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Effect of poultry manure on some soil physicochemical and biological properties

Akinyele O.A.[1*], Ijadunola J.A.[1], Ate J.T.[1], Fadele N.T.[1], Ajekiigbe D.A.[1], Anifowose O.O. [1] and Agude T.[2]
[1]Department of Agricultural and Bio-Environmental Engineering, Federal College of Agriculture, Ibadan, Nigeria
[2]Department of Agricultural Extension and Management, Federal College of Agriculture, Ibadan, Nigeria
seunakinyele.oa@gmail.com

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Abstract

Three different poultry wastes (Broiler, Layer, and Cockerel) were used in a controlled chamber at the Federal College of Agriculture in Ibadan to study the impact of poultry manure on specific soil properties. The soil samples were obtained from the teaching and research farm at the Institute of Agricultural Research and Training in Moor Plantation, Ibadan. The soil samples were ground and sieved after being air dried. Four buckets, A, B, C, and D, were filled with 7.0 kg of soil each, and 2.0 kg of various poultry wastes from broilers, layers, and cockerels were mixed in with the soil samples already present in the four buckets. For each sample, buckets A, B, C, and D - designated as broiler waste soil, layer waste soil, cockerel waste soil, and control soil were reproduced four times. In order to ensure that the trash gets absorbed into the soil, 75cl of distilled water was added to each bucket after the application of the wastes. After that, the samples were taken to a lab for an analysis of various soil qualities. To determine the fundamental characteristics of soil and the textural class of the soil sample used for the experiment, pre-soil analysis of the used samples was first conducted. According to the results of a one-way analysis of variance (one-way ANOVA), there are significant differences between the three soil samples containing poultry waste and the control sample without waste in terms of bulk density, particle density, and porosity ($F = 336.759, 12.605$, and 592.713, respectively; $df = 15$, $P<0.05$). The three samples containing poultry manure and the control sample with no waste, however, did not differ significantly in terms of moisture content, DO, BOD_5, COD, or pH ($F = 0.006, 0.157, 0.002, 2.116$, and 0.282, respectively; $df = 15$, P 0.05). With the post hoc test for multiple comparisons, three waste samples (Broiler, Layer, and Cockerel) were likewise found to be statistically different for bulk density and porosity at $P<0.05$, while broiler and layer waste samples were both found to be significantly different for particle density. With the exception of bulk density, where broiler waste has the biggest influence, and pH, where layer waste likewise has the highest effect, it can be concluded that the application of poultry wastes has a considerable impact on the soil qualities.

Keywords: Poultry manure, soil properties, bulk density, organic matter, environment.

Introduction

In South Western Nigeria, the chicken business employs a significant number of people, with Ogun, Osun, and Oyo State dominating production[1]. History demonstrates that chicken has some benefits over other animals, including a high level of energy and protein yield, a quick rate of income, and a short incubation period[2]. This expansion is partly attributed to population growth and increased consumer demand for poultry meat and eggs, maybe as a result of the low cholesterol level of poultry meat[3].

Small and medium sized chicken farms are expanding so quickly in developing countries like Nigeria as a result of the high levels of waste production. Due to the volume of produced poultry waste, it was improperly disposed of and applied at the wrong time, posing a threat to the environment's soil, water, and air quality. Due to a lack of awareness, lax government regulations regarding the disposal of animal waste, and the carefree attitude of farm owners, various modern management techniques for poultry waste, such as re-feeding to animals, greenhouse disposal, gasification, and biogas production, have not really gained importance in Nigeria[4].

Since soil is a loose substance that covers the surface of the ground, it contains both inorganic and organic components. Plant detritus, the putrefaction of numerous tiny soil-dwelling organisms, and manure are all examples of organic matter. Characteristics of the soil's physical composition can be seen or felt. They are the results of climatic conditions (such as rainfall and temperature) acting on soil parent materials, as well as topography (slope and direction) and living forms (type and amount such as forest, grass, and soil animals) throughout time. The type of soil created often changes in response to changes in any of the impacts[5].

The physical and chemical characteristics of the soil have a significant impact on agricultural practices like tillage, erosion, drainage, and irrigation, all of which can either positively or negatively affect crop productivity. These soil characteristics are crucial for the sustainable use of soil for agricultural production because plant roots' capacity to absorb soil solution and the soil's capacity to feed it back to the roots determine how much water, oxygen, and nutrients can be taken up by plants. The production of plants can be negatively impacted by soil characteristics such low hydraulic conductivity, which can restrict the free flow of water, oxygen, and even nutrients to the roots of plants[6]. This is true because soil, by itself, is only useful as a storage space for the nutrients, air, and water that plants require to flourish.

Typically, organic ingredients are added to the soil's primary mineral particles to create small clusters or aggregates, which improve the soil's structure and increase productivity[7]. The additional organic matter works as a cement in the soil, which may aid in the production of these aggregates and subsequently the soil structure. Medium and fine-textured soils, such as loams and clays, would be virtually impermeable to liquids and gases without the structure of the aggregate. Additionally, aggregation is more influenced by soil organic carbon, particularly in soils with a coarse texture. This demonstrates that soil structural stability is largely dependent on organic content[8].

Veterinary medications, pathogenic bacteria, and heavy metals are among the hazardous substances found in animal excrement from contemporary intensive farms[9]. Animal excrement may have negative effects on soil quality when applied over an extended period of time. The primary markers for defining soil quality were its physical characteristics, such as pore structure and aggregate stability. While aggregate stability has a favorable effect on seed germination, plant roots, and shoot development, soil pores play a critical role in the construction of soil structure, management of soil moisture and nutrients, and protection of microbial diversity.

