

EFFICACY OF FOOD WASTE AMENDED FEED ON SUSTAINABLE BROILER PRODUCTION

Anthony Boakye Antwi^{1,3*}, Nana Yaa Korankyewa Ayim², Amelan Paule Josephine Kouassi³,
Sampson Oduro-Kwarteng³, Jacob Alhassan Hamidu⁴, Goodman Sarfo Kantanka⁴, Patrick
Boakye⁵, Herman Erick Lutterodt⁶

¹Department of Environmental Health and Sanitation Education, University of Education,
Winneba, Ghana

²Erasmus University, Rotterdam

³Department of Civil Engineering, Kwame Nkrumah University of Science and Technology,
Kumasi, Ghana

⁴Department of Animal Science, Kwame Nkrumah University of Science and Technology, Kumasi,
Ghana

⁵Department of Chemical Engineering, Kwame Nkrumah University of Science and Technology,
Kumasi, Ghana

⁶Department of Food Science and Technology, Kwame Nkrumah University of Science and
Technology, Kumasi, Ghana

*Corresponding author: annyhot24@gmail.com/abantwi@uew.edu.gh

ABSTRACT

Products obtained from poultry (such as meat and eggs) have become a mainstay in the diets of individuals. However, an upsurge in the cost of traditional feed like maize, has imposed on humans the need to utilize other feed materials such as agricultural byproducts or food waste in poultry production. This study was conducted to determine the effect of formulated diet from treated food waste, on the growth performance of broilers fed with the feed. Food wastes sourced from different locations were dried and processed into feed of different formulations (containing apposite amounts of nutrients akin to conventional feeds) before being fed to broilers. It was noticed that the diets contained minimal concentrations of contaminants, thus rendering it safe for consumption. Diets containing the food waste-maize component of 75% cereals (rice, millet, banku and kenkey) with enzyme and 25% maize were deemed the most efficient in broiler production as it yielded the highest bodyweight in broilers, was efficiently consumed by broilers and had a better feed conversion ratio. Thus, this diet is most efficient as feed for broiler production.

Keywords: Broiler production, dehydration, feed safety, food waste nutrient.

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INTRODUCTION

Due to the high costs of traditional feed materials like yellow maize and soybean meal, the poultry sector in developing nations is experiencing some difficulties (Alagawany *et al.*, 2018). It is therefore prudent to utilize other agricultural byproducts or food waste that are less expensive than traditional feed materials as a result of rising costs for poultry feed ingredients (Alagawany *et al.*, 2018). Projection to the year 2050 indicates that there is an expected rise in demand for meat and other animal products, which will put more pressure on the food industry (Georganas *et al.*, 2020). Food waste (FW) could replace some of the cereal grains and plant proteins required in animal nutrition, reducing the need for people and animals to compete for the same food supply (Singh *et al.*, 2019).

Furthermore, since animal feed is the initial source in the food chain, there is a risk that contaminated feeds will transfer contaminants to animal tissues and body fluids, and eventually to products like eggs and meat (Arroyo-Manzanares *et al.*, 2015). The safety issue about animal feeds made from food waste is a concern whether a feed can first, satisfy the nutrient requirements, and second, contains dangerous components (Chen *et al.*, 2015). Treating food waste is a crucial step since it can make it easier to incorporate it into animal feeds (Georganas *et al.*, 2020). This study was therefore carried out to determine the effect of utilizing safe treated food waste processed into formulated diets on poultry growth. The formulation contains the apposite nutrients from the food waste and other constituents such as wheat bran, fish meal, soybean cake, oyster shell, salt, and vitamin/mineral premix. Furthermore, some of the feed contained enzyme supplementation in quantities needed to optimize nutrient utilization by poultry.

