Investigation and characterisation of poultry litter as a soil nutrient through composting using a statistical approach

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Abstract— The need for organic recycling is justified in the case of poultry waste because after ensuring hygienization there is a chance of obtaining a compost with substantial fertilizer value. The output of poultry manure has expanded as a result of the poultry industries rapid expansion, and in certain situations, this unplanned discharge of manure to the soil has had unfavorable environmental effects. The experiment was carried out within 60 days in 45*30 *18 (L*W*H) composting bin at laboratory condition. The thermophilic phase was reached within 21 days in all the combination, with a range of 24^0C to 56^0C. The temperature in the poultry waste and leaf litter combination decrease to ambient temperature at the end of 45 days towards. The Five different combinations of raw material i.e. leaf litter and poultry litter were used in preparation of compost. Physiochemical properties of compost were determined by the standard procedure. The objective of the study was to examine the impact of poultry compost application on different combination like control, 25%, 50%, and 75% and observation of soil health and nutrient levels in crops. The results showed that compost extract provided more nutrients in compost. The composting rate and different time intervals significantly ($p < 0.05$) affected the results. The seed germination index (GI), which is a necessary in many national standards, is a frequently used indication of compost maturity. Use of aqueous extracts in seed germination assays was examined for the primary phytotoxicity parameters influencing seed germination in compost. The research described in this article shows the suitability of seeds through germination bioassays and phytotoxicity of poultry composts. It also shows use of poultry litter and leaf litter bio compost as a soil nutrient.

Keywords: **Poultry litter, Leaf litter, Compost, Germination index**

1. INTRODUCTION

Compost is commonly defined as the aerobically stabilized or matured organic matter, although anaerobic processes can also lead to the production of a stabilized (or matured) organic material. A desired use of compost is its application to crops with the goal to enhance plant growth. High quality compost should be both mature and stable. A differentiation between the terms maturity and stability has been discussed in the literature [1] [2], [3]. The production of poultry litter has expanded dramatically with the growth of the poultry industry. Poultry farmers around the world are concerned about how to use or dispose off their products in a way that won't harm the environment. Poultry litter is recognised as the most valuable organic resource for fertilising because of its high level of plant nutrients. Among the various animal wastes produced by poultry industry in Nigeria is chicken manure. It has microorganisms in it that came from bedding and excrements [4]. The negative environmental effects from improper manure disposal can include odour, disease spread, nitrate leaching, and ground water contamination. Fresh Chicken manure application causes environmental issues like high pathogen and antibiotic concentration, among others. Fresh chicken manure has another significant problem as it cannot be applied to crops due to its caustic impact on the foliage [5].

Although litter utilisation technique is constantly being improved, land application is still the best solution. One of the largest and fastest expanding agro-based industries in the world is the poultry industry. Because it is accepted by most societies and has a comparatively low cholesterol content, poultry meat is in higher demand. Numerous environmental issues currently affect the poultry industry. The accumulation of a large amount of waste, by intensive industry, is one of the main issues. If the environmental and economically sustainable management systems are not developed, the large- scale accumulation of these wastes may cause disposal and contamination issues [6], [7]. Composting is a highly effective way to recycle biodegradable wastes since it kills pathogens, reduces toxic gas emissions and wastes volume, suppresses plant diseases and pests, and minimise phytotoxicity of the wastes when they are mixed into the soil. The indigenous microorganisms usually denote specific mixed culture of known, beneficial microorganisms that are being used effectively as microbial inoculants. They could exist naturally in soil or added as microbial inoculants to soil where they can improve soil quality, enhance crop production and create more sustainable agriculture and environment [8]. By venting or turning, aeration can be provided. The heap homogenization is a key benefit of the turning procedure [9]. Commonly, it is thought that the frequency of turning has an impact on both the kinetics of composting and the compost quality [10]. Lack of oxygen in composting materials resulted in lower temperature, decreased microbial activity, non- uniform moisture and temperature, anaerobic conditions and limited decomposition [11], as well as an increase in greenhouse gas emission (such as N_2O, and CH_4), the production of odours (H_2S), the lengthening of composting process, and decreases the compost quality [12].

However, excessive aeration can lead to heat loss, moisture loss, longer composting times, increased nutrient losses, and a slower composting process [13], among other negative effects. Aeration, whether active or passive, is still a crucial components of composting, with active aeration performing better since it accelerates maturity by 37.30% compared to passive (natural) aeration [14]. Composting provides the stabilization of organic matter and the elimination of pathogens, transforming waste into organic compost, which can be applied to soil. Some factors must be taken into consideration so that the process can occur efficiently by microorganisms: which are temperature, moisture, aeration, C/N ratio, time, particle size of the material and content of nutrients [15]. The study concluded that the intensification of plowing in the piles decreased the composting time, since the presence of oxygen in mass increases the speed of oxidation, accelerating the degradation of organic matter. On the other hand, it can represent increases in the cost of labour and makes it an economically unviable activity, although the decrease of the composting time with plowings allows dimensioning a smaller area for the composting yard [16], [17].

The purpose of the study was to evaluate the applicability and impact of composting from the poultry industry waste in combination with leaf litter which can be used safely in the environment as a soil nutrient. During the composting an attempt was made to add leaf litter in the compost as it is one of the source of nutrients and organic matter. Analysis of physicochemical characteristics of the Final compost combinations is done and germination indices for several seeds were also determined.

2. MATERIALS AND METHODOLOGY

2.1 Collection of waste:

Poultry litter was gathered from the nearby Kagal poultry farm, while plant leaf litter was gathered from the Shivaji University campus. After collection, the waste was air dried. The poultry litter was then kept under shade at room temperature for subsequent physico-chemical and phototoxic analysis.

2.2 Compost Combination preparation:

The source materials such as poultry manure, and leaf litter were analyzed for their Moisture, Organic Carbon, Nitrogen and The Total Organic Carbon (calculated by multiplying organic carbon (%) by a factor of 1.3) [18]. The percentage values were converted into numerals for the preparation of compost mixtures [19]. Experiment design was followed by:

Table No. 1: Feed stock Combination and percentage

Treatment	Feedstock	%
T1	Poultry Litter Control	100%
T2	Leaf Litter Control	100%
T3	Poultry litter + Leaf Litter	25%
T4	Poultry litter + Leaf Litter	50%
T5	Poultry litter + Leaf Litter	75%

2.3. Composting Experiment:

The composting bin experimental design was a 45*30*18 (L*W*H) completely randomized block design with five replicates. Walls of compost bins were made up of plastic blocks having aeration net of 3 cm width. Temperature prevailed at one side of the compost yard and the compost bins were monitored using compost thermometer. To maintaining the level of inoculums in consortium used for composting, log phase cultures with a culture density of 10^7 CFU/ml were maintained. To achieve this, growth curve and generation time of the organism were ascertained [20]. Using the above methods for characterising composting materials, the final compost extract was examined for its physico-chemical characteristics (pH, EC, TC, TN, TP, TK, Ca, Mg, and Na). The analysis of variance (ANOVA) on the data from each treatment and compost combination (Table no.3). To determine the relationships between the parameters, correlations were performed (Table No. 4). Utilizing a passively aerated composting technique based on earlier composting research by [21],[22] poultry waste was combined with leaf litter. According to the method used for characterization above, samples of mature and stabilized compost were taken at the end of composting and analyzed for their physico-chemical properties. Table no.2 the physico-chemical properties analyzed for the final compost.