Waste from poultry can aid in strengthening soil aggregates by adding reinforcement. It has been established over time that the presence of ammonia (NH_3) and hydrogen sulphide (H_2S) could increase the possibility for odours, as well as the amount of uric acid, which can rapidly breakdown and cause soil tilt[10]. When manure is put to the soil, it has a variety of effects and also provides micronutrients that plants may use immediately. Manure also contains nitrogen (as ammonium), phosphorus, and potassium. These substances also trigger biological processes that enable plants to access the nutrients found in manure and organic debris. The objective of this study was to describe the characteristics of poultry wastes from broiler, layer, and cockerel birds while using the wastes to amend the soil and analysing the impact of the wastes on the properties of the soil as a result.

Methodology

Soil/Waste Collection and Sampling: Three different poultry wastes (Broiler, Layer, and Cockerel) were used in the experiment, which was carried out in the Federal College of Agriculture's Controlled Chamber in Ibadan. The soil samples were obtained from the Institute of Agricultural Research and Training's Teaching and Research Farm in Moor Plantation. The soil samples were ground up, sieved with a 2 mm mesh-sized sieve, and then air dried. Each of the four buckets used for the experiment, labeled A, B, C, and D, was filled with 7.0 kg of soil. The Broiler, Layer, and Cockerel poultry wastes totaled 3.0 kg each, and the deep litter system was used to collect them. About 1.0 kg each of waste samples was taken to laboratory in order to analyze for waste characterization, while 2.0 kg each of the samples was mixed with the soil samples already in the four buckets. Buckets A, B, C, and D designated for Broiler Soil, Layer Soil, Cockerel Soil, and Control Soil respectively were replicated four times for each sample. Control Soil was the soil with no application of poultry waste. After the application of wastes, 75cl of distilled water was applied to each bucket to ensure that the waste goes into the soil. The samples were thereafter taken to laboratory in order to analyze for various properties of soil.

Soil Sample Analysis: Pre-analysis of the soil used was initially carried to establish the basic properties of soil and the textural class of soil sample used for the experiment. The samples represented in each bucket subsequently were analyzed using standard test methods to determine the effect of the soil properties as shown below:

Bulk Density: The bulk density of the soil sample was measured after it had been oven-dried at 105°C and weighed. The following expression was used to compute the bulk density of the soil[11].

$$\text{Bulk Density }(g/cm^3) = \frac{\text{Mass of oven dried soil sample}}{\text{Volume of soil sample}}$$

Moisture Content: The following standard procedure was used to determine the moisture content of the soil. After cooling in a desiccator, 2.0 g of each soil sample was placed in a moisture container and dried in an oven at 105°C for 24 hours to achieve consistent weight.

$$\text{Mositure Content} = \frac{\text{Weight of wet sample} - \text{Weight of dry sample}}{\text{Weight of wet sample}} \times 100\%$$

Dissolved Oxygen (DO): The Winkler test, which is manual titration method, was used to determine the concentration of dissolved oxygen in the soil samples. The method was first proposed by Winkler L.W.[12]. It was later modified by Strickland, J.D.H. and Parsons T.R.[13]. The analysis was performed in the laboratory to avoid delays that may result in a change in the oxygen content of the soil. It is usually expressed in mg/L.

Biochemical Oxygen Demand (BOD_5): The biochemical oxygen demand (BOD_5) was a five-day test carried out to measure the quantity of oxygen required by bacteria to biologically oxidize organic material under aerobic conditions[14].

It is usually expressed in mg/L. The soil sample in this experiment was incubated for five days at 20°C in the dark using a Winkler bottle to carry out the test.

Chemical Oxygen Demand (COD): The chemical oxygen demand (COD) test was used to establish the maximum quantity of oxygen that reactions in a measured solution may consume. Its results are often given as the mass of oxygen consumed per volume of solution (mg/L). COD is a measurement of the quantity of oxygen needed for all organic matter in a sample to completely oxidize to CO_2 and H_2O. In this experiment, the COD test was performed in accordance with ASTM regulations using a 0.5 N potassium dichromate solution in 50% sulphuric acid.

pH: The pH of the samples was determined using a glass electrode digital pH meter i.e. by potentiometric method[15].

Particle Density: Particle density has been defined as the density of the solid particles that make up a soil sample which is expressed in grams per cubic centimeter. The particle density of the samples was calculated by volumetric flask method, which is given by the following equation[16].

$$\text{Particle Density } (\text{g/cm}^3) = \frac{\text{Mass of oven dried sample}}{\text{Volume of soil solids only}}$$

Porosity: Porosity is the volume of soil voids that can be filled by water and/or air. It is inversely related to bulk density. The porosity of the samples was calculated by the equation below[17,18].

$$\text{Porosity} = \left(1 - \frac{\text{Bulk Density}}{\text{Particle Density}}\right) \times 100\%$$

Data Analysis: One-way Analysis of Variance (One-way ANOVA) was used to statistically analyze the experimental data, and post-hoc analysis was used to further compare and examine the levels of significance and changes among the soil parameters. As stated in Table-1, the experimental design used a Randomized Completely Block Design (RCBD) that was duplicated four times.

Table-1: Experimental Layout.

Soil Sample	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
T_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3
	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4
T_2	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3
	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4
T_3	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3
	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4
T_4	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3
	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4

Where: i. $P_1, P_2, P_3, P_4, P_5, P_6, P_7$,and P_8 represent the various soil properties analysed (Bulk Density, Moisture Content, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, pH, Particle Density, and Porosity respectively). ii. T_1 is the soil sample with broiler waste (Broiler Soil), while T_2 is the soil sample with layer waste (Layer Soil); T_3 is the soil sample with cockerel waste (Cockerel Soil), and T_4 is the soil sample with no waste application (Control Soil). iii. R_1, R_2, R_3, and R_4 are the replicates of each sample.

