	0.015	-0.015	-0.015	0.360**	-0.084	-0.054	0.015	0.081	-0.021	1.000	-0.087	0.355**	0.051	0.046
	0.000	0.000	0.874	0.874	0.875	0.000	0.385	0.576	0.878	0.401	0.826		0.367	0.000	0.594	0.631
Zn	0.089	-0.089	-0.319**	0.319**	0.319**	-0.367**	0.132	0.289**	-0.311**	-0.209*	0.489**	-0.087	1.000	-0.149	-0.174	-0.362**
	0.356	0.356	0.001	0.001	0.001	0.000	0.168	0.002	0.001	0.029	0.000	0.367		0.121	0.069	0.000
Cu	-0.248**	0.248**	0.175	-0.175	-0.175	0.182	-0.020	-0.056	0.052	-0.068	0.034	0.355**	-0.149	1.000	0.390**	0.324**
	0.009	0.009	0.067	0.067	0.067	0.056	0.834	0.561	0.593	0.480	0.728	0.000	0.121		0.000	0.001
Mn	-0.020	0.020	0.182	-0.182	-0.182	0.045	-0.232*	-0.058	-0.086	0.050	-0.022	0.051	-0.174	0.390**	1.000	0.468**
	0.836	0.836	0.057	0.057	0.057	0.639	0.015	0.550	0.371	0.606	0.821	0.594	0.069	0.000		0.000
Fe	-0.088	0.088	0.144	-0.144	-0.144	0.054	-0.442**	-0.091	-0.093	-0.253**	-0.302**	0.046	-0.362**	0.324**	0.468**	1.000
	0.360	0.360	0.135	0.135	0.135	0.577	0.000	0.343	0.334	0.008	0.001	0.631	0.000	0.001	0.000	

*P<0.05; **P<0.01.

3.2. Moisture

The litter moisture content ranged between 5.41 and 42.15 per cent (mean 16.96%), The type of floor (0.01), and drinkers (P<0.05) provided and integrating companies (p<0.05) were found to have a significant (P<0.05) influence on the moisture content of BPL samples (Table 2). The farms with semi-automatic bell-type drinkers had BPL with lesser moisture content than that found in farms with nipple-type drinkers. The moisture content of BPL was found to have a positive correlation (P<0.01) with pH, Mg and Cu contents, and found to have (P<0.01) negative correlation with DM content and EC (P<0.05) (Table 3).

3.3. Total Ash

The mean ash content (%) in BPL was 27.08 ±1.18, integrating companies had a significant (P<0.05) influence on ash content similarly the type of floor of the broiler farms and feeding of extra nutrients, was found to have a significant (P<0.01) effect on ash content, and the farms with cement floor had a lesser level of ash than mud floor (Table 2). The ash content was found to have a significant (P<0.01) correlation with the K content of BPL and a significant (P<0.05) positive correlation with the pH level of BPL. The ash content of BPL was found to have a highly significant (P<0.01) negative correlation with OM, OC, N, and Zn contents of BPL (Table 3).

3.4. Total Organic Matter/Total Volatile Solids

The OM of BPL was found to be affected significantly (P<0.05) by integrator companies, and the type of floor, feeding extra nutrients was found to have a highly significant (P<0.01) effect on OM of BPL. The farms with cement floors had BPL with higher levels of OM than those with mud floors. Similarly, the practice of feeding extra nutrients to the birds was also found to have a significant (P<0.01) effect on OM level of BPL (Table 2). The BPL collected from farms with the practice of feeding extra nutrients had a lesser level of OM than that found in farms without extra feeding. The OM was found to have a highly significant positive correlation (P<0.01) with OC, N, and Zn content and found to have a highly significant negative (P<0.01) correlation with ash content and K content (Table 3) and (P<0.05) pH.

3.5. Total Organic Carbon

The OC content of BPL was found to be affected by the integrator significantly (P<0.05). The BPL from the farms with cement floor was found to have a significantly (P<0.01) higher level of C than with mud floor (Table 4). The farms with extra nutrient feeding had BPL with lower levels of C than those farms not practicing extra feeding. The C content of BPL was found to have a high positive correlation (P<0.01) with OM, N, and Zn content and a negative correlation (Table 3) with ash content, K (P<0.01), C, and pH (P<0.05).

3.6. pH

The mean pH level (Table 1) of BPL collected from sampling geographical location was 8.43 ± 0.057). The pH level of BPL was found to be significantly (P<0.01) affected by the type of feed fed to broilers (Table 4). The farms fed with mash type of feed had BPL with a higher level of pH than that found in farms fed with crumble type of feed. The pH level of BPL was found to have a highly significant (P<0.01) positive correlation with moisture, Mg contents of BPL, and ash content (P<0.05) and have highly significant (P<0.01) negative correlation with DM content, EC, N, Zn content of BPL and also had significant (P<0.05) negative correlation with OM, OC and Ca contents of BPL (Table 3).

Table 4. Mean (± SE) of Organic C, pH, Electrical conductivity and N at Different Management Conditions.

Effect	n	C (%)	pH	EC (ds m[-1])	N (g kg[-1])
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Overall mean	**110**	36.72 ± 1.81	8.57 ± 0.15	5.62 ± 0.43	19.60 ± 2.20
Geographical location				**	*
Coimbatore	55	36.25 ± 1.72	8.54 ± 0.14	6.07 ± 0.41	21.25 ± 2.10[b]
Erode and Tirupur	55	37.19 ± 2.11	8.60 ± 0.18	5.17 ± 0.51	17.95 ± 2.57[a]
Integrator		*			**
Others	10	33.79 ± 2.77[a]	8.37 ± 0.23	5.74 ± 0.67	16.40 ± 3.38[a]
Shanthi	68	39.50 ± 2.22[b]	8.53 ± 0.18	5.54 ± 0.53	23.96 ± 2.70[b]
RMP	32	36.86 ± 1.87[ab]	8.82 ± 0.16	5.59 ± 0.45	18.44 ± 2.28[a]
Floor		**			
Cement	56	39.19 ± 1.86[b]	8.68 ± 0.16	5.68 ± 0.45	21.16 ± 2.27
Mud	54	34.24 ± 1.99[a]	8.47 ± 0.17	5.57 ± 0.48	18.04 ± 2.43
Roof					
Tiles	75	36.65 ± 2.08	8.44 ± 0.17	5.36 ± 0.50	20.20 ± 2.53
Asbestos	14	34.54 ± 2.29	8.55 ± 0.19	5.63 ± 0.55	22.13 ± 2.79
Metal	21	38.97 ± 2.00	8.72 ± 0.17	5.87 ± 0.48	16.46 ± 2.44
Extra feeding		**			*
No	95	39.49 ± 1.74[b]	8.57 ± 0.15	5.65 ± 0.42	21.89 ± 2.13[b]
Yes	15	33.95 ± 2.21[a]	8.57 ± 0.18	5.59 ± 0.53	17.30 ± 2.70[a]
Littering					
Coir pith	105	38.19 ± 1.16	8.57 ± 0.09	5.61 ± 0.28	18.92 ± 1.42
Rice husk	5	35.25 ± 3.25	8.57 ± 0.27	5.63 ± 0.78	20.28 ± 3.96
Type of feed			**		
Mash	33	35.06 ± 2.27	8.85 ± 0.19[b]	5.93 ± 0.54	17.83 ± 2.77
Crumble	77	38.38 ± 1.99	8.29 ± 0.17[a]	5.31 ± 0.48	21.37 ± 2.44
Watering					
Automatic	77	37.22 ± 2.06	8.52 ± 0.17	5.92 ± 0.50	18.44 ± 2.52
Nipple	33	36.22 ± 1.84	8.62 ± 0.15	5.33 ± 0.44	20.76 ± 2.24
Population size					
< 9000	80	36.46 ± 1.70	8.61 ± 0.14	6.08 ± 0.41	21.24 ± 2.08
9001-16800	18	36.18 ± 2.26	8.58 ± 0.19	5.66 ± 0.54	21.14 ± 2.76
>16800	12	37.52 ± 2.55	8.51 ± 0.21	5.12 ± 0.61	16.42 ± 3.11