2.4 Germination Index:

A modified technique is used in the germination bioassay (seed germination index) test. In this test for phytotoxicity, corn, soybean, brinjal, and tomato seeds were used. An aqueous extract of compost was prepared by mixing 10 g fresh solid compost with 100 ml deionised water, shaking the mixture for 1 hr and filtering it through a Whattman filter paper No. 42. Then, 5 ml of the supernatant (or deionised water for the control) was added to seeds (10 seeds per Petri dish) and the seeds were incubated at 25^0C in the dark [23]. A different treatment of the compost like 25%, 50%, 75% filtrate was prepared and the three replicates were run, separately for each type of Treatment of compost. The temperature was maintained within the optimum temperature germination range for all seeds used throughout the study. The seed germination percentage and root length were measured after an incubation period of seven days and were expressed as a percentage of the corresponding values of the control [24], [25]. Seeds with root lengths less than 2 mm were not rendered for seed germination. The test result were analysed by [26] Eqs., including the seeds germination (SG), the relative seed germination (RSG), the relative radical growth (RRG), and the seed germination index (GI) as follows:

$$SG = \frac{Number\ of\ Germinated\ Seeds}{Number\ of\ Total\ Seeds} \times 100\% \quad (1)$$

$$RSG = \frac{Number\ of\ Germinated\ Seeds\ (Sample)}{Number\ of\ Germinated\ Seeds\ (\ Control)} \times 100\% \quad (2)$$

$$RRG = \frac{Total\ radicles\ length\ of\ germinated\ seed\ (Sample)}{Total\ radicle\ lengthof\ germinated\ seed\ (Control)} \times 100\% \quad (3)$$

$$GI = RSG \times RRG \times 100\% \quad (4)$$

$$GI = \frac{GI50\%\ + GI\ 75\%}{2} \times 100\% \quad (5)$$

$$GI = \frac{GI\ 25\% + GI50\%\ + GI\ 75\%}{3} \times 100\% \quad (6)$$

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3. RESULTS AND DISCUSSION

Table No. 2. Analysis of physico-chemical parameters of Poultry litter (PL) and leaf litter (LL) compost

Conc	Days & Parameters	pH	EC µS/cm	OC %	OM %	WHC %	MC %	N %	P %	C:N %	Ca %	Mg %	Na %	K %	Cu mg/kg	Zn mg/kg	Cd mg/kg	Cr mg/kg	Ni mg/kg	Pb mg/kg	Mn mg/kg
T1 (PL cnt)	**15 Days**	9.77	4.12	29.14	50.24	36.94	35.21	1.03	1.86	28.29	7.88	0.75	1.73	4.52	18.23	40.23	4.02	29.32	9.56	16.45	20.23
	30 Days	8.6	3.31	36.8	63.44	26.36	32.02	0.98	4.7	37.55	0.84	0.98	0.74	0.74	15.23	34.56	3.56	28.33	13.46	19.54	18.75
	45 Days	7.27	3.45	31.23	53.84	83.17	40.52	1.54	3.12	20.28	1.24	0.78	0.72	0.82	16.56	34.75	2.45	15.62	15.21	19.99	21.24
	60 Days	7.9	4.25	42.37	73.05	37.37	42.9	1.55	3.42	27.34	1.09	1.01	0.77	1.07	12.85	29.56	0.79	9.86	12.78	23.75	22.56
T2 (LL cnt)	**15 Days**	7.44	3.11	20.07	34.60	28.05	38.45	1.07	0.69	18.75	5.95	0.48	1.92	4.46	13.23	35.63	2.45	28.96	7.45	16.14	18.45
	30 Days	8.2	3.72	29.21	50.36	49.22	33.25	1.12	0.87	26.08	0.98	0.79	1.02	0.72	15.02	35.61	2.62	25.63	8.21	19.27	19.12
	45 Days	7.3	3.78	30.86	53.20	86.56	42.45	1.09	3.57	28.31	1.17	0.78	0.94	0.89	12.32	28.9	1.25	18.91	9.52	22.41	19.78
	60 Days	7.36	4.11	40.1	69.13	64.26	46.9	1.21	3.9	33.14	0.98	0.99	1.03	0.83	9.23	25.45	0.85	10.96	10.24	24.74	21.99
T3 (PL + LL (25%)	**15 Days**	7.08	5.05	23.62	40.72	25.06	30.02	1.05	3.29	22.49	8.01	0.89	3.01	6.61	22.12	49.56	3.62	35.56	7.12	18.21	24.12
	30 Days	8.48	4.61	35.43	61.08	15.4	42.63	1.07	3.33	33.11	1.11	0.86	2.17	0.77	18.16	44.63	2.65	21.99	9.47	20.14	29.32
	45 Days	7.86	5.78	47.31	81.56	49.73	44.88	1.17	2.38	40.44	1.45	1.02	2.15	1.65	14.62	38.91	0.95	14.24	12.46	22.7	34.12
	60 Days	7.7	5.46	48.22	83.13	51.12	50.76	1.52	2.94	31.72	1.76	1.15	2.24	1.74	10.45	28.22	1.08	6.56	14.23	28.74	39.99
T4 (PL+ LL (50%)	**15 Days**	7.21	4.78	21.09	36.36	25.44	39.61	1.23	2.07	17.14	7.22	0.32	1.03	5.93	19.23	42.12	2.68	30.18	8.45	14.32	22.17
	30 Days	8.55	5.78	39.14	67.48	32.88	40.03	1.3	2.24	30.11	1.08	0.58	1.11	1.11	16.23	43.56	2.62	21.56	7.47	17.78	24.45
	45 Days	7.44	5.12	45.21	77.94	70.28	40.54	1.34	3.36	33.74	1.35	0.78	1.45	1.45	13.12	39.56	1.52	18.92	9.99	23.45	28.65
	60 Days	7.76	4.98	42.32	72.96	52.3	49.61	1.52	3.52	27.84	1.06	1.02	1.51	1.51	7.42	35.12	0.82	11.23	10.75	27.54	30.45
T5 (PL + LL (75%)	**15 Days**	7.36	5.56	28.02	48.31	47.07	32.14	1.51	2.02	18.55	8.11	0.73	2.36	6.16	21.45	58.32	4.12	35.89	5.62	21.27	26.21
	30 Days	8.37	5.78	39.53	68.15	41.09	43.13	1.61	1.81	24.55	1.32	1.02	2.19	1.19	21.05	41.12	3.35	22.02	7.56	24.57	32.12
	45 Days	7.14	5.44	41.45	71.46	84.44	47.98	1.62	2.89	25.59	1.77	1.21	2.46	1.46	17.25	36.56	1.25	12.75	9.46	26.54	38.12
	60 Days	7.03	5.79	46.71	80.53	53.35	52.91	1.75	5.55	26.69	2.05	1.32	2.48	1.78	9.23	24.51	0.95	9.98	10.35	28.74	40.12

Cnt = Concentration; PL = Poultry Litter; LL= Leaf Litter

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Table No. 3 Results of Two-Way ANOVA for physico-chemical properties of poultry compost

ANOVA		pH				Ec				OC				OM				MC			
SV	*df*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*
Rows	3	1.013	10.2	0.001	reject (H01)	0.203	0.249	0.860	Accept (H02)	289.36	15.69	0.0002	reject (H01)	58.75	9.356	0.0018	reject (H01)	66.99	48.65	5.449	reject (H01)
Columns	4	0.108	1.09	0.406	Accept (H02)	1.35	1.66	0.223	Accept (H02)	81.8	4.44	0.019	reject (H01)	73.6	11.7	0.0004	reject (H01)	266.4	193.5	8.758	reject (H01)

ANOVA		WHC				P				N				Ca				Mg			
SV	*df*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*
Rows	3	1998	22.8	0.00003	reject (H01)	5.95	35.3	3.108	reject (H01)	0.51	5.13	0.016	reject (H01)	1.26	2.96	0.075	Accept (H02)	0.563	8.969	0.002	reject (H01)
Columns	4	325.9	3.72	0.034	reject (H01)	1.5	8.91	0.001	reject (H01)	2.4	24.1	0.00001	reject (H01)	2.27	5.35	0.01	reject (H01)	0.1	1.593	0.239	Accept (H02)