Results and Discussion

The particle size distributions of the soil samples are shown in Table-2, the textural tests revealed that the soil is sandy with sand ranging between 83-86% while silt ranges between 10-12% and clay ranges between 2-5% among all the soil samples with the control soil inclusive. The soils' extremely high sand concentration, which results in strong water infiltration but limited water holding and nutrient storage capacity, was noted. The distribution of particle size classifies the soils as sandy, clayey, or loamy.

Table-2: Particle Size Distribution of Soil Samples.

Sample	Sand	Clay	Silt
Broiler Waste Soil	86.73	2.42	10.85
	86.05	3.07	10.38
	84.89	4.15	10.95
	83.90	5.32	10.79
Layer Waste Soil	85.20	4.03	10.78
	84.93	4.23	10.83
	83.88	3.64	12.48
	83.49	4.03	12.49
Cockerel Waste Soil	86.47	3.68	9.86
	85.87	3.62	10.52
	84.60	3.50	11.90
	83.78	3.90	12.32
Control Soil	84.17	5.52	10.31
	86.28	3.22	10.56
	85.93	3.27	10.81
	85.64	3.65	10.71

The wastes' characterization (Table-3) revealed that the application of poultry manures significantly affects the physicochemical and biological characteristics of the soils. Additionally, it was noted that when the soil samples were characterized, cockerel waste had the greatest BOD_5 and COD in comparison to other properties, and that this had a substantial impact after the four treatments.

Application of poultry manure to soil was found to improve soil organic matter, N and P content, and aggregate stability[19].

The organic matter content of the soil may increase as soil physical qualities improve. Because of the increased soil structure and macro porosity brought on by the addition of poultry manure, the soil moisture is able to hold more moisture and better absorb water, improving the mulching effect of organic matter[20].

Table-3: Characterization of Poultry Waste Samples.

Parameter	Broiler	Layer	Cockerel
Moisture (%)	43.70	67.90	55.70
Total Solid (%)	81.75	90.90	86.84
Volatile Solid (%)	81.75	86.31	85.35
Fixed Solid (%)	3.30	3.31	3.30
Total Dissolved Solids (%)	1.48	1.29	1.20
COD (mg/l)	21.22	21.63	22.67
BOD_5 (mg/l)	16.82	16.66	17.88
Dissolved Oxygen (mg/l)	5.86	6.22	6.71
Nitrogen (%)	1.05	1.17	1.09
Phosphorus (%)	0.58	0.63	0.62
Potassium (%)	0.70	0.78	0.81
Organic Matter (%)	56.30	67.90	55.70
Organic Carbon (%)	46.38	44.62	45.97
NH_4-N (%)	0.016	0.016	0.011

From the results of physicochemical and biological properties (Table- 4), it was observed the control sample has highest bulk density while cockerel sample has the least, which shows that the control sample (without waste application) has great effect on the bulk density of the soil followed by cockerel sample. It explained that the wastes generally have effect on the bulk density of the soil. For moisture content, control soil has the highest value with least value recorded for cockerel waste soil. The rate of oxygen dissolved was high for the second replications of all the waste and control soils.

However, BOD_5 and COD values fall almost in same ranges across all the waste soils and the control soil, meanwhile, the layer waste soil has the highest BOD_5 while broiler waste soil has the least BOD_5; the highest COD was recorded at cockerel waste soil and lowest COD at control soil. The pH of all the samples shows that the soil is slightly alkaline, as the values falls within same range.

The particle density also ranges within same while the highest porosity was recorded for cockerel waste soil and least was recorded for control soil as porosity of broiler and layer waste soils fall within same range. The application of different poultry manures in the soil could be responsible for the high porosity.

Given that continuous use of poultry manure will raise the soil's salinity and make it unusable after years of cultivation, it can be inferred that the use of poultry manure has a substantial impact on the soil's qualities. The use of cockerel waste is advised since it primarily amplifies organic properties. According to Table-4, soil treated with cockerel waste had the highest porosity value (68.97–74.13). This is preferable since it will increase soil permeability and crop roots' ease of entry into the soil[21]. The results further validates earlier findings that using organic manure enhances biological activity, which raises the amount of organic matter in the soil[22].

The results similarly discovered that usage of organic manure increase nitrogen, phosphorus and potassium contents of the soil. The accessibility of some elements and their supply to the plant during the period of growth is enhanced by organic manure. Also, poultry manure increases the existence of phosphorus, potassium and magnesium in the soil as a result of the incessant lowering of the pH by manure applications. Figures 1-8 also showed the effects of the physicochemical and biological properties of soil.

Table-4: Physicochemical and Biological Properties of Soil Samples.

Sample	Bulk Density	Moisture Content	Dissolved Oxygen	BOD	COD	pH	Particle Density	Porosity
Broiler Waste Soil	0.89	28.50	6.45	16.72	26.18	7.78	2.65	66.65
	0.86	31.90	6.66	17.61	26.32	8.45	2.65	67.55
	0.77	23.30	4.41	15.77	21.77	7.69	2.57	69.81
	0.77	36.50	5.23	14.52	20.83	7.50	2.56	69.97
Layer Waste Soil	0.89	38.60	6.61	15.94	24.92	7.90	2.68	66.80
	0.87	26.10	6.64	16.49	25.13	8.51	2.66	67.28
	0.77	25.30	5.42	17.80	23.80	7.72	2.55	69.75
	0.77	29.20	5.30	14.62	22.91	7.95	2.55	69.95
Cockerel Waste Soil	0.88	29.70	6.44	16.84	25.69	7.48	2.84	68.97
	0.86	21.90	6.50	17.25	26.49	8.31	2.89	70.17
	0.72	32.10	5.46	14.87	24.87	7.87	2.76	73.81
	0.71	37.60	5.28	15.61	23.14	8.02	2.75	74.13
Control Soil	1.99	27.80	5.75	15.81	22.45	7.88	2.75	27.41
	1.98	27.20	6.25	16.30	22.69	8.50	2.72	27.25
	1.97	24.80	5.62	17.65	21.65	7.51	2.71	27.24
	1.97	39.60	5.28	14.92	21.52	7.08	2.71	27.27