*P<0.05; **P<0.01.

3.7. Electrical Conductivity (EC)

The mean EC (ds m^{-1}) was 5.74 ± 0.13 (Table 1), the geographical location (Table 4) of the farm was found to have a highly significant influence on (P<0.01) the EC level of BPL and the BPL collected from Coimbatore district had higher EC level than that found in BPL collected from farms of Erode and Tirupur districts. The EC level of BPL had a significant positive correlation with DM and Ca contents and was found to have a highly significant (P<0.01) negative correlation with pH and Fe content and a significant (P<0.05) negative correlation with moisture and Mn contents (Table 3).

3.8. Total Nitrogen

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The mean N (g kg^{-1}) content in BPL samples collected (Table 1) from the surveyed area was 24.2 ± 0.84 and ranged between 4.5 and 36.6. The N content was found to be significantly (P<0.05) affected by the geographical location of the farm (Table 4), the practice of feeding extra nutrients to the broiler birds, and the integrator company (P<0.01). The N content was found to have a highly significant (P<0.01) positive correlation with OM, OC, Ca, and Zn content of BPL and it was found to have a highly significant (P<0.01) negative correlation with ash content, pH and K content of BPL (Table 3). The mean C/N ratio of BPL samples collected from the surveyed area was 21.42 ± 1.24 and it ranged from 7.54 to 79.74 (Table 1).

3.9. Macro Plant Nutrient Analysis

The average calcium (Ca) content in BPL samples collected from the surveyed area was 22.2 g kg^{-1} (Table 1). This Ca content was significantly influenced (P<0.01) by the geographical location of the farm, the integrating company, the type of floor (P<0.05), and the practice of feeding extra nutrients (Table 5). Additionally, Ca content exhibited a highly significant positive correlation (P<0.01) with N and Zn, and electrical conductivity (P<0.05). Conversely, it had a highly significant negative correlation (P<0.01) with iron (Fe) content and pH levels (P<0.05) of BPL (Table 3).

The phosphorus (P) content in BPL ranged between 4.4 and 31.5 g kg^{-1}, with a mean value of 11.3 g kg^{-1}. The type of feed (P<0.01) and floor (P<0.05) significantly influenced P content, litter derived from mash-type feed recorded higher P content (13.95) than crumble (9.67) similarly, BPL from cement floors recorded higher P content compared to mud floors (Table 5). The P content of BPL showed a positive correlation (P<0.01) with K content and a negative correlation with Zn (P<0.05) and Fe (P<0.01) contents of BPL (Table 3).

The mean K content in BPL was 14.9 ± 1.17 g kg^{-1}. Broiler sheds with cement floors had higher K content (P<0.01) than those with mud floors (Table 5), the geographical location of the farm and type of feed also influenced the variation in K content. The K content displayed a highly significant positive correlation (P<0.01) with ash and P contents of BPL, and a highly significant negative correlation (P<0.01) with OM, OC, N, and Zn contents of BPL (Table 3).

The Mg content in BPL was not significantly affected by any of the factors listed. However, Mg content showed a significant positive correlation (P<0.01) with moisture content, pH level, and copper (Cu) content of BPL, while exhibiting a significant negative correlation (P<0.01) with the DM content of BPL (Table 3).

Table 5. Mean (± SE) of Phosphorus, Potassium, Calcium and Magnesium at Different Management Conditions.

Effect	n	Ca (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Mg (g kg^{-1})
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Overall mean	**110**	19.26 ± 2.05	11.80 ± 1.10	12.11 ± 1.59	11.42 ± 0.41
Geographical location		**		*	
Coimbatore	55	21.67 ± 1.95^b	12.34 ± 1.05	13.66 ± 1.51^b	11.43 ± 0.39
Erode and Tirupur	55	16.84 ± 2.39^a	11.28 ± 1.28	10.57 ± 1.85^a	11.41 ± 0.47
Integrator		**			
Others	10	15.15 ± 3.15^a	11.72 ± 1.69	10.96 ± 2.44	10.83 ± 0.63
Shanthi	68	24.28 ± 2.51^b	12.31 ± 1.35	13.07 ± 1.95	11.36 ± 0.50
RMP	32	18.34 ± 2.12^a	11.40 ± 1.14	12.31 ± 1.64	12.07 ± 0.42
Floor		*	*	**	
Cement	56	17.53 ± 2.11^a	12.74 ± 1.13^b	13.28 ± 1.64^b	11.47 ± 0.42
Mud	54	20.98 ± 2.26^b	10.88 ± 1.21^a	10.96 ± 1.75^a	11.37 ± 0.45
Roof					
Tiles	75	20.54 ± 2.35	11.63 ± 1.27	11.50 ± 1.82	11.54 ± 0.47
Asbestos	14	17.89 ± 2.59	10.74 ± 1.40	11.84 ± 2.01	11.26 ± 0.52
Metal	21	19.34 ± 2.27	13.06 ± 1.22	13.02 ± 1.76	11.47 ± 0.45

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Extra feeding		*			
No	95	20.96 ± 1.98	11.01 ± 1.06	10.77 ± 1.53	11.41 ± 0.39
Yes	15	17.55 ± 2.51	12.61 ± 1.35	13.47 ± 1.95	11.43 ± 0.50
Littering					
Coir pith	105	19.69 ± 1.32	10.83 ± 0.71	12.49 ± 1.02	11.48 ± 0.26
Rice husk	5	18.81 ± 3.68	12.79 ± 1.98	11.74 ± 2.85	11.36 ± 0.73
Type of feed			**	*	
Mash	33	21.56 ± 2.58	13.95 ± 1.38[b]	14.68 ± 1.99[b]	11.43 ± 0.51
Crumble	77	16.95 ± 2.27	9.67 ± 1.22[a]	9.54 ± 1.75[a]	11.41 ± 0.45
Watering					
Automatic	77	19.59 ± 2.34	12.68 ± 1.26	12.05 ± 1.81	11.10 ± 0.46
Nipple	33	18.92 ± 2.09	10.93 ± 1.12	12.18 ± 1.61	11.74 ± 0.41
Population size					
< 9000	80	19.52 ± 1.93	11.40 ± 1.04	13.03 ± 1.49	11.66 ± 0.38
9001-16800	18	21.78 ± 2.56	12.65 ± 1.38	12.22 ± 1.98	11.46 ± 0.51
>16800	12	16.47 ± 2.89	11.38 ± 1.55	11.09 ± 2.24	11.15 ± 0.58

*P<0.05; **P<0.01.