MATERIALS AND METHODS (METHODOLOGY)

Food Waste Sourcing and Thermal Treatment

FW was obtained from various locations, restaurants, fast foods, boarding schools, chop bars and markets in the Oforikrom Municipality of Ghana and transported to the Environmental Quality Engineering Laboratory, Kwame Nkrumah University of Science and Technology (KNUST), Ghana. The Food waste (FW) collected were grouped into cereals, tubers and vegetables. The cereal category consisted of rice, millet, banku and kenkey while the tubers were cassava, yam, and plantain. The vegetables consisted of carrots, onions, tomatoes and cabbage. The FW was collected from the source locations over a period of 22 weeks for two seasons (rainy and dry seasons, from November to April). The quantities of cereals, tubers and vegetables collected over the weeks were 4124.5 kg, 3868.5 kg and 1833.9 kg, respectively. The FW after collection was subjected to dehydration technologies (using an electric oven and a rotary drum dryer) after initial drying using a solar cabinet dryer for 24 hours, as a pretreatment to decrease initial moisture content of the FW, as well as to lessen the drying time of the succeeding dehydration technologies employed in the study. Subsequent drying using an electric oven spanned between 3 hours at an average temperature range of 120°C for cereal FW and averagely 4 hours at an average temperature of 150°C for tuber FW. By virtue of its efficiency, the rotary drum dryer was used to dry only cereal FW at an average temperature range of 300°C for averagely 2 hours. The solar cabinet dryer and electric oven was used to dry cereals, tubers and vegetables.

Size Reduction of Food Waste

Upon cooling down, the dried FW was homogenized into a uniform particle size by milling using a sieve with a diameter size of 2 mm.

Feed Formulation

The FW was then used to formulate the feed. A total of 100 kg of each dietary treatment was formulated for the study. The feed was formulated according to conventional feed composition (Adu-Gyamfi, 2017; Kangah, 2019) with some modifications. For 100 kg of each treatment, the following feed materials were included: dried food waste, maize, wheat bran, fish meal, soyabean cake, oyster shell, salt, Vitamin/Mineral premix, soybean oil and enzyme. With the exception of the dried food waste, all the other feed ingredients were purchased at the Ejisu market of the Ashanti Region of Ghana. The enzyme used, KEMZYME was a multienzyme that included beta-glucanase, beta-xylanase, protease, alpha-amylase and phytase. Enzyme was added in the diets of Treatment 2 (T2) and Treatment 4 (T4). Soybean oil was added in the diets of Treatment 6 (T6) and Treatment 8 (T8). The maize component of the feed was replaced in different concentrations with FW (Adu-Gyamfi, 2017; Kangah, 2019)) across the different treatments according to the following compositions:

Control (Cntrl) – 100% maize

Treatment One (T1) – 50% tubers and 50% maize

Treatment Two (T2) – 50% tubers + enzyme and 50% maize

Treatment Three (T3) – 75% cereals and 25% maize

Treatment Four (T4) – 75% cereals + enzyme and 25% maize

Treatment Five (T5) – 50% food waste only (consisting of 50% cereals, 40% tubers and 10% vegetables) and 50% maize

Treatment Six (T6) – 50% food waste (consisting of 50% cereals, 40% tubers and 10% vegetables) + soybean oil and 50% maize

Treatment Seven (T7) – 100% food waste only (consisting of 50% cereals, 40% tubers and 10% vegetables)

Treatment Eight (T8) – 100% food waste (consisting of 50% cereals, 40% tubers and 10% vegetables) + 2x soybean oil.

Nutritional Composition Analysis of Feed

Nutritional analysis (crude protein (CP), crude fibre (CF), crude fat (CFa), moisture content (MC), ash content (AC), and carbohydrate content (CC) in the various dietary treatment were determined at the Food Science Technology Laboratory, KNUST. The nutritional content in the samples was determined using procedures described by Association of Official Analytical Chemists (AOAC) (2005).

The nitrogen free extract (NFE) was calculated as follows: $NFE = 100 - (\%CP + \%CFa + \%AC + \%CF)$.

The metabolizable energy was calculated as follows: $Energy (Kcal/Kg) = (37 * \%CP) + (8.18 * \%CFa) + (35 * \%NFE)$.

Laboratory Analysis to Determine Contaminants in The Feed

The various dietary treatments were then analyzed for various microbial groups, mycotoxins, antinutrients and heavy metals.