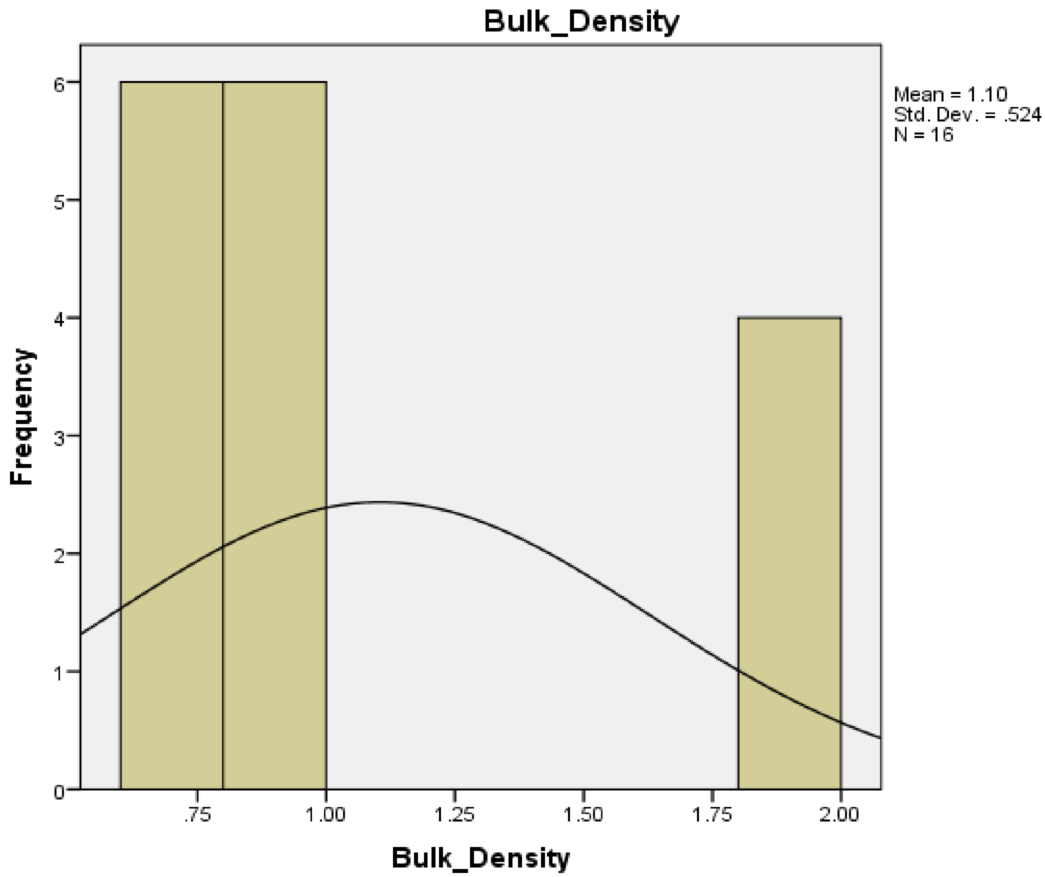

Figure-1: Bulk Density.

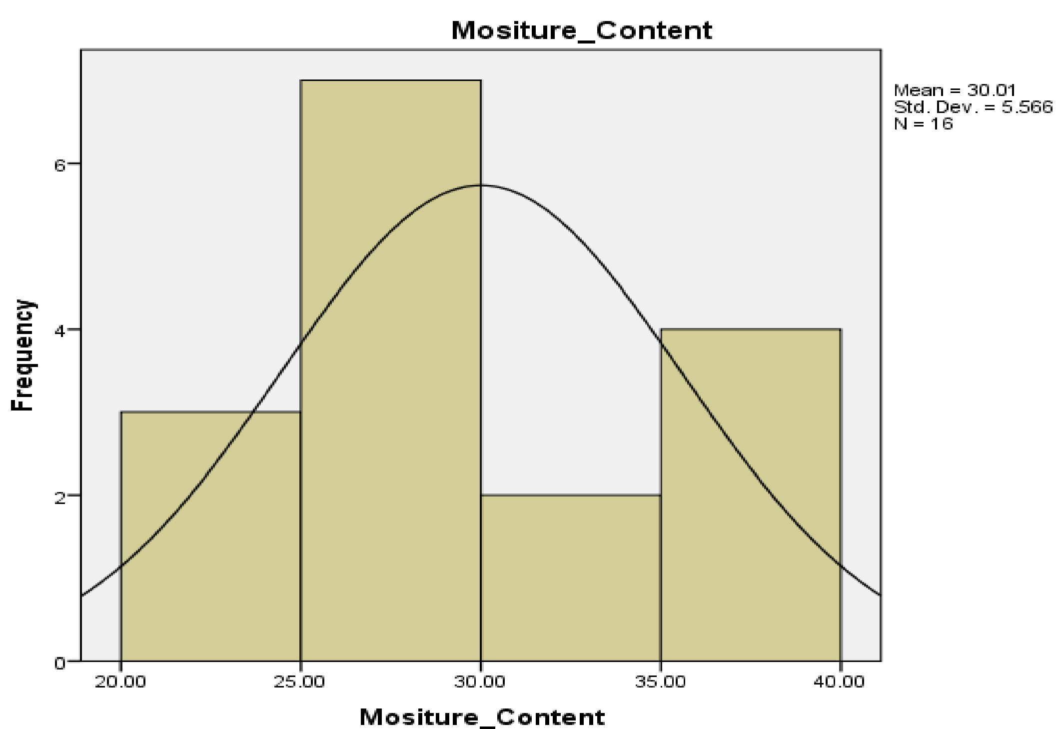

Figure-2: Moisture Content.