3.10. Micro Plant Nutrient Analysis

The Zn level of BPL was found to be significantly (P<0.01) affected by the integrator company (Table 6) and was found to be (P<0.01) positively correlated (Table 3) with a level of OM, C, N, and Ca content and the Zn was found to be negatively (P<0.01) correlated with ash content, pH, K, Fe and P content of BPL (P<0.05). The mean Cu content (mg kg^{-1}) of BPL collected from the surveyed area was 25.01±2.05 (Table 1). It ranged between 1.43 and 135.82 mg kg^{-1}. The manure management factor did not have any influence on the Cu content of BPL.

Table 6. Mean (± SE) of Zinc, Copper, Manganese and Iron at Different Management Conditions.

Effect	n	Zn(mg kg^{-1})	Cu(mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})
		Mean ± SE	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**
Overall mean	**110**	**161.58 ± 81.48**	**19.48 ± 7.16**	**217.94 ± 20.30**	**2435.28 ± 316.435**
Geographical location					
Coimbatore	55	183.97 ± 77.58	19.26 ± 6.82	204.95 ± 19.33	2176.14 ± 301.29
Erode and Tirupur	55	139.19 ± 94.95	19.69 ± 8.34	230.94 ± 23.66	2694.42 ± 368.74
Integrator	**				
Others	10	23.43 ±124.94	17.61 ± 10.98	215.19 ± 31.13	2746.84 ± 485.20
Shanthi	68	336.94 ± 99.77	16.16 ± 8.77	203.61 ± 24.86	1875.67 ± 387.45
RMP	32	124.37 ± 84.12	24.67 ± 7.39	235.04 ± 20.96	2683.34 ± 326.69
Floor			*		
Cement	56	127.82 ± 83.79	15.76 ± 7.36	198.66 ± 20.88	2289.51 ± 325.40
Mud	54	195.34 ± 89.70	23.20 ± 7.88	237.23 ± 22.35	2581.05 ± 348.35
Roof					
Tiles	75	190.63 ± 93.49	21.27 ± 8.22	217.05 ± 23.29	2739.71 ± 363.09
Asbestos	14	184.17 ± 103.17	19.83 ± 9.07	230.63 ± 25.71	2252.91 ± 400.67
Metal	21	109.94 ± 90.19	17.34 ± 7.92	206.16 ± 22.47	2313.22 ± 350.24
Extra feeding					
No	95	209.36 ± 78.56	21.54 ± 6.90	216.55 ± 19.58	2462.06 ± 305.09
Yes	15	113.80 ± 99.74	17.42 ± 8.76	219.34 ± 24.85	2408.51 ± 387.33
Littering					
Coir pith	105	165.64 ± 52.33	21.44 ± 4.59	200.11 ± 13.04	2278.75 ± 203.24
Rice husk	5	157.52 ± 146.29	17.52 ±12.85	235.78 ± 36.45	2591.81 ± 568.10

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Type of feed			*	**	
Mash	33	121.72 ± 102.30	18.92 ± 8.99	189.49 ± 25.49	1867.54 ± 397.30
Crumble	77	201.44 ± 90.04	20.04 ± 7.91	246.40 ± 22.44	3003.03 ± 349.66
Watering				*	
Automatic	77	148.21 ± 92.98	17.89 ± 8.17	216.50 ± 23.17	2121.99 ± 361.08
Nipple	33	174.95 ± 82.79	21.06 ± 7.28	219.39 ± 20.63	2748.58 ± 321.55
Population size					
< 9000	80	110.22 ± 76.73	23.47 ± 6.74	209.11 ± 19.12	2520.59 ± 297.99
9001-16800	18	171.01 ± 101.76	21.66 ± 8.94	218.23 ± 25.36	2285.00 ± 395.20
>16800	12	203.50 ± 114.90	13.30 ± 10.10	226.50 ± 28.63	2500.25 ± 446.22

The Cu content of BPL was found to be positively (P<0.01) correlated with moisture, Mg, Mn, and Fe contents and it was found to have a negative (P<0.01) correlation with DM content of the BPL sample (Table 3). The mean Mn content was 200.34 ± 6.004 mg kg-1 and was found to be significantly (P<0.05) influenced by type of the floor in the broiler shed and type of the feed fed to the birds. The Mn content was higher in BPL samples collected from houses with mud floors and farms feeding with crumble type of feed type and was found to be positively (P<0.01) correlated with the Cu and Fe content of the BPL sample. The Fe content of BPL was found to be significantly (P<0.01) affected by type of the feed fed to the birds and the watering system used in the farms (P<0.05) farm. The BPL samples collected from the farms providing crumble type of feed and semi-automatic bell drinkers had higher Fe content than others. The Fe content of the BPL sample was found to be positively (P<0.01) correlated with Cu and Mn content and a negative correlation with EC, P, Ca, and Zn was observed.

3.11. Physicochemical Characteristics of BPL at the Point of Utility

The mean ± physicochemical characteristics of BPL at the point of utility are presented in Table 7. The mean DM and moisture content were 77.41 ± 3.95 and 22.59 ± 3.95 % respectively. The average micro-mineral content of Zn, Cu, Mn, and Fe (mg kg^{-1}) at point of utility were 196.44 ± 13.44, 46 ± 3.55, 272.35 ± 7.13, and 4245.14± 343.92 respectively.

Table 7. Mean (± SE) Physicochemical Characteristics of BPL at Point of Utility (n = 20).