Microbial Analysis of Feed

The presence and quantities of microbial groups such as Total Coliforms (TC), Faecal Coliforms (FC), *Escherichia coli* spp. (EC), *Staphylococcus* spp. (SS), Faecal Enterococci (FE), *Salmonella* spp Mould and Yeast in the various dietary treatments were determined at the Microbiology Laboratory of the Department of Theoretical and Applied Biology, KNUST. The most probable number method was used to determine TC, FC, and EC in the samples as carried out in other studies (Ameh *et al.*, 2017; Idu *et al.*, 2011; Stanley *et al.*, 2014). The pour plate method was used to determine the FE, SS, *Salmonella* spp., Moulds and Yeast in samples as carried out in other studies (Ameh *et al.*, 2017; Idu *et al.*, 2011; Stanley *et al.*, 2014).

Antinutrient Content Analysis of Feed

The presence of antinutrients such as phytate, tannins and oxalate in the various feed formulations were determined at the Food Science Technology Laboratory, KNUST. The phytate content in samples was determined using the volumetric titration method for determining phytate described by Damilola *et al.* (2013) and Egbebi *et al.* (2016). The oxalate content in samples was determined using the titration method described by Egbebi *et al.* (2016) and Borquaye *et al.* (2017). The tannin content in samples was determined using Folin-Ciocalteu method described by Damilola *et al.* (2013) and Eneh *et al.* (2018).

Heavy Metal Content Analysis of Feed

The presence of these heavy metals, Arsenic (As), Cadmium (Cd), Lead (Pb) and Mercury (Hg) in the various dietary treatments were determined at the Soil Science Laboratory

of the Department of Agriculture, KNUST. The heavy metals content in samples was determined using the wet acid digestion preparation step with Flame Atomic Absorption Spectrometry procedures described by Garg (2012) and Owusu-Asante *et al.* (2022).

Mycotoxin Content Analysis of Feed

The presence of Aflatoxins, B1, B2, G1 and G2, Ochratoxin A (OTA) and Zearalenone were determined at the Clinical Analysis Laboratory, KNUST. Aflatoxin, OTA and Zearalenone were determined in the samples based on the QUECHERS method with modifications and High-Performance Liquid Chromatography (HPLC) contained in AOAC Official Method 2005.08 (AOAC, 2005; Lim *et al.*, 2018; Sirhan *et al.*, 2014). The Total Aflatoxins (TF) was obtained by summing the values obtained for Aflatoxins B1, B2, G1 and G2.

Broiler Growth Performance Study

A total of 500 Cobb 500 broilers were then fed the formulated feed. The broiler production study took place at the Department of Animal Science, Faculty of Agriculture. The broilers were allocated to 9 treatments (based on the dietary treatment) and each replicated 4 times in pens measuring 1 m by 0.7 m. Each replicate had between 13 to 15 broiler chicks. Birds were brooded on the same standard feed for 3 weeks and at the end of the 3rd week, the birds were then fed with the formulated feed till the end of the 8th week.

The effect of the different dietary treatments was measured on growth performance, weekly feed intake, weekly body weight and feed conversion ratio, which was calculated as:

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Feed intake}}{\text{Body weight gain}}$$