ANOVA		Na				K				C:N				Cu				Zn			
SV	*df*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*
Rows	3	0.363	4.22	0.029	reject (H01)	0.35	3.97	0.035	reject (H01)	92.3	5.68	0.011	reject (H01)	81.9	24.1	0.00002	reject (H01)	245.5	10.53	0.001	reject (H01)
Columns	4	1.764	20.5	0.00002	reject (H01)	0.81	9.22	0.001	reject (H01)	16.5	1.01	0.438	Accept (H02)	12.2	3.6	0.037	reject (H01)	66.17	2.838	0.072	Accept (H02)

ANOVA		Cd				Cr				Ni				Pb				Mn			
SV	*df*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*	*MS*	*F*	*P-value*	*Decision*
Rows	3	6.952	35.8	2.88	reject (H01)	465	45.8	7.62	reject (H01)	17.8	12.1	0.0006	reject (H01)	80.6	40.4	1.499	reject (H01)	75.32	10.25	0.001	reject (H01)
Columns	4	0.566	2.92	0.067	Accept (H02)	1.38	0.14	0.966	Accept (H02)	13.3	9.07	0.001	reject (H01)	18.4	9.24	0.001	reject (H01)	165.5	22.52	0.00001	reject (H01)

P-value 0.05 (>0.05) = statistically insignificant, p-value 0.05 (<0.05) = statistically significant.
H01 = Alternative hypothesis a statement, there exists some relationship between two measured phenomenon
H02 = the null hypothesis is a statement. There exists no relation between two variables

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Table No. 4 Significant Correlation Coefficient between macro and microelement in Poultry compost

Variables	***pH***	***EC***	***OC***	***OM***	***WHC***	***MC***	***N***	***P***	***C:N***	***Ca***	***Mg***	***Na***	***K***	***Cu***	***Zn***	***Cd***	***Cr***	***Ni***	***Pb***	***Mn***
pH	1																			
EC	0.03	1																		
OC	0.44	0.52	1																	
OM	0.44	0.52	1	1																
WHC	-0.11	0.00	0.32	0.32	1															
MC	0.20	0.39	0.71	0.71	0.40	1														
N	0.07	0.54	0.52	0.52	0.41	0.61	1													
P	-0.02	0.10	0.51	0.51	0.21	0.40	0.24	1												
C:N	0.43	0.11	0.69	0.69	0.03	0.25	-0.25	0.40	1											
Ca	-0.55	0.01	-0.70	-0.70	-0.39	-0.53	-0.25	-0.38	-0.60	1										
Mg	0.12	0.36	0.76	0.76	0.32	0.57	0.50	0.60	0.45	-0.48	1									
Na	-0.29	0.60	0.07	0.07	-0.17	0.12	0.20	-0.04	-0.11	0.39	0.36	1								
K	-0.45	0.10	-0.66	-0.66	-0.40	-0.49	-0.19	-0.34	-0.60	0.98	-0.47	0.43	1							
Cu	-0.38	0.14	-0.54	-0.54	-0.35	-0.67	-0.20	-0.43	-0.39	0.55	-0.37	0.30	0.53	1						
Zn	-0.16	0.29	-0.45	-0.45	-0.40	-0.63	-0.19	-0.44	-0.31	0.59	-0.45	0.37	0.61	0.82	1					
Cd	-0.43	-0.14	-0.65	-0.65	-0.50	-0.83	-0.38	-0.40	-0.36	0.61	-0.47	0.14	0.54	0.81	0.73	1				
Cr	-0.39	-0.21	-0.81	-0.81	-0.51	-0.89	-0.56	-0.45	-0.42	0.73	-0.65	0.13	0.70	0.74	0.75	0.89	1			
Ni	0.37	-0.23	0.51	0.51	0.29	0.39	0.17	0.47	0.46	-0.53	0.42	-0.37	-0.54	-0.48	-0.60	-0.46	-0.64	1		
Pb	0.26	0.45	0.82	0.82	0.50	0.78	0.70	0.53	0.33	-0.55	0.86	0.26	-0.49	-0.58	-0.50	-0.68	-0.80	0.36	1	
Mn	0.08	0.79	0.71	0.71	0.20	0.71	0.66	0.30	0.23	-0.25	0.69	0.64	-0.18	-0.19	-0.13	-0.44	-0.56	0.16	0.76	1

3.1 Germination Index:

Three main steps are involved in the seed germination test in which an aqueous extract of compost was prepared and seeds incubated were in the extract. Finally, measure and compute the indicators related to the test findings using Eqs. (1-6), such as the seed germination (SG), relative seed germination (RSG), relative radical growth (RRG), and seed germination index (GI). The Fig No. 1 to 4 provides a detail of further information on the typical test techniques in research.

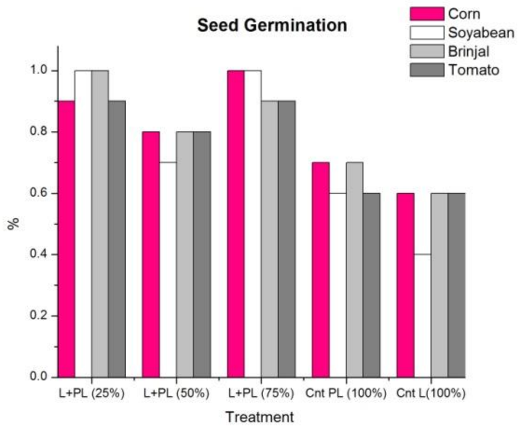

Fig No. 1 Seed Germination

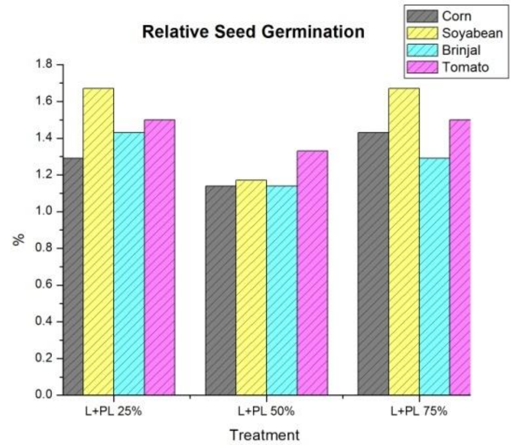

Fig No. 2 Relative Seed Germination

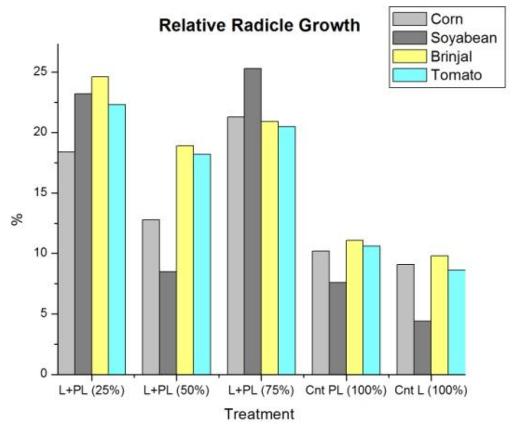

Fig No. 3 Relative Radical Growth

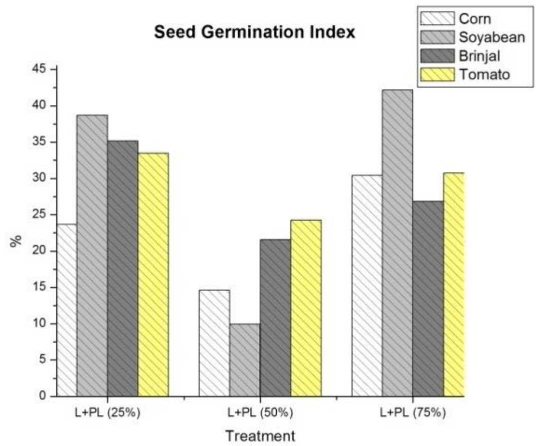

Fig No. 4 Seed Germination Index

4. DISCUSSION:

4.1 Physico-chemical properties of the compost: Composting is one of the basic trends in the recovery and organic recycling of waste. The composting of materials such as poultry litter and leaf litter waste is a great challenge, particularly due to the various physico-chemical properties of these materials. Through this organic waste transformation biologically, it can obtain a product of standard value suitable for use as fertilizer or as an agent improving soil properties. The poultry litter and leaf litter waste show a high organic matter content. The poultry litter was supplemented with leaf litter, which added the nitrogen and moisture levels needed. The result of analysis of variance in Table No. 3 shows that compost rate and some of their interactions have significant ($P < 0.05$) effects on all physico-chemical properties of the compost examined in this study. Table No. 2 shows the mean effect of different processing parameters on physico-chemical properties of the compost.