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Sl.No.	Character	Minimum	Maximum	Mean (±SE)
1	Dry matter (%)	45.81	94.39	77.41 ± 3.95
2	Moisture (%)	5.61	54.19	22.59 ± 3.95
3	Ash (%)	21.47	74.16	43.97 ± 4.76
4	Organic matter (%)	25.84	78.53	56.03 ± 4.76
5	Organic carbon (%)	15.02	45.66	32.58 ± 2.77
6	pH	6.40	8.20	6.93 ± 0.12
7	EC(ds m^{-1})	1.38	13.10	6.52 ± 0.82
8	N (g kg^{-1})	11.80	21.80	17.34 ± 0.63
9	C : N ratio	8.21	25.31	18.40 ± 1.12
10	Calcium (g kg^{-1})	10.00	27.90	16.51 ± 1.23
11	Phosphorous (g kg^{-1})	5.90	8.50	7.37 ± 0.16
12	Potassium (g kg^{-1})	6.07	19.79	14.52 ± 0.64
13	Magnesium (g kg^{-1})	4.10	34.48	14.41 ± 2.02
14	Zinc (mg kg^{-1})	139.0	405.80	196.44 ± 13.44
15	Copper (mg kg^{-1})	23.80	84.60	46 ± 3.55
16	Manganese (mg kg^{-1})	223.60	337.20	272.35 ±7.13
17	Iron (mg kg^{-1})	2400.20	8458.60	4245.14 ± 343.92

4. Discussion

4.1. Dry Matter

The mean DM content recorded (83.04 %) in this study with a range of 57.85 to 94.59 per cent is found to be concurrent within the range (40 to 60 %) reported by Kelleher et al. [23]. The average and the range found in this study is close to the results of Stephenson et al. [24] who reported (6.02 to 95.30) DM % with an average of 80.5 per cent. Chastain et al. and Hersztek et al. [25,26] reported the mean DM content of BPL as 78.5 and 44.5 per cent, respectively. The variation may be due to differences in watering system, type of shed, type of management, and other environmental factors. The DM content of BPL was found to be affected by the type of drinker. Nipple drinkers minimize the water spillage to litter is evident from higher DM content compared with semi-automatic bell drinkers. The DM was negatively correlated with moisture, pH, Mg, and Cu contents. Similarly, DM was found to be positively correlated with EC, this may be due to an increase in available mineral contents and consequently increase in EC.

4.2. Moisture

The range of moisture content recorded in the present study (Table 1) corresponds closely with the reported values of 20.35, 21.88, and 25.4 per cent respectively [10,27,28]. It is not incompatible with the reports of Sistani et al., Ogunwande et al., and Gao et al. [19,29–31] who reported higher moisture content of 44 to 47.7, 54, 78.2, and 80.9 per cent respectively. The dirt floor had lower litter moisture (14.62%) than the concrete floor (16.22%) which is in agreement with Kunkle *et al* [52] who reported 24.6 per cent liter moisture on the concrete floor and 22.3 per cent on the dirt floor. On the contrary, Abreu et al. [53] observed a similar value between the concrete floor (30.37% and mud floor (30.50%), the dirt floor had more possibility to absorb litter moisture than the impervious cement floor was the contributing factor. Similarly, The type of drinkers used in the broiler farm was found to impact the moisture content, and the BPL, samples collected from the farms with nipple drinkers had higher moisture content, and is in agreement with the observations of McMasters et al. [60] indicating higher water spilling with nipple drinkers, and modern nipple with tray can solve this, even the high flow rate of the nipple may lead to higher litter moisture content [59]. Different

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companies maintain different production management strategies particularly nutrient composition in the feed which influences the moisture content of excreta and in turn litter moisture [54]. The moisture content of the BPL was found to have a significant positive correlation with pH, Liang et al. [51] reported an increase in pH while the moisture content of litter increased, which might be due to increased absorption and retention of NH_3, when litter moisture increases which favour to protonation to NH4+ which might be a negative correlation with electrical conductivity as this may be due to dilution of mineral contents in the BPL. In this analysis, Mg and Cu are the two micronutrients that had a positive correlation with litter moisture other micro or macro minerals did not exert any significant correlation but van der Hoeven-Hangoor [55] confirmed that dietary Na, protein, P, and Ca had a positive influence on excreta moisture.

4.3. Ash

The mean (27.08 %) ash content recorded in BPL samples and its range (Table 1) was found to be in adherence with the ash content reported by Ogunwande et al. Hersztek et al. and Mathialagan and Rajkumar [10,19,26] have recorded 27.32 and 16.6 per cent respectively. Similarly, Ogunwande et al. and Fasina [30,32] reported 52.34 and 34.29 per cent respectively. Stephenson et al [24] recorded the mean ash content of 24.37 with a range of 8.9 to 54.4 per cent. The observed variation may be due to differences in floor type [24], quality of the feed ingredients, and other factors. The integrator company, floor type of the broiler farm, and practice of extra feeding had a significant effect on the ash content. This may be due to variations in the quality of the feed formulated by the integrator, the degree of scraping during the clean-out procedure, and imbalanced dilution of nutrients by feeding extra ingredients respectively. The ash content was found to have a significant ($P<0.01$) positive correlation with the K content, and pH ($P<0.05$) level of BPL and have a highly significant ($P<0.01$) negative correlation with OM, OC, N, and Zn contents of BPL. Similarly, Stephen et al. [24] reported a positive correlation between broiler litter ash content with N, P, K, Ca, Fe, Mn, and Zn and opined that it might be due to soil contamination but present observation revealed that except Ca and P, other properties did not exert any significant difference due to floor type, hence it could be concluded that the dietary variation might be the reason the ash content.

4.4. Organic Matter

The range of OM recorded in this study (Table 1) is consistent with the results obtained by Brodie et al. and Tiquia et al. [13,33] who recorded an OM content of BPL of 78.7 and 50.9 per cent respectively. The OM of the BPL samples had been determined by the integrator company, type of floor, and practice of extra feeding which may be due to increase or decrease in OM of the feed, increase in ash content, and dilution effect of the practice of extra feeding respectively. The OM had a positive correlation with OC, N, and Zn and a negative correlation with ash and K, A strong relationship between OM and OC and ash content was reported by Larney et al. [56] in feedlot manure and compost. Emeterio Iglesias Jimenez & Victor Perez Garcia [57] studied the relationship of OM to OC in municipal solid waste, compost, and city refuse compost and reported a positive correlation between OM and OC. Further, the microbial composting of BPL and subsequent degradation of OM and mineralization of N are indicated by the positive correlation.

4.5. Organic Carbon

The mean level of OC found in the survey (Table 1) is compatible with the results of Brodie et al., Mendonca Costa et al., Tiquia et al., and Kelleher et al. [13,23,34,35] who recorded 22.72 to 41.8, 45.9, 49.1, and 28 to 40 per cent respectively. Similarly, Hersztek et al., Praes et al. and Ogunwande et al. [26,27,30] reported 32.3, 30.58, and 26.4 per cent respectively. The OC was found to be affected by the integrator Company, type of floor, and practice of feeding extra nutrients and the results indicated a strong relationship between the OM and OC [56].