Data Management and Analysis

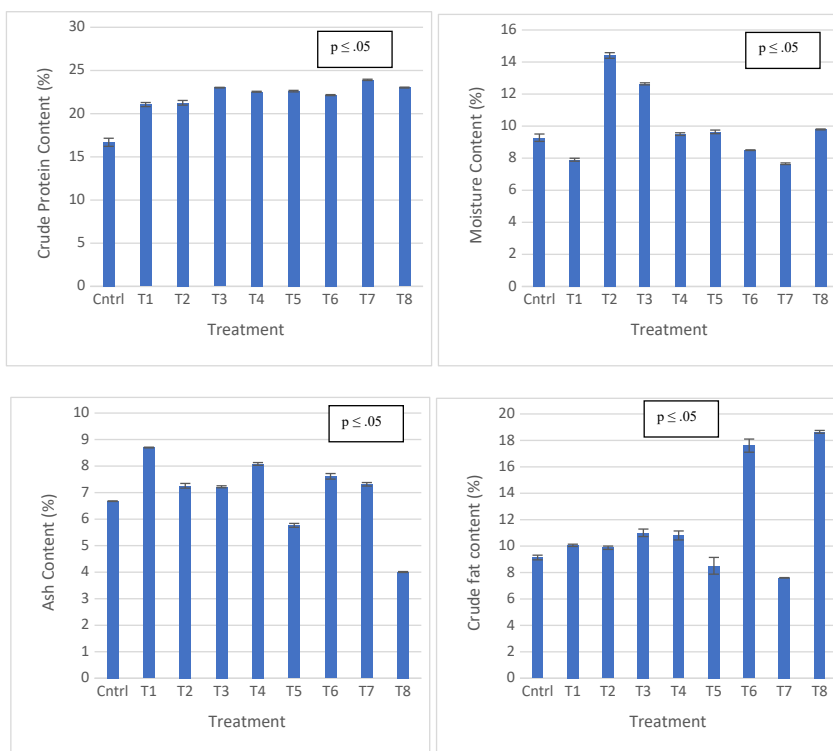
Microsoft Excel 2013 was used to enter data and analyze data using descriptive statistics, mean, standard deviation and ranges. Using the SPSS version 17 software, the significant difference of nutritional and safety quality between the feed samples were determined. Furthermore, the various growth performance indices of broilers fed with the different treatments throughout the experimental period were also determined by calculating the body weight of broilers, the feed consumed by the broilers and the feed conversion ratio.

RESULTS AND DISCUSSION

Nutritional Content of Food Waste Based Experimental Diets

The various nutritional content of the different food waste formulated diets was measured as seen in Figure 3.1.

The crude protein content ranged from 16.68% to 23.92% and was significantly different across the experimental diets ($p = 0.000 \leq .05$). The moisture content was between 7.65% to 14.41% and was significantly different across the experimental diets ($p = 0.000 \leq .05$). The ash content spanned from 4.01% to 8.70% and was significantly different across the experimental diets ($p = 0.000 \leq .05$). The crude fat content ranged from 7.60% to 18.65% and was significantly different across the experimental diets ($p = 0.000 \leq .05$). The crude fibre content spanned from 2.79% to 12.72% and was significantly different across the experimental diets ($p = 0.000 \leq .05$). The carbohydrate content ranged from 32.26% to 55.80% and was significantly different across the experimental diets ($p = 0.000 \leq .05$). The metabolizable energy was between 3868.24 Kcal/kg to 4287.33 Kcal/kg and was significantly different across the experimental diets ($p = 0.000 \leq .05$).