a) ***Temperature:*** There were very slight temperature rises during the first 10 days of composting, and then only ambient temperatures were maintained. For instance, T1 62^0 C steadily decreases after up to 45 days to reach ambient temperature. Similar patterns seen in T1 were also seen in T2, with the exception of temperature rise up to 53°C. The temperature rise from 58 to 62°C at the beginning of the composting period it's indicating that the microbial action generating to the poultry litter and leaf litter combinations (T3 and T4). The temperature profile change due to the microbial activity, revealed step increases in temperature and a very gradual decrease to reach ambient. According to [27] the hypothermic phase's beginning and the composting process might be speed up by adding ammonia-oxidizing archaea to poultry waste compost. After all the treatment, the mixture was refilled into the compost bins after being watered to a moisture level of 45 to 60%.

b) ***Odour:*** The T1 and T2 sets had the strongest ammonia odour after 45 days, and the T3 had have no detectable ammonia odour. This may be attributable to improved aeration, which accelerated decomposition. As a result of periodic mixing, which increased the oxygen supply in the pile and boosted the microbial consortium's activity, no odour was produced in the following set of T5. After the decomposition process, black, humus-like materials with an earthy smell were discovered in each set. Organic substrates with high odour potential frequently accumulate in excess when there is a lack of air or a low pH [28], [29]. The smell of composting feedstock is assumed to be caused by the release of volatile organic acids, gaseous carbon, or other chemical components [30], [31].

c) ***Colour:*** The colour appears throughout the composting period, with the first stage showing a yellowish colour on day 30. After completing the 30 days, the colour changed from brown to dark black.

d) ***pH*:** Initially between 8.48 and 8.55, the initial pH levels in T3 and T5 increased slightly over the period of 30 days to between 8.2 and 8.37, and then declined to final values between 7.03 to 7.86, as observed in T5 and T3 (Table No.2). The degradation of easily degradable organic matter in composting piles may be the cause of the high pH values that were recorded over the 30 days, when temperature values were 39^0C. After three weeks, the five treatments' constant drop in pH values might be caused by the synthesis of organic acids. ANOVA analysis indicates a significant relationship between row factor and pH values, rejecting the null hypothesis, while no significant relationship is found between column factor and pH values, accepting the null hypothesis (Table No. 3). According to [32] the pH increased with increasing compost rate but decreased and shifted to more acidic direction with increasing steeping time. This disparity may have been due to slight increase in basic cations as the compost rate increases and the microbial activities to dissolve the carbonic acid as the steeping time increases. Also, it may have been due to increase in molecular vibration as water temperature increases which results in the ability of compost extracts to ionize and form more hydrogen ions.

e) ***Electrical Conductivity (EC)*:** As a chemical indicator of the composting status, electrical conductivity is used, as an indirect assessment of the soluble salts in a sample. Beginning at 60 days in sets T2, T3, and T5, EC values significantly increased as the process progressed in 3 sets before stabilising at the end phase of decomposition. The EC values ranged from 3.08 to 5.79 µS/cm from the beginning of the raw materials decomposition to the end. At a final conductivity of 3.08, which is recorded at the T4, aeration has been proven to accelerate the decomposition of poultry litter and leaf litter. Analysis shows that there is no significant difference in EC values based on the factors examined, as indicated by the high p-values of 0.860 for the row factor and 0.223 for the column factor, leading to acceptance ($P > 0.05$) of the null hypothesis (H01 and H02) for EC. (Table No. 3). The volatilization of ammonia and the precipitation of mineral salts, which occurred as the composting process progressed, could be the causes of the declines in EC at the composting process' final stages [33]. The initial increase in EC may have occurred from the release of mineral salts such phosphates and ammonium ions as a result of the breakdown of organic materials [34].

f) ***Organic Carbon (OC) & organic matter (OM):*** The organic carbon values of the compost extract range from 20.07 to 48.22%. The T3 treatment had the highest carbon content in the composting period at day 60, ranging from 48.22% to 20.7% at the initial 15 days of the composting period in the T2 treatment. The overall observation shows during the composting period, organic carbon increased in each time interval. According to [35], the percentage of carbon and organic matter is responsible for improving soil structure, with the highest range being observed to be 52.70% and organic matter being 90.85% (Table No. 2). The micro-organisms cells must contain carbon in order to function properly and to create variety of organic compounds. Moreover, it makes up roughly 50% of the dry mass of micro-organisms. The OC showed (Table No. 3) significant differences between the different levels of the row factor (p-value= 0.00018) and the column factor (p-value = 0.019), indicating its sensitivity to these factors ($P < 0.05$). As metabolic activity declines during the composting process, the carbon content and the rate of CO_2 generation also decline [2].

The organic matter content was around 28.84% for T1 on 45th day composting period, after wards there is fluctuation. Such decrease is explained by the continued mineralization of organic compound [22]. The increase can be explained by the concentration of organic matter as a result of the different forms of loss: dry matter loss [36] and water loss. For all the five treatment the reduction in organic matter between the start and the end of composting is significant. It was 28.84% and 38.41% to arrive at final values of 45.13% and 49.53% for T3 and T5 at the day 60 respectively. The results show (Table No. 3) a significant difference in OM scores based on the factors examined, with both the row factor and column factor rejecting their respective null hypothesis (H01 and H02) due to the less p-values of 0.0018 and 0.00041, respectively ($P < 0.05$). During the composting period the aerobic micro-organism consumed oxygen to degrade organic matter [26].

g) Moisture content (MC): Due to influencing microbiological activity of the compost, moisture is one of [37] the main physical elements that indirectly control the temperature of the compost. In the composting period moisture content showed various fluctuations in the initial stage of composting. The moisture content was high in the first 15 days of composting i.e T3, T4 and T5 (Table No. 2) had thermophilic phases less than T1 and T2 treatment. At the starting of the composting process the moisture content should be suitable. Moisture content showed (Table No. 3) significant difference between row factor (p-value=5.449) and column factor (p-value= 8.758) values, leading to rejection of the respective null hypothesis ($P < 0.05$). The initial stages of composting should have a moisture level of between 40 and 65% [38]**.** The procedure and the quality of the compost are both impacted by changes in moisture content. Since biological activity becomes slow by moisture content below 35% and prevented from transferring oxygen by an over abundance of moisture [39].

h) Water Holding Capacity (WHC): The water holding capacity is important for the composting process. It was observed that the water holding capacity increased after 15 days of composting period. The maximum result shown in the treatments T2, T5, and T1 are within a range between 83.17% to 86.56%; this result was observed after completion of 45 days of the composting period. The less WHC result is shown in treatment T3, i.e., 15.4% in the 30 days of the composting period. ANOVA analysis shows (Table No. 3) a significant differences in WHC values based on row factor and column factor, rejecting the null hypothesis (H01 and H02) for both factors due to the low p-values of 0.00003 and 0.034 respectively ($P < 0.05$). As there is organic matter, the water holding capacity increases [40]. The water holding capacity is the amount of water that is given by soil for crop use. The water holding capacity indicates the soil quality and productivity [41].

i) ***Phosphorous (P):*** The concentration of available phosphorous in the resultant composts varies widely among the treatments of the study with the lowest concentration being obtained in the T2 for initial stage and the highest in T3 at the end of composting. It was shown that in the compost extract's total Phosphate increased as the compost degradation rate and steeping period increased. The phosphorous (P) parameters showed (Table No. 3) significant differences between the row factor (p-value=3.108) and column factor (p-value=0.001) values, leading to the rejection of the corresponding null hypothesis ($P < 0.05$). This indicates that increasing the amount of compost and allowing it to remain suspended in water for a longer period of time may encourage the solubilisation and mineralization of the organic phosphorus to release inorganic phosphorus and therefore enhance Total Phosphate. On the other hand, it was seen that Total Phosphate decreased as water temperature increased which means that the microbial bio mineralization activities are slowed down by water temperatures in the range of thermophilic [42].