4.6. pH

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The range of pH recorded (Table 1) in the BPL samples is found to be in adherence with the reported results [13,28,30,36] and comparable with the values reported by Kelleher et al., Ogunwande et al., and Ravindran et al. [19,23,34] who recorded pH levels as 6.6 to 8.8, 6.35 and 6.94 to 7.97 respectively. The pH of BPL recorded in this study was found to be influenced by the type of feed, BPL from birds fed with mash-type feed recorded a higher pH than those fed with crumble. A strong positive correlation of pH with moisture, ash content, and Mg content was noticed. Higher moisture content favors protonation to NH_4+ and a subsequent increase in the pH [51] might be the reason for the positivity. A higher amount of exchangeable base in the poultry manure ash was reasoned out for an increase in the soil pH by Azeez Jamiu et al. [58]. The negative correlation of pH with DM, OM, OC, EC, N, Ca, and ZN had been observed. A strong negative correlation between pH and N was reported by Rogeri et al. [62] while characterizing the poultry litter in Brazile and Anncarol et al. [61] while composting rice straw with chicken and donkey manure. The DM, OM, and OC have closely linked parameters and their negative correlation with pH might be due to the degradation of OM by litter microbes and N mineralization.

4.7. Electrical Conductivity

The PBL sample analysis revealed that the EC recorded ranged between 1.47 and 10.05 ds m^{-1} with a mean of 6.52, which is compatible with the reports of Kelleher et al. and Ogunwande et al. [19,23] who have reported 2.0 to 9.8 and 6.8 ds m^{-1} respectively. It does not follow the reports of Gao et al and Ravindran et al. [31,34] who recorded 12.4 and 2.5 to 12.0 ds m^{-1} respectively. The geographical location of the farm was found to have a significant impact on the EC. EC of the BPL had a positive correlation with DM and Ca contents, dietary inclusion of Ca might influence this positivity. Similarly, EC had a negative correlation with pH, Fe, and Mn.

4.8. Nitrogen

The results found in this study are in accordance with the results of Bolan et al., Tabler and Berry, Hersztek et al., Praes et al., Mendonca Costa et al., and Stephenson et al. [24,26,27,35,37,39] who reported 25.7, 32.3, 24.9, 23.5,21 and 23 to 60 with a mean value of 40 g kg^{-1} respectively. However, it differs from the results obtained by Ravindran et al. [34]. The level of N in the BPL is determined by the geographical location of the farm and integrator company. The N content had a positive correlation with OM, OC, Ca, and Zn contents and a negative correlation with ash, pH, and K. The positivity of TN with K is opposed to the reports ofKaranja et al. [61] and Rogeri et al [62] but the negative correlation with pH and ash content aligns with the report of Stephen et al. [24] and Rogeri et al. [62].

The C: N ratio arrived in the study range and is found to be in adherence with the results reported by Mendonca Costa et al. and Ravindran et al. [34,35]. However, the meat value is not compatible with the values reported by Ogunwande et al., Tiquia et al., and Gao et al. [13,19,31] who reported lower C: N ratios of about 14, 14.1, and 7.48 respectively. The variation may be due to the difference in bedding material, reuse of bedding material, and storage methods employed.

4.9. Major Plant Nutrient Analysis

The range of Ca content (Table 1) found in this study coincides with reported values of 8.1 to 61.3 g kg^{-1} [23,24,34,37,38] with an average of 23.1 g kg^{-1}. Similarly, the Ca positively correlated with N, Zn, and EC and negatively correlated with Fe and pH. The level of P content observed is found to be in concomitance with the results reported by Bolan et al., Hersztek et al., Kelleher et al., and Stephenson et al. [23,24,26,37] who recorded 5.6 to 39.2 with an average of 15.6 g kg^{-1}. However, it is not similar to the results of Ravindran et al., Pessoa et al., Sharpley et al., and Tawadchai Suppadit [28,34,38,40] who reported higher values. The lower P excretion in the BPL may be due to development in nutritional concepts such as precise P dispensing mechanisms, and phytase enzyme utilization [64]. The P level in the BPL has a positive correlation with K content and a negative correlation with Zn and Fe contents of BPL. The mean K content of 14.9 g kg^{-1} found in this study

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(Table 1) conforms with Hersztek et al., Pessoa et al., and Bolan et al. [26,37,38] who recorded 29.9 7.8 and 10.12 g kg^{-1} respectively, Stephenson et al. [24] also recorded 7.3 to 51.7 with an average of 23.2 g kg^{-1}. The K content of the BPL has a significant positive correlation with ash and P and a negative correlation with OM, OC, N, and Zn contents. The mean Mg content of the BPL samples from the commercial broiler poultry farms are in concurrence with Brodie et al., and Sistani et al. [29,33], still lower values were reported by Ravindran et al., Bolan et al., and Kelleher et al. [23,34,37,39] who reported 0.31 to 4.03, 3.5, 5 g kg^{-1} respectively]. The factors of broiler farm management do not affect Mg and it has a significant positive correlation with moisture, pH, and Cu and a negative correlation with DM content.

The Ca, P, and K content in the BLP is influenced by the floor type in which the birds are being reared, mud floors contribute more of Ca, and cement concrete floors contribute more of P and K, similarly, geographical location affects Ca and K content of BPL. The nutritional aspect was also found to influence macro mineral excretion, the farms that practice feeding with mash type of feed were found to have more P and K in BPL, and the uniformity and precision in the feeding of P and K in the crumble feed preparation might be the reason. The P has a positive correlation with K and P and K have a negative correlation with Zn. Ca and P have a negative correlation with Fe, the interrelationship of these minerals in the broiler diet might be the reason for this correlation.

4.10. Micro Plant Nutrient Analysis

The BPL samples Zn levels observed are consistent with previous reports by Pessoa et al., Sistani et al., and Van Ryssen [29,38,42], who recorded Zn levels of 71, 436, and 254 mg kg^{-1}, respectively. Similar findings were also reported by Ravindran et al. and Sturgeon [34,43]. Stephenson et al. [24] recorded Zn levels between 106 and 669 mg kg-1, with an average of 315 mg kg^{-1}. The Cu content of BPL obtained is in line with the findings of Hersztek et al., Tawadchai Suppadit, and Lopez-Mosquera et al. [26,28,41], who reported Cu levels of 42.0, 70.8, and 71.3 mg kg-1, respectively. However, higher concentrations were recorded by Pessoa et al. and Ravindran et al. [34,38], with levels ranging from 621 to 2412 mg kg-1. Stephenson et al. [24], in their survey on broiler litter, recorded Cu levels between 25 and 1003 mg kg-1, with an average of 473 mg kg^{-1}. The manganese (Mn) level in this survey is within the range recorded by Stephenson [24]. Similar findings have also been reported by Van Ryssen, Tawadchai Suppadit, and Lopez-Mosquera et al. [28,41,42]. However, slightly higher levels of Mn (500 mg kg^{-1}) were reported by Brodie et al. [33] and 728.3 mg kg^{-1} by Pessoa et al. [38]. The type of floor and feed used in the farms were found to influence the Mn content. The iron (Fe) content in the BPL samples concurs with reports by Pessoa et al. and Sistani et al. [29,38], who recorded Fe levels of 4122 and 1055 mg kg^{-1}, respectively. Lower levels were reported by Sturgeon [43] (695 mg kg-1), while higher ranges were reported by Stephenson et al. [24] (529 to 12604 mg kg-1, with an average of 2377 mg kg^{-1}). Factors such as the type of feed and watering system influence the Fe content. Except for the influence of integrating company (Zn), floor type (Mn), and feed type (Mn and Fe) watering method (Fe), none of the manure management factors influence the micro-mineral profile. Cu, Fe, Mn, and Zn (with Fe) are positively correlated, which might be due to the natural interrelationship of these micro-minerals. Their relationships with micro-minerals are discussed in the respective chapter. Fe and Mn have a negative correlation with electrical conductivity (EC), while Zn has a negative correlation with ash, OM, and OC, and a positive correlation with pH and N content.