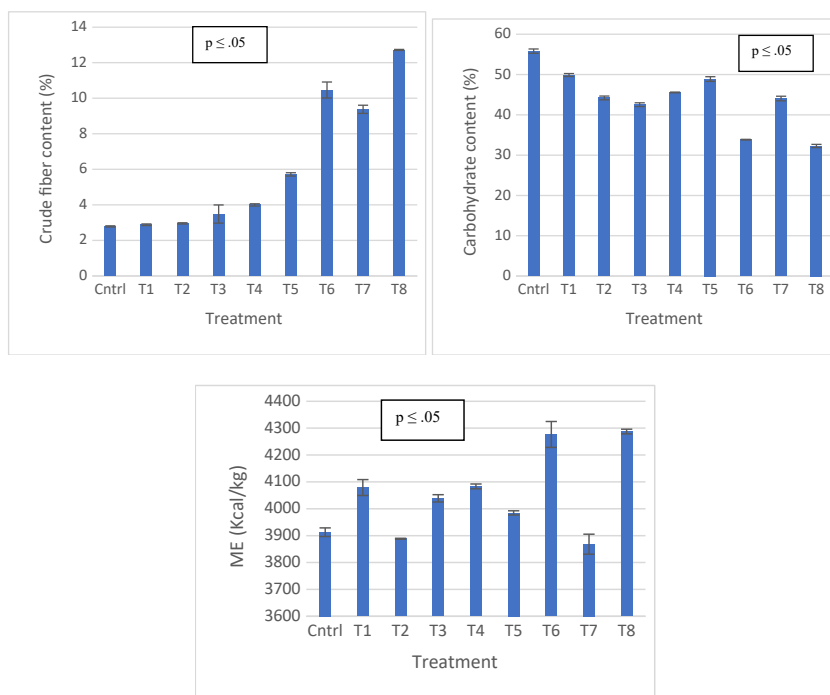


Figure 3.1 Average nutritional content in experimental diets

The crude protein in the food waste-based diets were generally higher than the conventional diet. This results was contradictory to a study by (Noori *et al.*, 2022) who indicated that the dried food waste had less protein than usual feed, thus it was advised to include a protein source. However, other studies by Esmail (2016) indicated that broiler diets containing crude protein content of 19 – 23% is acceptable. The results obtained in this study for formulated diets was within this range. With the exception of the feed treatments T2 (14.4%) and T3 (12.6%), the animal diets formulated had average moisture content values below 10%. The moisture content of the formulated diets in this study was generally within the standard (10 – 12%) for prepared broiler feed (Islam *et al.*, 2015). Varying levels of ash content (4.01% to 8.70%) were recorded in the diets. Treatments T6 and T8 yielded the highest levels of crude fat (17.60% and 18.65% respectively) and crude

fibre (10.46% and 12.72% respectively) as a result of it containing soybean oil. Moreover, T8 which had more soybean oil was found to contain more crude fat and crude fibre content as compared to T6 which had less soybean oil. T6 (33.83%) and T8 (32.26%), diets which contained more oil component were observed to have the least carbohydrate content. The carbohydrate content was higher in conventional maize diets than all the other food waste-based diets. The energy content of the diets was found to be highest in the diets T6 (4276.62 Kcal/kg) and T8 (4287.33 Kcal/kg) that contained soybean oil. This could be attributed to the appropriate levels of carbohydrate content and increased crude fat and crude fibre content of those diets. The diet (T8) containing more soybean oil was found to have more metabolizable energy.

Safety Quality of Food Waste-Based Diets**Microbial Load of Food Waste-Based Diets**

The results of the study indicated the presence of different microbial groups in food waste formulated feed (Table 3.1 – Table 3.2).

Table 3.1 Microbial Load in Experimental Diets

Trt	TC (100mg cfu) (Mean ± Stdev)	FC (100mg cfu) (Mean ± Stdev)	E. Coli (100mg cfu) (Mean ± Stdev)
Cntrl	0.00E+00 ± 0	0.00E+00 ± 0	0.00E+00 ± 0
T1	2.35E+07 ± 0	2.10E+06 ± 0	0.00E+00 ± 0
T2	4.15E+05 ± 0	2.30E+05 ± 0	0.00E+00 ± 0
T3	4.15E+05 ± 0	0.00E+00 ± 0	0.00E+00 ± 0
T4	9.15E+06 ± 0	1.63E+06 ± 1.01E+06	0.00E+00 ± 0
T5	1.62E+05 ± 9.62E+04	0.00E+00 ± 0	0.00E+00 ± 0
T6	6.65E+06 ± 3.54E+06	4.15E+05 ± 0	9.00E+04 ± 0
T7	6.65E+05 ± 3.54E+05	4.00E+04 ± 0	0.00E+00 ± 0
T8	2.35E+06 ± 0	2.30E+05 ± 0	9.00E+04 ± 0
Overall P-value	0.000	0.001	-