j) ***Nitrogen (N):*** The nitrogen content of all compost treatment the T3 and T5 having poultry waste are high, which increases with the quantity of poultry and leaf litter compost and ranges between T3 highest range 2.32% and T5 range 3.55% respectively (Table No.2). ANOVA analysis (Table No. 3) shows a significant difference in the variable N (representing a particular parameter) based on both the row factor and the column factor, as indicated by the low p-values of 0.016 and 0.000011, respectively, leading to the rejection of null hypothesis (H01 and H02) for both factors ($P < 0.05$). So the result shows higher nitrogen as compare to other treatments, which indicates the nitrogen availability to soil and the plant. Nitrogenous chemicals are constantly changing, primarily as a result of microbial activity. Organic nitrogen makes up the majority of feedstock, with minor levels of nitrate (NO_3) and ammonium (NH_4^+). Since they are soluble in water and readily accessible by microbes and plants, the NO_3 and NH_4 forms of nitrogen are classified as "available N". Ammonification, nitrification, denitrification, and biological immobilisation are the four processes that change nitrogen into other substances [43]. One of the maturity indices for compost is the NH_4^+/NO_3^- ratio. It is sometimes referred to as the oxidation index or nitrification index of mineral forms of nitrogen. Thus, the maturity increases as the NH_4^+/NO_3^- value decreases the value of ratio below 3 shows mature compost [44].

k) ***Calcium (Ca):*** The Ca values for the compost extract 0.88 to 3.85 mg/kg which increased with composting rate and steeping time. The calcium (Ca) parameters showed no significant differences between rows factor values (p-value=0.075), leading to acceptance of the null hypothesis. However, significant difference were found between the levels of the column factor (p-value=0.01), leading to rejection of the null hypothesis (Table No. 3). The increasing Calcium could be attributed to higher concentration of Ca in the compost as reported [45], higher mineral concentration in compost explain greater concentration of nutrient in its extracts. However, decreasing in Calcium with increasing water temperature could be a sign that water temperature above mesophilic temperature slows down the microbial mineralization activities [32].

l) ***Magnesium (Mg):*** The Mg values were 0.48 to 1.78 mg/kg. The highest range was found in treatment T3, i.e., 1.78 after day 60, and the lowest range was observed in treatment

T2, i.e., 0.48 for the initial day. ANOVA analysis shows a significant difference in the variable Mg (representing specific parameters) based on the rows factor, as evidenced by the low p-value of 0.0021, leading to the rejection of the null hypothesis (H01) for the rows factor leads. However, there is no significant difference in Mg based on the column factor, as indicated by the relatively high p-value of 0.239, leading to acceptance of the null hypothesis (H02) for the column factor (Table No. 3). These values were found to be higher than the compost Magnesium. According to [45], the solubilisation and mineralization of organic Mg in the compost may be the cause of the rise in Mg content in the compost extract, as was observed in other minerals studied in this work.

m) ***Sodium (Na):*** The highest range shown in the treatment T5 i.e 2.46 and lowest range is 0.72 in treatment T1. The sodium (Na) parameters showed (Table No. 3) significant differences between rows factor levels (p-value= 0.029), leading to rejection of the null hypothesis. Likewise, it showed significant differences between the levels of the column factor (p-value= 0.000027), leading to the rejection of the null hypothesis ($P < 0.05$). Similar to other minerals reported earlier in this study, Na of the compost extract increased with increasing compost rate and steeping time but decreased with increasing water temperature. The increase in Na concentration could be attributed to further solubilization and mineralization of the organic matter [46]

n) ***Potassium (K):*** The potassium result indicated that the concentration had increased in the day 60th. The higher potassium concentration was found in treatments T3 and T5, where the range is between 2.84% and 2.28% after day 60. ANOVA analysis (Table No. 3) shows a significant difference in the variable K (representing a given parameters) based on both the row factor and the column factor, as indicated by the less p-values of 0.035 and 0.001, respectively, leading to the rejection ($P < 0.05$) of the null hypothesis (H01 and H02) for both factors. According to the observations, K concentration increased during co-composting (2.82-3.26%), as found by [47]. The compost's K concentration increased due to mineralization, while it decreased due to fixation [48] found a similar potassium value in the composting of food waste and observed that Potassium released by microorganisms increased from the initial to the stage of composting. The poultry litter was stored under the in-pit method, which produced the maximum potassium concentration (13.6 g kg-1), and this was considerably different from the under-shed and outside ways.

o) ***C:N:*** The C:N ratio, shows how much nitrogen is available for the compost's biological decomposition process. It has been widely mentioned that a decline in this ratio as composting progresses is a sign of stable, mature compost. The C:N ratio showed significant differences between rows factor levels (p-value=0.011), leading to rejection of the null hypothesis. However, no significant differences were found between the levels of the column factor (p-value= 0.438), leading to acceptance of the null hypothesis (Table No. 3).

4.2 Heavy metal concentration: The heavy metal concentration in compost is one of the main factors that restrict marketing and use due to bioaccumulation potential of these metals. Analysis of compost samples showed the presence of all 7 heavy metals. Copper (Cu), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Lead (Pb), Manganese (Mn).

p) ***Copper (Cu):*** The Cu result shows that in the 60-day composting period, the composting range decreased at the end of the composting period. The result shows that at the initial stage of composting, all the treatments increased the concentration of Cu, i.e., from 13.23 to 22.12 mg/kg at the 15-day time interval. The level of Copper concentration decreased in treatments T4 and T5, i.e., 7.42 and 9.23 mg/kg, after 60 days of composting. ANOVA analysis shows (Table No. 3) a significant difference in the variable Copper (representing a particular parameters) based on both the row factor and the column factor, as indicated by the less p-values of 0.000022 and 0.037, respectively, leading to the rejection of null hypothesis (H01 and H02) for both factors ($P < 0.05$). According to some researchers, adding 6% biochar has the best passivation effect on copper, and the amount of copper in compost decreases significantly after composting [49]. [50] Found that the residual fraction and sulphide/organic matter-bound fraction of the compost mixture have a strong affinity for Copper stability. After composting, Cu's potential mobility and bioavailability are decreased.

q) ***Zinc (Zn):*** The Zn concentration was observed in the initial stage; the concentration was increased, i.e., 35.63 to 58.32 mg/kg, and decreased at the end of composting, i.e., 24.51 to 35.12 mg/kg. The zinc (Zn) parameters showed significant differences between row factor levels (p-value=0.001), leading to rejection of the null hypothesis. However, no significant differences were found between the levels of the column factor (p-value =0.072, leading to acceptance of the null hypothesis (Table No. 3). The interaction between functional groups of organic matter, primarily carboxylic and phenolic groups, and these metals during compost's humification may have resulted in more stable interactions, decreasing Cu and Zn in the labile fraction, and increasing the organic matter bound fraction [51].

r) ***Cadmium (Cd):*** In this poultry litter composting, initially the Cd content was recorded at the highest concentration; the range is between 4.02 and 4.12 mg/kg in treatments T1 and T5. The analysis shows (Table No. 3) a significant difference in the variable Cd based on the row factor, leading to the rejection of the null hypothesis (H01), while there is no significant difference based on the column factor, leading to the acceptance of the null hypothesis (H02). The Cd was found in the oxidizable fraction at the beginning of the composting. The Cd concentration decreased by half at the end of the process. The greatest decrease was found in T1, T3, and T2 treatments; the range is between 0.79, 0.82, and 0.85 mg/kg. [47]

s) ***Chromium (Cr):*** The Cr content had an upward trend over time, although this pattern wasn't steady until 60 days had passed since composting. In the beginning of composting, the Cr value is greater; it ranges between 35.56 and 35.89 mg/kg in T3 and T5 treatments. Towards the end of composting, however, the result demonstrates a decreasing Cr concentration, ranging between 6.56 and 9.86 mg/kg in the T3 and T1 treatments. The chromium (Cr) parameters showed significant differences between the levels of the rows factor (p-value= 7.62), leading to rejection of the null hypothesis. However, no significant differences were found between the levels of the column factor (p-value=0.966), leading to acceptance of the null hypothesis (Table No. 3). The scientist [52] observed, as organic matter was bound to organic matter, the amount of Cr decreased, while the amount of Cr associated with the residual fraction increased.