4.11. Physicochemical Characteristics of BPL at the Point of Utility

The DM, OM, and OC contents in BPL samples collected at the point of utility were found to be lower compared to the results obtained from the in-house BPL samples, which accounted for approximately 6.8, 19.9, and 23.15 per cent respectively. The reduction in these contents could be attributed to the biodegradation of OM during the storage process. This finding is consistent with the results reported by Xingjun Lin et al. [44], who observed a 20.8 % DM loss, and 27 per cent OC loss, and suggested that aerobic digestion and anaerobic decomposition might be the underlying reasons.

The pH of the in-house litter was 8.43, whereas the pH of BPL at the point of utility was 6.93, indicating a 17.79 % decline. This decline suggests that the litter material reached the pH stabilization phase. The change in pH could be attributed to the transformation of N and carbon, lignocellulose carbon degradation [45,46], and the production of organic acids and carbon dioxide. However, it is noteworthy that Xingjun Lin et al. [44] observed a higher pH after the storage of chicken manure.

The mean electrical conductivity (EC) (dS m^{-1}) was approximately 6.52, which is 13.59 per cent higher than that of the in-house BPL (5.74). The higher EC could be attributed to higher OM loss and concentrations of mineral salts. This highlights the necessity of proper composting of BPL before using it as a soil amendment, as safe and stable compost should ideally have an EC of 3 dS m^{-1} [47–49].

Compared to the in-house total Kjeldahl nitrogen (N) content (24.2%), there was a significant reduction in N at the point of utility (17.34%), accounting for a 28.3 per cent loss of TKJN. The long-term storage in the open field and moisture loss during storage, combined with ammonia volatilization, could be the reasons for the N loss. Xingjun Lin et al. [44] reported a 38.6 per cent loss of N from conventionally cage-reared poultry manure stored for 202 days and found a positive correlation between N loss and moisture content. However, in our observation, the mean moisture content of stored manure was 22.59 per cent, which was approximately 33.12 per cent higher than that of the in-house samples, and no significant correlation between moisture and N content was observed. The C:N ratio of BPL at the point of utility was 18.4, which was lower than that of the in-house BPL (21.42), accounting for a 14.1 per cent decline. This decline is likely due to the loss of N and OM during the storage period, in agreement with Pablo Tittonell et al. [50], who reported a reduction in C:N following long-term open-air storage of cattle manure.

The long-term storage of BPL at the point of utility resulted in a high loss of macro minerals such as Ca, P, K, and Zn, at rates of 25.64, 34.78, 2.55, and 28.0 per cent respectively. Leaching of minerals during open-field storage may be the reason for this loss, as similarly reported by Xingjun Lin et al. [44], who found an average loss of 11 per cent P and 10.2 per cent K while storing chicken manure for 202 days. On the other hand, high concentrations of Mg (24.22%), Cu (83.93%), Mn (35.94%), and Fe (78.98%) were recorded, which may be attributed to the loss of OM during the long storage period.

5. Conclusions

The in-house BPL from commercial poultry farms is a rich source of plant nutrients, their physiochemical analysis revealed that BPL is rich in OM, C, N and is also rich in macro and micro plant nutrients. The study revealed the type of floor in the rearing house played a vital role in the physiochemical properties of BPL, particularly on the ash, OM, OC, Ca, P, and K content, the type of drinker (nipple Vs bell-type) played a major role in litter moisture and DM. The pH of the BPL had a positive correlation with moisture and ash content and showed negativity to DM, OM, OC, EC, and N content. The inter-relationship between OM, OC, and N is established by its positive correlation. The BPL after prolonged storage revealed a loss of DM, OM, and OC and a substantial increase in EC warrant proper composting before using BPL as soil amendment. The long-term storage leads to a loss of plant nutrients like Ca, P, K, and Zn, while concentration minerals like Mg, Cu, Mn, and Fe tend to escalate.

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References

1. Report, 2023. India Poultry Market Report by End Use (Food Services, Households), Distribution Channel (Traditional Retail Stores, Business to Business (B2B), Modern Retail Stores), and Region 2023-2028 accessed from: https://www.imarcgroup.com/indian-poultry-market
2. Mehta Rajesh and Nambiar, R.G. (2007). The poultry industry in India, paper presented in Poultry in the 21st Century: avian influenza and beyond, International Poultry Conference Bangkok, 5-7, November 2007, pp 1-61.
3. Chatterjee R. N. and Rajkumar, U. (2015). An overview of poultry production in India. Indian Journal of Animal Health, 54(2):89-108.
4. FAO. 2023. World Food and Agriculture – Statistical Yearbook 2023. Rome. https://doi.org/10.4060/cc8166en
5. BAHS, 2023. Basic Animal Husbandry Statistics – 2023, Government of India, Ministry of Fisheries Animal Husbandry and Dairying, Department of Animal Husbandry and Dairying, Krishi Bhavan, New Delhi, India. https://dahd.nic.in/sites/default/filess/BAHS2023.pdf
6. Thirunavukkarasu M; Sivakumar K; Ramesh V; Purushothaman Mr; Murali N; Mahimairaja S. A Survey Profile on Broiler Poultry Litter Production and Disposal in Tamil Nadu, India. Int. J. Curr. Microbiol. App. Sci. 2019; 8(12): 782-789. https://doi.org/10.20546/ijcmas.2019.812.102
7. Huang, J; Yu , Z; Gao H; Yan, X;, Chang, J; Wang C. Chemical structures and characteristics of animal manures and composts during composting and assessment of maturity indices. PLoS ONE; 2017;12(6): https://doi. org/10.1371/journal.pone.0178110
8. Dev Raja and Antil, R.S. Evaluation of maturity and stability parameters of composts prepared from farm wastes. Archives of Agronomy and Soil Science. 2012; 58:817–832
9. Ko, H.J; Kim, K.Y; Kim, H.T; Kim, C.N; Umeda, M. Evaluation of maturity parameters and heavy metal contents in composts made from animal manure. Waste Manage, 2008; 28:813–820.
10. Mathialagan, P; N. Vimal Rajkumar. 2012; Renewable energy (Poultry litter). Final Report submitted to Tamil Nadu Energy Development Agency, Government of Tamil Nadu, India.
11. Melony Wilson,V.M; Daniels; M; Nathan Slaton; Van Devender, K. Sampling Poultry Litter for Nutrient Content. Cooperative Extension Service, University of Arkansas. 2008; FSA9519-PD-9-06N.
12. APHA, Standard Methods for the Examination of Water and Wastewater. 20th Edition, American Public Health Association, American Water Works Association and Water Environmental Federation, Washington DC, 1995.
13. Tiquia, M.S.; Wan, H.C.; Nora F.Y. T. Microbial Population Dynamics and Enzyme Activities During Composting, Compost Science & Utilization, 2002, 10, 150-161.
14. USCC. Test Methods for the Examination of Composting and Compost USA Composting Council, Bethesda, MD, USA, 2002.
15. Qasim, W.; Lee, M.H.; Moon, B.E.; F.G. Okyere, F.G.; Khan, F.; Nafees, M.; Kim. H.T. Composting of chicken manure with a mixture of sawdust and wood shavings under forced aeration in a closed reactor system. *Inter. J. of Recy. of Org. Was. in Agri.*, 2018 7:261-267.
16. Allison, L.E. Organic carbon: In: Blacck, C.A.; Evans, D.D.; White, J.L.; Ensiminger, L.E.; Clark, F.E.; Dinauer (Editors), Methods of soil analysis, Part 2: Chemical and Microbiological properties. SSSA, Madison, WI, 1965, pp.367-378.
17. Rynk, R., Van de Kamp, M.; Willson, G. B.; Singley, M. E.; Richard, T. L.; Kolega, J. J.; Gouin, F. R.; Laliberty Jr.L.; Kay, D.; Murphy, D.W.; Hoitink, H. A. J.; Brinton, W. F. On-Farm Composting Handbook, NRAES-54, Natural Resources, Agriculture, and Engineering Service, Cooperative Extension, 152 Riley-Robb Hall, Ithacy, NY, 1992, 14853-5701.
18. Barrington, S., Choiniere, D.; Trigui, M;. Knight, W. Effect of carbon source on compost nitrogen and carbon losses. *Bioresour. Technol*., 2002, 83: 189–194.
19. Ogunwande G.A.; Lawrence A.O.; Ogunjimi, James A. Osunade. Fate of compost nutrients as affected by co-composting of chicken and swine manures. *Int. Agrophy*., 2014, 28: 177-184. doi: 10.2478/intag-2014-0006.