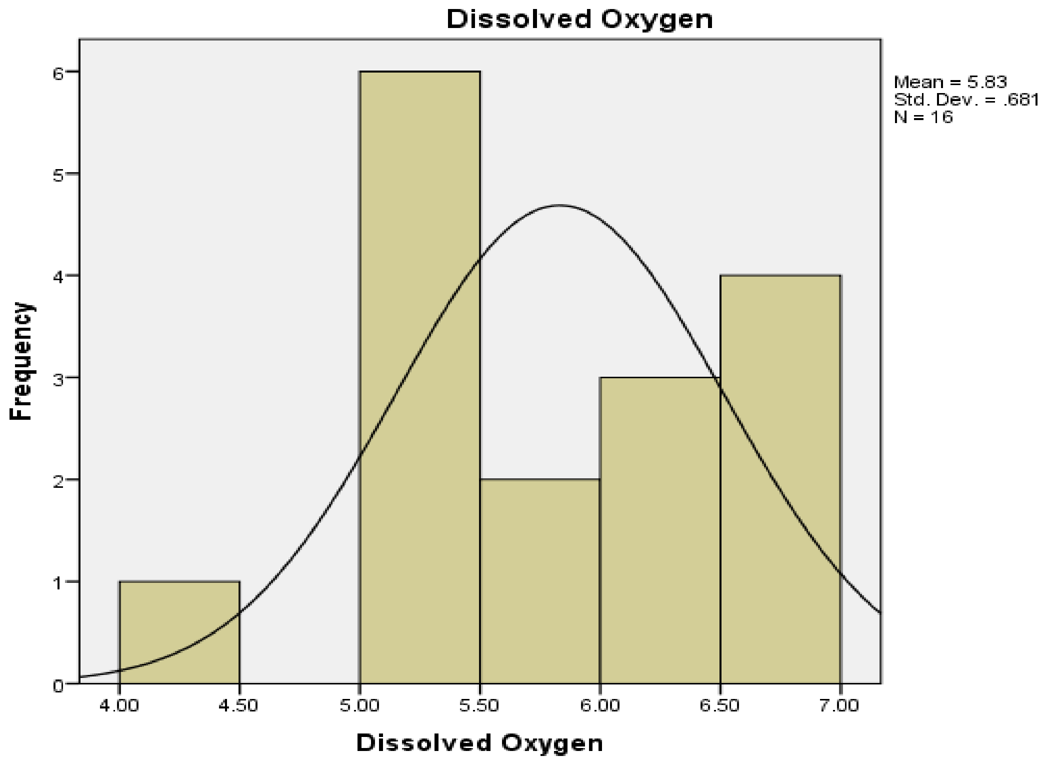

Figure-3: Dissolved Oxygen.

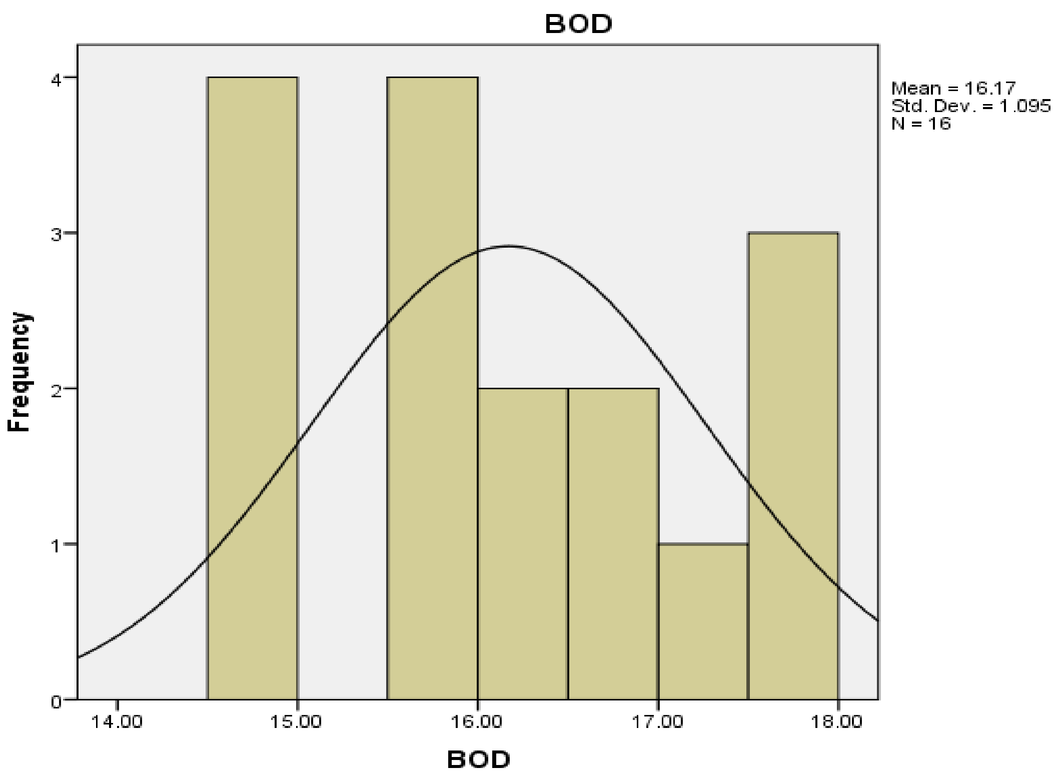

Figure-4: Biochemical Oxygen Demand (BOD).