Trt – Treatment; Cntrl – Control; Stdev – Standard Deviation

Table 3.2 Microbial Load in Experimental Diets

Trt	Staph (1ml cfu) (Mean ± Stdev)	FE (1ml cfu) (Mean ± Stdev)	Yeast (1ml cfu) (Mean ± Stdev)	Mould (1ml cfu) (Mean ± Stdev)
Cntrl	4.75E+01 ± 7.78E+0	0.00E+00 ± 0	1.29E+06 ± 1.43E+06	3.15E+05 ± 1.29E+04
T1	4.23E+04 ± 5.06E+04	1.75E+02 ± 3.54E+01	1.36E+05 ± 1.69E+04	1.00E+05 ± 1.14E+04
T2	6.82E+04 ± 2.65E+04	2.80E+02 ± 4.24E+01	1.56E+04 ± 9.24E+03	5.94E+02 ± 1.25E+02
T3	1.92E+04 ± 0	0.00E+00 ± 0	2.36E+03 ± 1.21E+03	2.57E+03 ± 4.63E+02
T4	1.06E+04 ± 2.69E+03	1.00E+02 ± 2.83E+01	3.54E+04 ± 1.17E+04	1.93E+04 ± 1.99E+04
T5	2.60E+04 ± 2.86E+04	0.00E+00 ± 0	3.09E+05 ± 5.06E+04	3.01E+05 ± 1.67E+04
T6	1.11E+05 ± 2.27E+04	0.00E+00 ± 0	5.17E+05 ± 3.71E+04	4.84E+05 ± 1.90E+04
T7	4.77E+05 ± 1.17E+04	0.00E+00 ± 0	2.72E+05 ± 1.74E+04	1.45E+05 ± 2.30E+04
T8	6.44E+05 ± 1.61E+04	3.03E+03 ± 4.31E+02	3.45E+05 ± 6.08E+03	2.87E+05 ± 1.51E+04
Overall P-value	0.000	0.000	0.308	0.000

Trt – Treatment; Cntrl – Control; Stdev – Standard Deviation

Several bacterial groups, TC, FC, E. Coli, Staph, and FE, as well as fungal groups, mould and yeast were found in the diets fed to broilers in this study. TC, FC, E. Coli and FE were not found in the Control samples. *Salmonella* spp. were not found in the diets. Studies have indicated that microbes such as *Campylobacter* and *Salmonella* may be isolated in poultry (Dame-Korevaar *et al.*, 2021). The absence of

Salmonella in feed samples bodes well for the safety of the feed. Varying concentrations of microbes were found in the formulated diets. The microbial contamination may be due to the moisture content found in the feed that encourage proliferation of the microbes. The presence of moisture in feed supports a lot of microorganisms, aiding it in starting the decaying process (O'Connor *et al.*, 2021).

Furthermore, microbes may be introduced into diets through the preparation and storage of the feed. Furthermore, the microbial contamination may be from infestation such as rodents, insects and birds. Indicators of faecal contamination such as *E. Coli* and FE were found in some diets. The faecal contamination may be due to faecal matter from rodents, insects and birds. The bacterial groups in this study were generally in quantities that did not render the feed unsafe. Any detection of pathogenic *E. coli* strains and fecal *Enterococci* are unacceptable as they indicate the presence

of faecal contamination (Islam *et al.*, 2020; Yadav *et al.*, 2022). Fungal contamination according to Sultana *et al.* (2017) should not exceed 1×10^5 cfu/g. The fungal groups obtained in this study were generally below these values.

Antinutrient Concentration of Food Waste-Based Diets

The antinutrient concentrations (phytate, oxalate and tannins) observed in the formulated feed are shown in Table 3.3.

Table 3.3 Antinutrients Concentration in Experimental Diets

Treatment	Phytate (mg/100g) (Mean $\pm$ Stdev)	Oxalate (mg/100g) (Mean $\pm$ Stdev)	Tannins (mg/100g) (Mean $\pm$ Stdev)
Cntrl	8.89E+02 $\pm$ 3.43E+01	4.55E+03 $\pm$ 6.12E+01	1.35E+03 $\pm$ 4.55E+02
T1	3.27E+02 $\pm$ 7.82E+0	3.44E+03 $\pm$ 2.43E+02	1.14E+03 $\pm$ 3.83+02
T2	4.63E+02 $\pm$ 1.76E+01	3.59E+03 $\pm$ 3.71E+02	3.45E+02 $\pm$ 9.85E+0
T3	3.45E+02 $\pm$ 2.67E+01	3.72E+03 $\pm$ 3.67E+02	4.43E+02 $\pm$ 1.22E+01
T4	4.08E+02 $\pm$ 1.75E+01	3.91E+03 $\pm$ 6.08E+01	8.99E+02 $\pm$ 1.03E+02
T5	1.13E+02 $\pm$ 1.75E+01	5.05E+03 $\pm$ 2.42E+02	4.84E+02 $\pm$ 1.48E+02
T6	5.94E+02 $\pm$ 8.63E+0	5.95E+03 $\pm$ 3.71E+02	1.59E+03 $\pm$ 1.58E+02
T7	3.39E+02 $\pm$ 1.83E+01	3.50E+03 $\pm$ 2.48E+02	4.65E+02 $\pm$ 6.42
T8	3.51E+02 $\pm$ 4.95E-02	4.26E+03 $\pm$ 1.23E+02	1.83E+02 $\pm$ 7.57
Overall P-value	0.000	0.000	0.001