20. AOAC. Official methods of analysis, 20th edn, Gaithersburg, USA, 2016.
21. Zhu, N.; Deng, C.; Xiong Y.; Qian, H.. Performances Characteristics of three aeration systems in the swine manure composting. *Bioresour. Technol*., 2004, 95: 319-326.
22. Snedecor, G.W.; Cochran, W.G. Statistical methods, 8th Edition, Iowa State Press, USA. 1996, pp. 254-268.
23. Kelleher, B. P.; Leahy, J. J.; Henihan, A. M.; O'Dwyer, T. F.; Sutton, D.; Leahy, M. J. Advances in poultry litter disposal technology – a review. *Bioresour. Technol*., 2002, 83:27–36.
24. Stephenson, A.H,; McCaskey, T.A.; Ruffin, B.G. A survey of broiler litter composition and potential value as a nutrient resource. *Biological Wastes*, 1990, 34(1): 1-9
25. Chastain. J.P,; Camberato, J.J.; Skewe, P. Poultry Manure Production and Nutrient Content. In: Poultry Waste Management Handbook, 1999, NRAES.
26. Hersztek.M.; Gondek K.; Klimkowicz-Pawlas A.; Baran A. Effect of wheat and miscanthus straw biochars on soil enzymatic activity, ecotoxicity, and plant yield. *International Agrophysics*, 2017, 31: 367–375. https://doi.org/10.1515/intag-2016-0063.
27. Praes, M.F.F.M.; Lucas Junior, J.; Duarte, K.F.; Sorbara, J.O.B.; Matos Junior J.B.; Sgavioli, S.; Domingues,C.H.F.; Garcia, R.G; Hermes, R.G. Reduced Nutrient Excretion and Environmental Microbial Load with the Addition of a Combination of Enzymes and Direct-Fed Microbials to the Diet of Broiler Chickens. *Brazilian J. of Poultry Science*, 2016, 18(1):125-132.
28. Tawadchai Suppadit. Effects of pelleting process on fertilizing values of broiler litter. *J. ISSAAS*, 2009, 15(2): 136 -146.
29. Sistani, K.R.; Brink, G.E.; McGowen, S.L.; Rowe, D.E.; Oldham, J.L.. Characterization of broiler cake and broiler litter, the by-products of two management practices. *Bioresour. Technol*., 2003, 90: 27–32.
30. Ogunwande G.A.; Ogunjimi L.A.O.; Fafiyebi J.O. Effects of turning frequency on composting of chicken litter in turned windrow piles. *Int. Agrophysics*, 2008, 22: 159-165.
31. Gao, M.; Li, B.; Yu, A.; Liang, F.; Yang, L.; Sun, Y. The effect of aeration rate on forced-aeration composting of chicken manure and sawdust. *Bioresour. Technol*., 2010, 101: 1899–1903.
32. Fasina O.O. Flow and Physical Properties Of Switchgrass, Peanut Hull, And Poultry Litter. Transactions of the ASABE., 2006, 49(3): 721–728.
33. Brodie, H.L.; Carr, L.E.; Condon, P. A comparison of static pile and turned windrow methods for poultry litter compost production. *Compost Sci. Util*., 2000, 8: 178-189.
34. Ravindran, B.; Hupenyu A.; Mupambwa, Sibongiseni Silwana, Pearson N.S.; Mnkeni. Assessment of nutrient quality, heavy metals, and phytotoxic properties of chicken manure on selected commercial vegetable crops. *Heliyon*, 2017, 3:1-17. https://doi.org/10.1016/j.heliyon.2017.e00493.
35. Mendonca Costa, M.S.; Silva de, F.H.; Bernardi, L.A.; Mendonca Costa, D.C;. Pereira, H.E.E.; Francisconi Lorin, M.A.T.; Rozatti, Carneiro, L.J. Composting as a cleaner strategy to broiler agro-industrial wastes: Selecting carbon source to optimize the process and improve the quality of the final compost. *J. Cleaner Prod*., 2017, 142: 2084-2092.
36. Coufal, C.D.; Chavez, C.; Niemeyer, P.R.; Carey, J.B. Nitrogen emissions from broilers measured by mass balance over eighteen consecutive flocks. *Poult. Sci*., 2006, 85: 398-403.
37. Bolan, N.S.; Szogi, A.A.; Chuasavathi, T.; Seshadri, B.; Rothrock, M.J. Panneerselvam, P. Uses and management of poultry litter. *World's Poult. Sci. J*., 2010, 66: 673–698.
38. Pessoa, S.M.; Heredia Zárate, N.A.; Vieira, M.C.; Cardoso, C.A.L.; Poppi, N.R.; Formagio, A.S.N.; Silva, L.R. Total biomass and essential oil composition of OcimumgratissimumL.in response to broiler litter and phosphorus. *Rev. Bras. Pl. Med., Campinas*., 2015, 17(1):.18-25.
39. Tabler, G.T.; Berry, I.L. Nutrient Analysis of Poultry Litter and Possible Disposal Alternatives. *Avian Advice*., 2003, 32(5):6-8.
40. Sharpley, A.; Slaton, N.; Tabler, Jr.T.; VanDevender, K.; Jones, F.; Daniel, T. Nutrient analysis of poultry litter. *Arkansas Coop. Ext. Ser*. .2009, FSA9529.
41. Lopez-Mosquera, M.E.; Cabaleiro, F.; Sainz, A. Lopez-Fabaa, M.J.; Carral, E. Fertilizing value of broiler litter: Effects of drying and pelletizing. *Bioresour. Technol*., 2008, 99: 5626–5633.
42. Van Ryssen, J.B.J. Poultry litter as a feedstuff for ruminants: A South African scene. SA-ANIM SCI, 2001, 2: 1-8. http://www.sasas.co.za/Popular/Popular.html 1 .
43. Sturgeon, L.E. Fertilizer value of densified broiler litter. MS Thesis Submitted to the Graduate Faculty of Auburn University, USA, 2008.