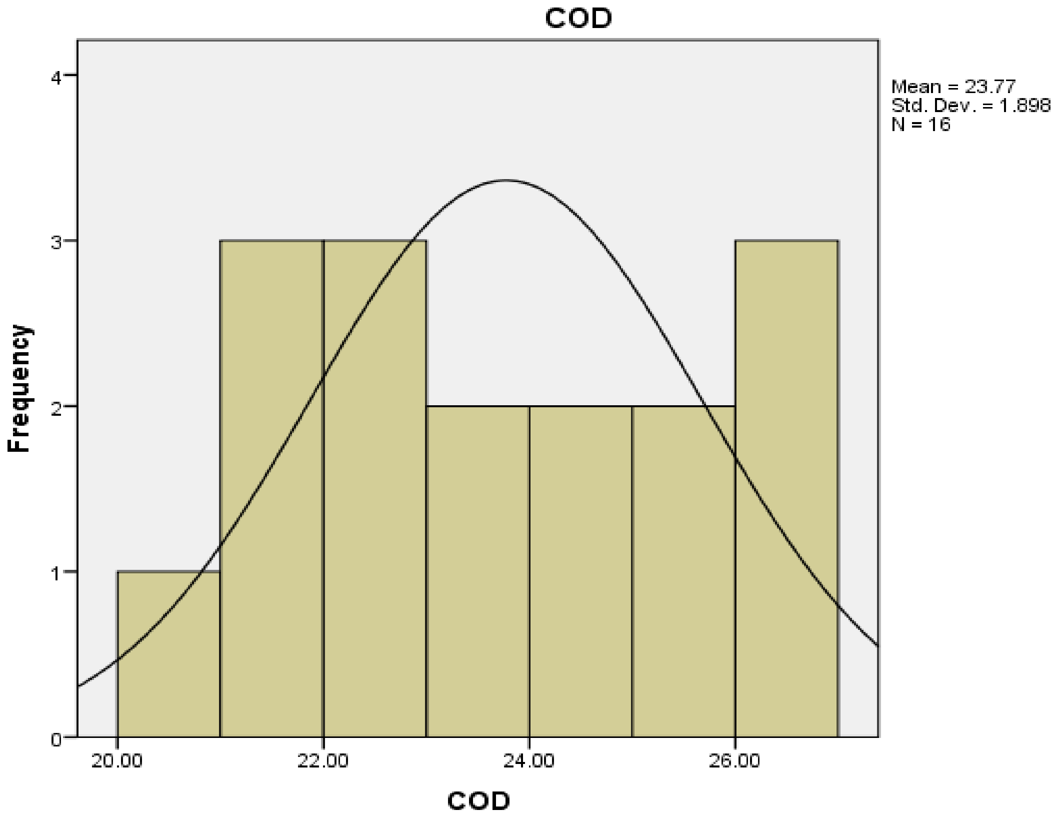

Figure-5: Chemical Oxygen Demand (COD).