t) ***Nickel (Ni):*** The result showed low concentration of Ni from the initial day of composting process. There is slightly increase the Ni level were noted in all T2, T3, T4 and T5 treatment. The T3 treatment concentration increases in 15 days time interval i.e. 7.12, 9.47, 12.46, 14 .23 mg/kg respectively. The T1 treatment was totally unstable till the end of composting. The nickel (Ni) parameters showed significant differences between the row factor (p-value=0.0006) and column factor (p-value= 0.001) values, leading to the rejection($P < 0.05$) of the respective null hypothesis, indicating the influence of these factors affect the variability of Ni concentration in the analyzed samples (Table No. 3). The dominance of the residual Cr and Ni fractions from initial to final composting demonstrated the exceedingly poor bioavailability of these metals in poultry litter compost [52].

u) ***Lead (Pb):*** On the 60th day of composting period maximum concentration of Pb observed in T3 and T5 treatment i.e. 28.74 mg/kg and minimum concentration observed in

T1 and T2 i.e. 23.75 and 24.74 mg/kg. The results indicate a significant difference in the variable Pb based on both the row factor and the column factor, with the null hypothesis (H01 and H02) being rejected ($P < 0.05$) due to less p-values of 1.499 and 0.001 respectively (Table No. 3). The significantly increased Pb concentrations were observed over the composting time and are related to carbon loss (as C-CO_2) and the mass lost from organic matter mineralization during composting [53]. The final step of composting is when Pb is converted to components that are more mobile (bioavailable), hence the fraction of Pb in stable components is increased. According to this result, these sludge and compost mixes do not readily release heavy elements like lead [54].

v) ***Manganese (Mn):*** The Mn content had an upward trend over time, although this pattern wasn't steady until 60 days had passed since composting. In the beginning of composting, the Mn value is greater; it ranges between 39.99 and 40.12 mg/kg in the T3 and T5 treatments. Towards the end of composting, however, the result demonstrates a decreasing Mn concentration, ranging between 21.99 and 22.56 mg/kg in the T2 and T1 treatments. The analysis shows a significant difference in the variable Mn based on both the row factor and the column factor, indicated by the low p-values of 0.001 and 0.00001, respectively, leading to the rejection of the null hypothesis ($P < 0.05$) (H01 and H02) for leads both factors (Table No. 3).

The table no. 4 shows correlation coefficients between various compost properties, including pH, Electrical conductivity (EC), Organic Carbon (OC), Organic Matter (OM), Water Holding Capacity (WHC), Moisture Content (MC), Nitrogen (N), Phosphorous (P), Carbon: Nitrogen ratio (C:N), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Copper (Cu), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Lead (Pb) and Manganese (Mn). The coefficients indicate the strength and direction of the relationships between these properties. The notable findings include: EC correlates positively with multiple properties, indicating associations with OC, OM, WHC, MC, N, P, Cu, Zn, Cd, Cr, Ni, Pb and Mn. OC and OM are strongly correlated and positively associated with EC, WHC, MC, N, P, C:N, Cu, Zn, Cd, Cr, Ni, Pb, and Mn. WHC and MC exhibit moderate positive correlations with multiple properties. N, P, and C:N show positive correlation with several elements, indicating their interdependencies. Additionally, Ca shows negative correlations with OM, WHC, MC, and N. Mg shows positive correlations with various properties, while Cu, Zn, Cd, Cr, Ni, and Pb exhibit positive correlations with multiple properties, emphasizing their interconnectedness. Mn demonstrates positive associations with several properties as well. These findings highlight the complex relationships and interplay between different compost properties, providing insight for understanding soil health and nutrient dynamics.

4.3 Germination Index:

These methods are effective in the handling of seeds, especially in measuring the radical length of germinated seeds accurately. The third step is involves the calculation of GI (Eqs. 2–4). The GI value, not less than 80%, usually means that compost has no phytotoxicity [55]. The result shows that the GI value increased from 14.62% to 30.42% which is observed in the Treatment (L+ PL 50% and L+ PL 75%). In addition, as seen from Eqs. (4–6), the accuracy of GI to evaluate the toxicity of compost could be improved by increasing the weight of GI values of different dilutions. [56] Prepared compost extract with the fresh sample and distilled water at the ratio of 1:2 (w/v), and then it was diluted with distilled water to different treatment of the compost i.e control, 25%, 50%, 75% and of the extract (v/v). The global germination index (Eq. (5)), i.e. the average of GI values of the 50% and 75% of the Treatment extracts, was adopted in their study. The results showed that the index values of the samples were above 80% and the germination percentages of the extracts, which proved to be a high phytotoxicity of the samples. Similarly, according to the test Eq. (6) the results showed that the GI values Corn 90%, Soyabean 90%, Bringal 90% and Tomato 80.66% respectively. The proposed study that the two Treatment s of compost extract (RRG=90% and GI=90%) were both over 100%, which indicated non-inhibitory effect of compost. Compost is considered to be phytotoxin-free if GI values are greater than 80% [25]. The high GI found in this research might be attributed to the compost extracts' adequate levels of NH4 + and other nutrients [57].

There are three different ways to interpret and analyse the results of the seed germination test. First, the combination of relative seed germination (RSG) and relative radical growth (RRG) in GI, both of which can reflect the toxicity of compost, makes it a commonly used method. Second, RRG is more sensitive indicator than RSG to the toxicity so RRG is used alone [58]. Finally, differing toxic levels of the compost inhibit radical elongation and seed germination; as a result, RSG and RRG are used to independently determine the toxicity. In other words, it is not necessary to evaluate the impact of compost on radical elongation if it inhibits seed germination; however, if it does not, it is vital to evaluate the impact of compost on the radical. [59] Used the indices of SG (Eq. (1)), RRG and GI to determine the profile of the toxicity of pig manure during composting. The results showed that the RRG values of four species of seeds (Corn, Soyabean, Brinjal, Tomato) were significantly and positively correlated, and the SG values of all seeds were more than 70% (seven germinated seeds of ten seeds per Petri dish), which indicated that compost had no effect on germination of the seeds. In this research observed all Treatment of the compost had GI values beyond this limit, they can all be considered phytotoxin-free.

5. CONCLUSION

The compost made from poultry litter contained nutrients that are important for plant growth, including trace elements. Maturation of the poultry litter compost was accompanied by a decline in compost temperature to ambient temperatures. To improve the composting process, it is recommended to limit the composting experiment duration to 60 days to allow the sample to fully decompose, increase nitrogen and phosphorus, and meet the criteria of typical mature compost. The C/N and moisture content recommended to initiate the composting process is reflected in the temperature development and organic matter degradation rate, which are optimal for the cleanliness and stabilization of the end product in the evaluated period. The ANOVA table shows a comprehensive analysis of different parameters and shows significant differences between the values of different factors for pH, EC, OC, OM, MC, WHC, P, Na, K, C:N, Cu, Zn, Cd, Cr, Ni, Pb and Mn, with some parameters showing that the null hypothesis is accepted for certain factors and rejected for others ($P < 0.05$). The correlation coefficient between different variables and indicates the strength and direction of their relationship, with positive values indicating positive correlation and negative values indicating negative correlation. The closer the value is to 1 or -1, the stronger the correlation. The diagonal values are all 1 because they represent the correlation of a variable with itself. However, the composted poultry litter contained more stabilized organic matter. The seed germination test is an effective and economical bioassay for evaluating the potential toxicity of compost prior to its use. The study found that composting is highly dependent on microbial activity and that the growth of this community needs to be encouraged through an appropriate irrigation process. In addition to increasing soil productivity, the composting process will limit the use of chemical fertilizers and help to reduce the amount of waste going to landfill. To achieve a sustainable future, it is important for communities to develop similar eco-friendly research.