44. Lin X; Zhang R; Jiang S; El-Mashad H. Losses of Solids, Moisture, Nitrogen, Phosphorus, Potassium, Carbon, and Sulfur from Laying-Hen Manure in Storage Facilities. Water Air Soil Pollut. 2017;228:102. DOI: 10.1007/s11270-017-3275-y.
45. Onwosi CO; Igbokwe VC; Odimba JN; Eke IE; Nwankwoala MO; Iron IN; Ezeogu LI. Composting technology in waste stabilization: On the methods, challenges and future prospects. J Environ Manage. 2016;190:140-157. https://doi.org/10.1016/j.jenvman.2016.12.051.
46. Xu WP; Reuter T; Xu XP; Hsu YH; Stanford K; McAllister TA. Field scale evaluation of bovine-species DNA as an indicator of tissue degradation during cattle mortality composting. Bioresour Technol. 2011;102:4800-4806.
47. Murshid N; Yaser AZ; Rajin M; Saalah S; Lamaming J; Taliban M. Vegetable waste composting: a case study in Kundasang, Sabah. Borneo Science the Journal of Science and Technology. 2023; 4(1):1-16. DOI: 10.51200/bsj.v43i1.4405 volume 4(1).
48. Gao M; Li B; Yu A; Liang F; Yang L; Sun Y. The effect of aeration rate on forced-aeration composting of chicken manure and sawdust. Bioresour Technol. 2010;101(6):1899–1903.
49. Rawoteea SA; Mudhoo A; Kumar S. Co-composting of vegetable wastes and carton: Effect of carton composition and parameter variations. Bioresour Technol. 2017; 227:171–178.
50. Tittonell P; Rufino MC; Janssen BH; Giller KE. Carbon and nutrient losses during manure storage under traditional and improved practices in smallholder crop-livestock systems—evidence from Kenya. Plant Soil. 2010; 328:253–269.
51. Liang, W.-Z; Classen, J. J; Shah, S. B; Sharma-Shivappa, R. Ammonia Fate and Transport Mechanisms in Broiler Litter. *Water, Air, & Soil Pollution*. 2014; 225(1). DOI: 10.1007/s11270-013-1812-x.
52. Kunkle WE; Carr LE; Carter TA; Bossard EH. Effect of flock and floor type on the levels of nutrients and heavy metals in broiler litter. Poultry Science 1991; 60:1160-1164.
53. Abreu VMN; Abreu PG de; Jaenisch FRF; Coldebella A; Paiva DP de. Effect of Floor Type (Dirt or Concrete) on Litter Quality, House Environmental Conditions, and Performance of Broilers. Brazilian Journal of Poultry Science. 2011; 13(2): 127-137.
54. Francesch M and Brufau J. Nutritional factors affecting excreta/litter moisture and quality., 2004; 60(1):64-75. DOI: https://doi.org/10.1079/WPS20035
55. Van der Hoeven-Hangoor E; Paton ND; van de Linde IB; Verstegen MW; Hendriks WH. Moisture content in broiler excreta is influenced by excreta nutrient contents. J Anim Sci. 2013;91(12):5705-13. doi: 10.2527/jas.2013-6573. Epub 2013 Oct 14. PMID: 24126278.
56. Larney Francis J.; Benjamin H. Ellert; Andrew F. Olson. Carbon, ash, and organic matter relationships for feedlot manures and composts. Canadian Journal of Soil Science. 2005; 85(2):261-264. DOI: 10.4141/S04-060
57. Emeterio Iglesias Jimenez; Victor Perez Garcia. Relationships between Organic Carbon and Total Organic Matter in Municipal Solid Wastes and city refuse composts. Bioresource Technology. 1992; 41(3); 265-272. DOI: 10.1016/0960-8524(92)90012-M
58. Azeez Jamiu; Adeyemo Eyitomilayo; Olowoboko Toyin; Afolabi Tahjudeen. Agronomic Evaluation of Manure Ashes: Effect on Soil Reaction and Electrical Conductivity. Jordan Journal of Earth and Environmental Sciences. 2020; 11 (2): 86-92.
59. Quilumba C; Quijia E; Gernat A; Murillo G; Grimes J. Evaluation of different water flow rates of nipple drinkers on broiler productivity. J Appl Poult Res. 2015;24(1):58-65. DOI: 10.3382/japr/pfv005.
60. McMasters JD; Harris GC Jr; Goodwin TL. Effects of nipple and trough watering systems on broiler performance. Poult Sci. 1971;50(2):432-435. doi: 10.3382/ps.0500432.
61. Anncarol W Karanja; Ezekiel M. Njeru; John M. Maingi . Assessment of physicochemical changes during composting rice straw with chicken and donkey manure. International Journal of Recycling of Organic Waste in Agriculture. 2019;8; 65-72. https://doi.org/10.1007/s40093-019-0270-x
62. Rogeri DA; Ernani PR; Mantovani A; Lourenço KS. Composition of poultry litter in southern Brazil. Rev Bras Cienc Solo. 2016;40:e0140697. doi: 10.1590/18069657rbcs20140697.

63. Li MX; He XS; Tang J; Li X; Zhao R; Tao YQ; Wang C; Qiu ZP. Influence of moisture content on chicken manure stabilization during microbial agent-enhanced composting. Chemosphere. 2021;264; 2; 128549. doi: 10.1016/j.chemosphere.2020.128549.
64. Ashworth AJ; Chastain JP; Moore PA Jr. Nutrient Characteristics of Poultry. In: Animal Manure: Production, Characteristics, Environmental Concerns and Management. Waldrip HM; Pagliari PH; He Z; editors. ASA Special Publication 67. Madison, WI: ASA and SSSA; 2019. p. 5585. doi:10.2134/asaspecpub67.c5.