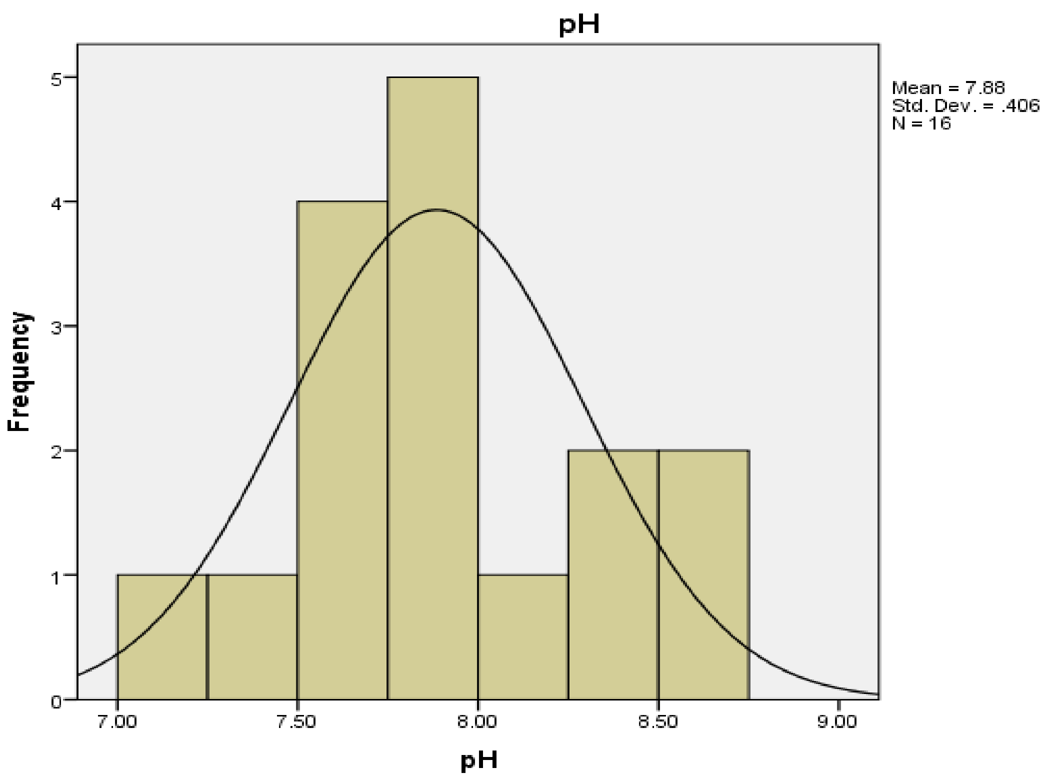

Figure-6: pH

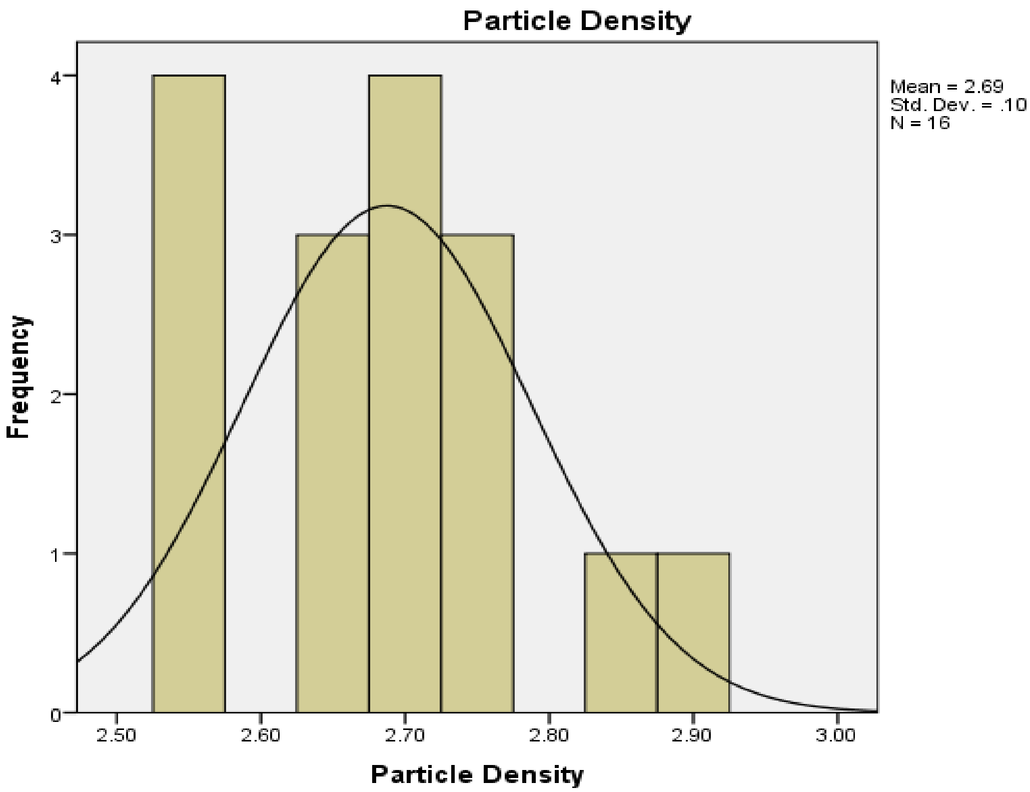

Figure-7: Particle Density.

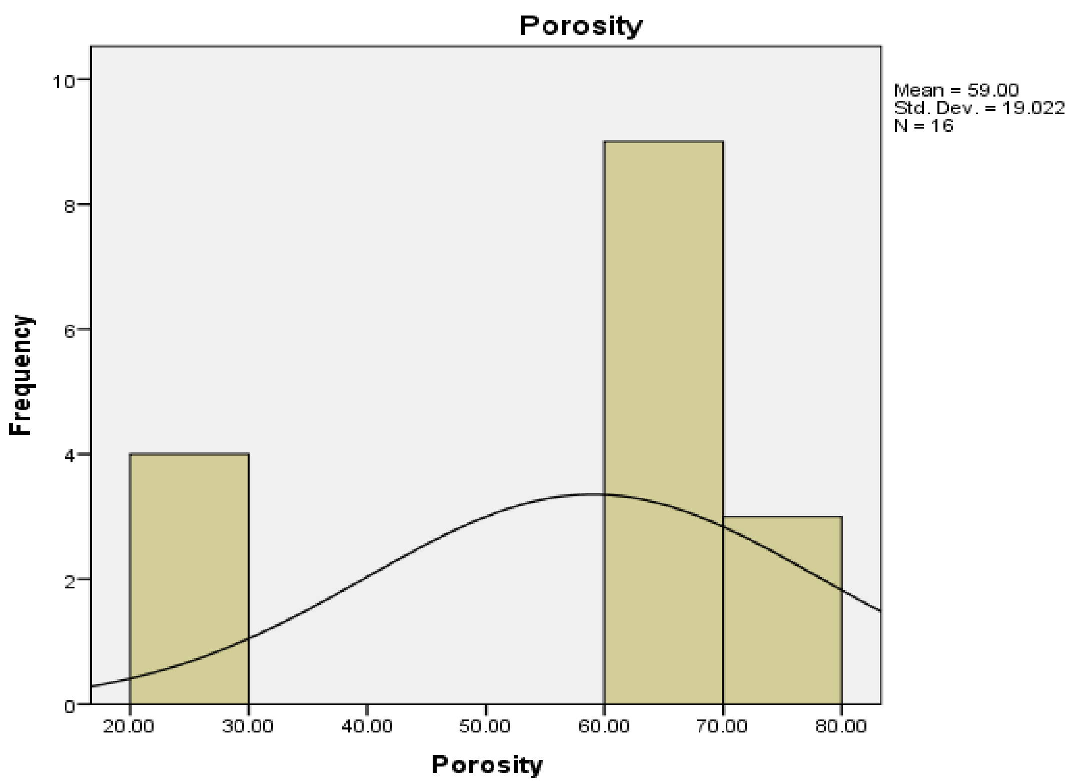

Figure-8: Porosity.

The three soil samples containing poultry wastes and the control sample with no waste differ significantly in terms of bulk densities, according to one-way ANOVA in Table-5 (F = 336.759, df = 15, P 0.05). The bulk densities were found to be moderately low, indicating a low degree of compaction that may have been caused by the local soil's nature and its potential inability to sustain plant development and other agricultural operations due to the presence of manure. From the investigation, it can be inferred that poultry wastes significantly affect the bulk density of soil samples. Additionally, it was discovered that bulk density may be used to evaluate the degree of soil compaction. In general, high bulk density denotes less pore space for water transport, root development, and seedling germination[23].