REFERENCES:

[1] D. A. Iannotti, T. Pang, B. L. Toth, D. L. Elwell, H. M. Keener, and H. A. J. Hoitink, "A Quantitative Respirometric Method for Monitoring Compost Stability," *Compost Sci. Util.*, vol. 1, no. 3, pp. 52–65, Jun. 1993, doi: 10.1080/1065657X.1993.10757890.

[2] E. Epstein, "Science of composting Technomic Publishing Company," *Lanc. USA*, p. 487, 1997.

[3] L. Wu, L. Q. Ma, and G. A. Martinez, "Comparison of methods for evaluating stability and maturity of biosolids compost," Wiley Online Library, 2000.

[4] S. Hachicha *et al.*, "Biological activity during co-composting of sludge issued from the OMW evaporation ponds with poultry manure—Physico-chemical characterization of the processed organic matter," *J. Hazard. Mater.*, vol. 162, no. 1, pp. 402–409, 2009.

[5] C. Mondini, R. Chiumenti, F. Da Borso, L. Leita, and M. De Nobili, "Changes during processing in the organic matter of composted and air-dried poultry manure," *Bioresour. Technol.*, vol. 55, no. 3, pp. 243–249, 1996.

[6] B. P. Kelleher, J. J. Leahy, A. M. Henihan, T. F. O'dwyer, D. Sutton, and M. J. Leahy, "Advances in poultry litter disposal technology–a review," *Bioresour. Technol.*, vol. 83, no. 1, pp. 27–36, 2002.

[7] J. F. Power *et al.*, *Land application of agricultural, industrial, and municipal by-products.* Soil Science Society of America Inc., 2000.

[8] B. L. Kumar and D. S. Gopal, "Effective role of indigenous microorganisms for sustainable environment," *3 Biotech*, vol. 5, pp. 867–876, 2015.

[9] G. A. Ogunwande, L. A. O. Ogunjimi, and J. O. Fafiyebi, "Effects of turning frequency on composting of chicken litter in turned windrow piles," *Int. Agrophysics*, vol. 22, no. 1, pp. 159–165, 2008.

[10] G. A. Ogunwande, J. A. Osunade, and L. A. O. Ogunjimi, "Effects of carbon to nitrogen ratio and turning frequency on composting of chicken litter in turned-windrow piles," *Agric. Eng. Int. CIGR J.*, 2008.

[11] P. E. Boyle, M. C. Savin, and L. S. Wood, "The effect of turning frequency on in-vessel compost processing and quality," *Discov. Stud. J. Dale Bump. Coll. Agric. Food Life Sci.*, vol. 16, no. 1, pp. 14–23, 2015.

[12] Z. Jiang-Ming, "Effect of turning frequency on co-composting pig manure and fungus residue," *J. Air Waste Manag. Assoc.*, vol. 67, no. 3, pp. 313–321, 2017.

[13] D. Oudart, "Modélisation de la stabilisation de la matière organique et des émissions gazeuses au cours du compostage d'effluents d'élevage," PhD Thesis, INSA de Toulouse, 2013.

[14] P. P. Bhave and B. N. Kulkarni, "Effect of active and passive aeration on composting of household biodegradable wastes: a decentralized approach," *Int. J. Recycl. Org. Waste Agric.*, vol. 8, no. S1, pp. 335–344, Dec. 2019, doi: 10.1007/s40093-019-00306-7.

[15] M. J. Diaz, E. Madejon, F. Lopez, R. Lopez, and F. Cabrera, "Optimization of the rate vinasse/grape marc for co-composting process," *Process Biochem.*, vol. 37, no. 10, pp. 1143–1150, 2002.

[16] K. Wang, W. Li, J. Guo, J. Zou, Y. Li, and L. Zhang, "Spatial distribution of dynamics characteristic in the intermittent aeration static composting of sewage sludge," *Bioresour. Technol.*, vol. 102, no. 9, pp. 5528–5532, 2011.

[17] N. Zhu, C. Deng, Y. Xiong, and H. Qian, "Performance characteristics of three aeration systems in the swine manure composting," *Bioresour. Technol.*, vol. 95, no. 3, pp. 319–326, 2004.

[18] P. Muthuvel and C. Udayasoorian, “Soil, plant, water and agrochemical analysis,” *Tamil Nadu Agric. Univ. Coimbatore India*, 1999.
[19] R. Rynk *et al.*, “On-Farm Composting Handbook (No. 631.875 O-58o),” *Northeast Reg. Agric. Eng. Serv. Coop. Ext. N. Y. NY USA*, 1994.
[20] M. T. Abdelhamid, T. Horiuchi, and S. Oba, “Composting of rice straw with oilseed rape cake and poultry manure and its effects on faba bean (Vicia faba L.) growth and soil properties,” *Bioresour. Technol.*, vol. 93, no. 2, pp. 183–189, 2004.
[21] P. Sequi, M. De Nobili, L. Leita, and G. Cercignani, “A new index of humification,” *Agrochimica*, vol. 30, no. 1–2, pp. 175–179, 1986.
[22] G. A. Ogunwande, L. A. O. Ogunjimi, and J. O. Fafiyebi, “Effects of turning frequency on composting of chicken litter in turned windrow piles,” *Int. Agrophysics*, vol. 22, no. 1, pp. 159–165, 2008.
[23] G. Wang, Y. Yang, Y. Kong, R. Ma, J. Yuan, and G. Li, “Key factors affecting seed germination in phytotoxicity tests during sheep manure composting with carbon additives,” *J. Hazard. Mater.*, vol. 421, p. 126809, Jan. 2022, doi: 10.1016/j.jhazmat.2021.126809.
[24] D. P. Komilis and I. S. Tziouvaras, “A statistical analysis to assess the maturity and stability of six composts,” *Waste Manag.*, vol. 29, no. 5, pp. 1504–1513, May 2009, doi: 10.1016/j.wasman.2008.10.016.
[25] F. Zucconi, “Evaluating toxicity of immature compost,” *Biocycle*, pp. 54–57, 1981.
[26] Y. Luo *et al.*, “Seed germination test for toxicity evaluation of compost: Its roles, problems and prospects,” *Waste Manag.*, vol. 71, pp. 109–114, Jan. 2018, doi: 10.1016/j.wasman.2017.09.023.
[27] K. Xie *et al.*, “Improved composting of poultry feces via supplementation with ammonia oxidizing archaea,” *Bioresour. Technol.*, vol. 120, pp. 70–77, Sep. 2012, doi: 10.1016/j.biortech.2012.06.029.
[28] R. Rynk *et al.*, “On-Farm Composting Handbook,” Jan. 1992.
[29] S. M. Tiquia, J. H. C. Wan, and N. F. Y. Tam, “Extracellular enzyme profiles during co-composting of poultry manure and yard trimmings,” *Process Biochem.*, vol. 36, no. 8–9, pp. 813–820, Mar. 2001, doi: 10.1016/S0032-9592(00)00281-8.
[30] S. M. Tiquia, T. L. Richard, and M. S. Honeyman, “[No title found],” *Nutr. Cycl. Agroecosystems*, vol. 62, no. 1, pp. 15–24, 2002, doi: 10.1023/A:1015137922816.
[31] S. M. Tiquia and N. F. Y. Tam, “Co-composting of spent pig litter and sludge with forced-aeration,” *Bioresour. Technol.*, vol. 72, no. 1, pp. 1–7, Mar. 2000, doi: 10.1016/S0960-8524(99)90092-5.
[32] T. F. Oyewusi, J. A. Osunbitan, G. A. Ogunwande, and O. A. Omotosho, “Investigation into physico-chemical properties of compost extract as affected by processing parameters,” *Environ. Chall.*, vol. 5, p. 100370, Dec. 2021, doi: 10.1016/j.envc.2021.100370.
[33] J. W. C. Wong, S. W. Y. Li, and M. H. Wong, “Coal Fly Ash as a Composting Material for Sewage Sludge: Effects on Microbial Activities,” *Environ. Technol.*, vol. 16, no. 6, pp. 527–537, Jun. 1995, doi: 10.1080/09593331608616294.
[34] M. Fang, “Co-composting of sewage sludge and coal fly ash: nutrient transformations,” *Bioresour. Technol.*, vol. 67, no. 1, pp. 19–24, Jan. 1999, doi: 10.1016/S0960-8524(99)00095-4.
[35] S. Tayade, D. Dabhade, and H. Wanjari, “Preparation and Physico-chemical analysis of compost prepared from poultry litter”.
[36] L. Zhang *et al.*, “Impacts of iron oxide nanoparticles on organic matter degradation and microbial enzyme activities during agricultural waste composting,” *Waste Manag.*, vol. 95, pp. 289–297, Jul. 2019, doi: 10.1016/j.wasman.2019.06.025.

[37] A. G. Swamy, S. E. Arland, S. Batakurki, and J. Kumar, "Phytochemical analysis of Capsicum annuum longum stalk as low cost adsorbent for waste water treatment," vol. 6, no. 2, 2018.
[38] M. K. Manu, D. Li, L. Liwen, Z. Jun, S. Varjani, and J. W. C. Wong, "A review on nitrogen dynamics and mitigation strategies of food waste digestate composting," *Bioresour. Technol.*, vol. 334, p. 125032, Aug. 2021, doi: 10.1016/j.biortech.2021.125032.
[39] R. Rynk, J. Ziegenbein, C. Oshins, N. Koerting, J. Hardin, and J. Gage, "Chapter 11 - Process management," in *The Composting Handbook*, R. Rynk, Ed., Academic Press, 2022, pp. 501–548. doi: 10.1016/B978-0-323-85602-7.00011-X.
[40] C. Sanjivani Tanaji, S. Prajkta Shahaji, and J. Aasawari Suhas, "Stabilization of dairy industry sludge with leaf litter using as composting and its effect on Spinacia oleracea plant growth," *Mater. Today Proc.*, vol. 73, pp. 455–463, 2023, doi: 10.1016/j.matpr.2022.09.600.
[41] A. S. Mangrich *et al.*, "Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation," in *ACS Symposium Series*, S. Ahuja, J. B. de Andrade, D. D. Dionysiou, K. D. Hristovski, and B. G. Loganathan, Eds., Washington, DC: American Chemical Society, 2015, pp. 339–354. doi: 10.1021/bk-2015-1206.ch016.
[42] T. F. Oyewusi, J. A. Osunbitan, G. A. Ogunwande, and O. A. Omotosho, "Investigation into physico-chemical properties of compost extract as affected by processing parameters," *Environ. Chall.*, vol. 5, p. 100370, Dec. 2021, doi: 10.1016/j.envc.2021.100370.
[43] R. Cáceres, K. Malińska, and O. Marfà, "Nitrification within composting: A review," *Waste Manag.*, vol. 72, pp. 119–137, Feb. 2018, doi: 10.1016/j.wasman.2017.10.049.
[44] M. P. Bernal, S. G. Sommer, D. Chadwick, C. Qing, L. Guoxue, and F. C. Michel, "Current Approaches and Future Trends in Compost Quality Criteria for Agronomic, Environmental, and Human Health Benefits," in *Advances in Agronomy*, Elsevier, 2017, pp. 143–233. doi: 10.1016/bs.agron.2017.03.002.
[45] A. P. Pant, T. J. K. Radovich, N. V. Hue, and R. E. Paull, "Biochemical properties of compost tea associated with compost quality and effects on pak choi growth," *Sci. Hortic.*, vol. 148, pp. 138–146, Dec. 2012, doi: 10.1016/j.scienta.2012.09.019.
[46] M. Sartaj, L. Fernandes, and N. K. Patni, "Performance of forced, passive, and natural aeration methods for composting manure slurries," *Trans. ASAE*, vol. 40, no. 2, pp. 457–463, 1997.
[47] E. Guerra-Rodríguez, M. Diaz-Raviña, and M. Vázquez, "Co-composting of chestnut burr and leaf litter with solid poultry manure," *Bioresour. Technol.*, vol. 78, no. 1, pp. 107–109, May 2001, doi: 10.1016/S0960-8524(00)00159-0.
[48] S. Clark, "Development of a biologically integrated food waste composting system," *Berea Coll. Ky. USA*, 2000.
[49] W. Liu *et al.*, "Effects of biochar on nitrogen transformation and heavy metals in sludge composting," *Bioresour. Technol.*, vol. 235, pp. 43–49, Jul. 2017, doi: 10.1016/j.biortech.2017.03.052.
[50] S. Nomeda, P. Valdas, S.-Y. Chen, and J.-G. Lin, "Variations of metal distribution in sewage sludge composting," *Waste Manag.*, vol. 28, no. 9, pp. 1637–1644, Jan. 2008, doi: 10.1016/j.wasman.2007.06.022.
[51] J. Kang, Z. Zhang, and J. J. Wang, "Influence of humic substances on bioavailability of Cu and Zn during sewage sludge composting," *Bioresour. Technol.*, vol. 102, no. 17, pp. 8022–8026, Sep. 2011, doi: 10.1016/j.biortech.2011.06.060.
[52] C. da C. B. de Souza, N. M. B. do Amaral Sobrinho, E. S. A. Lima, J. de O. Lima, M. G. F. do Carmo, and A. C. García, "Relation between changes in organic matter structure of poultry litter and heavy metals solubility during composting," *J. Environ. Manage.*, vol. 247, pp. 291–298, Oct. 2019, doi: 10.1016/j.jenvman.2019.06.072.

[53] D. Lu *et al.*, “Speciation of Cu and Zn during composting of pig manure amended with rock phosphate,” *Waste Manag.*, vol. 34, no. 8, pp. 1529–1536, Aug. 2014, doi: 10.1016/j.wasman.2014.04.008.

[54] S. Nomeda, P. Valdas, S.-Y. Chen, and J.-G. Lin, “Variations of metal distribution in sewage sludge composting,” *Waste Manag.*, vol. 28, no. 9, pp. 1637–1644, 2008.

[55] S. M. Tiquia, N. F. Y. Tam, and I. J. Hodgkiss, “Effects of composting on phytotoxicity of spent pig-manure sawdust litter,” *Environ. Pollut.*, vol. 93, no. 3, pp. 249–256, 1996, doi: 10.1016/S0269-7491(96)00052-8.

[56] A. C. Mitelut and M. E. Popa, “Seed germination bioassay for toxicity evaluation of different composting biodegradable materials,” *Romanian Biotechnol. Lett.*, vol. 16, no. 1, 2011.

[57] C. Romero, P. Ramos, C. Costa, and M. C. Márquez, “Raw and digested municipal waste compost leachate as potential fertilizer: comparison with a commercial fertilizer,” *J. Clean. Prod.*, vol. 59, pp. 73–78, Nov. 2013, doi: 10.1016/j.jclepro.2013.06.044.

[58] S. M. Tiquia, N. F. Y. Tam, and I. J. Hodgkiss, “Effects of composting on phytotoxicity of spent pig-manure sawdust litter,” *Environ. Pollut.*, vol. 93, no. 3, pp. 249–256, 1996, doi: 10.1016/S0269-7491(96)00052-8.

[59] Y. Luo *et al.*, “Seed germination test for toxicity evaluation of compost: Its roles, problems and prospects,” *Waste Manag.*, vol. 71, pp. 109–114, Jan. 2018, doi: 10.1016/j.wasman.2017.09.023.