The findings of the ANOVA analysis (Table-5) further show that the particle densities of the three soil samples containing chicken wastes and the control sample containing no waste differ significantly (F = 12.605, df = 15, P 0.05). This implies that the various poultry manures had a significant impact on the soil particle density. The mass of soil samples in a particular volume is used to determine the soil particle density, which focuses solely on the soil particles and not the entire volume occupied by the particles and pore spaces in the soil. It is clear that the impacts of poultry manure on soil particle density are significant.

Table-5 demonstrates that there are notable differences in the porosities between the three soil samples containing poultry manure and the control sample containing no waste (F = 592.713, df = 15, P 0.05). Low porosity is anticipated to limit water infiltration, which over time increases run-off. The high porosity has been proven to be caused by the sandy soil[23]. According to the study, when overall porosity increased, soil bulk density fell as well, increasing water infiltration and water holding capacity and lowering soil temperature. The porosity values were found to be significantly different (at P 0.05), and this resulted from the impact of the poultry wastes on the soil porosity. However, same ANOVA results in Table-5 shows that there are no significant differences in moisture content, dissolved oxygen (DO), biochemical oxygen demand BOD), chemical oxygen demand (COD) and pH, among the three samples with poultry manure and the control sample with no waste (F = 0.006, 0.157, 0.002, 2.116, 0.282 respectively; df = 15, P < 0.05). Although BOD_5, COD, DO, and organic matter are the key biological qualities, it can be assumed that using poultry manures has a cumulative influence on the biological properties of soil[21]. Additionally, additional parameters exhibit the same pattern as that in the control sample. This suggests that the quantity of applied poultry waste and the biological characteristics are directly related. Additionally, it can be noticed that alkaline soils exhibit phosphorus and other micronutrient deficiencies while acidic soils usually display calcium, phosphorus, and magnesium deficiencies[23].

Table-6 shows the results of the post hoc test for multiple comparisons between the properties that are significantly different at P < 0.05. It can be deduced for bulk density and porosity that three waste samples (Broiler, Layer and Cockerel) are significantly different at P < 0.05, for particle density, it can be seen that broiler and layer waste samples are both significantly different.

Table-5: Analysis of Variance (ANOVA) for the Soil Properties. Significant at P < 0.05*, * in a column are significantly different.

Parameters		Df	Total	Mean	F	Sig.
Bulk Density	Between Groups	3	15	1.1044*	336.759	.000*
	Within Groups	12				
Moisture Content	Between Groups	3	15	30.0063	.006	.999
	Within Groups	12				
Dissolved Oxygen	Between Groups	3	15	5.8312	.157	.923
	Within Groups	12				
BOD	Between Groups	3	15	16.1700	.002	1.000
	Within Groups	12				
COD	Between Groups	3	15	23.7725	2.116	.152
	Within Groups	12				
pH	Between Groups	3	15	7.8844	.282	.837
	Within Groups	12				
Particle Density	Between Groups	3	15	2.6875*	12.605	.001*
	Within Groups	12				
Porosity	Between Groups	3		59.0006*	592.713	.000*
	Within Groups	12				

Table- 6: Post Hoc Test for Multiple Comparisons between Significantly Different Properties at P < 0.05. Significant at P < 0.05*.

Dependent Variable	(I) Sample	(J) Sample	Mean Difference (I-J)	Sig.
Bulk Density	Broiler Waste	Layer Waste	-.00250	1.000
		Cockerel Waste	.03000	.907
		Control	-1.15500*	.000*
	Layer Waste	Broiler Waste	.00250	1.000
		Cockerel Waste	.03250	.886
		Control	-1.15250*	.000*
	Cockerel Waste	Broiler Waste	-.03000	.907
		Layer Waste	-.03250	.886
		Control	-1.18500*	.000*
	Control	Broiler Waste	1.15500*	.000*
		Layer Waste	1.15250*	.000*
		Cockerel Waste	1.18500*	.000*
Particle Density	Broiler Waste	Layer Waste	-.00250	1.000
		Cockerel Waste	-.20250*	.001*
		Control	-.11500	.051
	Layer Waste	Broiler Waste	.00250	1.000
		Cockerel Waste	-.20000*	.001*
		Control	-.11250	.057
	Cockerel Waste	Broiler Waste	.20250*	.001*
		Layer Waste	.20000*	.001*
		Control	.08750	.165
	Control	Broiler Waste	.11500	.051
		Layer Waste	.11250	.057
		Cockerel Waste	-.08750	.165
Porosity	Broiler Waste	Layer Waste	.05000	1.000
		Cockerel Waste	-3.27500	.085
		Control	41.20250*	.000*
	Layer Waste	Broiler Waste	-.05000	1.000
		Cockerel Waste	-3.32500	.079
		Control	41.15250*	.000*
	Cockerel Waste	Broiler Waste	3.27500	.085
		Layer Waste	3.32500	.079
		Control	44.47750*	.000*
	Control	Broiler Waste	-41.20250*	.000*
		Layer Waste	-41.15250*	.000*
		Cockerel Waste	-44.47750*	.000*

Conclusion

It was concluded from the study that the use of poultry wastes has significant effect on the soil's physicochemical and biological characteristics, with cockerel waste having the greatest impact on almost all of the soil's characteristics except for bulk density where broiler waste has the highest effect and for pH where the layer waste also has the highest effect.

The poultry manure reduced the bulk density of the soil and enhanced the moisture content. The usage of poultry manure could potentially be considered as enhancing soil organic matter, nutrient availability, and high yield. It was therefore recommended that more studies could still be carried out on the poultry wastes to discover if the age of the birds may have any impact on the type of waste produced at different stages of their growth.

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