Trt – Treatment; Cntrl – Control; Stdev – Standard Deviation

Varying concentrations of antinutrients were found in the feed in this study. This was expected as phytate, oxalate, and tannins concentrations are expected to be prevalent in cereals, tubers and maize as antinutrients are naturally occurring substances found in several plant based products (Nikmaram *et al.*, 2017). These antinutrients interfere with the digestibility and bioavailability of the nutrients they bind, lowering the nutritional content of diets that contain them (Singh *et al.*, 2019). Phytates have been found to bind cations and prevents their absorption (Dahdouh *et al.*, 2019). Tannins also bind to proteins to form protein complexes thereby causing the protein digestibility to reduce (Popova & Mihaylova, 2019). The presence

of these antinutrients in this study were in minimal concentrations and therefore was not expected to significantly restrict the adequate absorption of nutrients in the feed.

Heavy Metals Content of Food Waste-Based Diets

From the study it was identified that heavy metals were found in formulated feed (Table 3.4).

Table 3.4 Heavy Metal Concentration in Experimental Diets

Trt	Arsenic (mg/kg) (Mean ± Stdev)	Cadmium (mg/kg) (Mean ± Stdev)	Lead (mg/kg) (Mean ± Stdev)	Mercury (mg/kg) (Mean ± Stdev)
Cntrl	3.42E-02 ± 5.77E-05	2.52E-01 ± 3.55E-02	1.80E-01 ± 2.08E-03	6.92E-02 ± 9.00E-04
T1	3.52E-02 ± 5.77E-05	2.43E-01 ± 3.55E-02	1.50E-01 ± 2.31E-03	6.26E-02 ± 1.20E-03
T2	3.32E-02 ± 1.15E-04	4.47E-01 ± 2.08E-02	1.37E-01 ± 3.61E-03	7.04E-02 ± 1.23E-03
T3	3.42E-02 ± 2.65E-04	2.53E-01 ± 8.50E-02	1.38E-01 ± 4.04E-03	7.66E-02 ± 2.16E-03
T4	3.54E-02 ± 1.53E-04	7.97E-01 ± 6.81E-02	1.52E-01 ± 2.65E-03	6.03E-02 ± 1.88E-03
T5	3.31E-02 ± 5.77E-05	2.97E-01 ± 1.40E-02	1.28E-01 ± 2.65E-03	6.76E-02 ± 2.19E-03
T6	3.48E-02 ± 1.15E-04	5.90E-01 ± 1.00E-02	1.36E-01 ± 3.06E-03	6.15E-02 ± 1.20E-03
T7	3.33E-02 ± 5.77E-05	8.30E-01 ± 1.05E-02	1.29E-01 ± 4.58E-03	5.92E-02 ± 5.13E-03
T8	3.25E-02 ± 5.13E-04	3.80E-01 ± 2.65E-02	1.20E-01 ± 3.21E-03	6.75E-02 ± 1.55E-03
Overall P-value	-	0.000	0.000	0.000

Trt – Treatment; Cntrl – Control; Stdev – Standard Deviation

According to Adamse *et al.* (2017), the levels of elements such as cadmium, mercury and arsenic are typically low in feed items with a plant origin. This assertion was found to be consistent with the results of this study as minute and varying concentrations of heavy metals (As, Pb, Hg and Cd) were found in all treatments of feed. Heavy metals in feed could have originated from industrial pollution, geological sources, or particular feed additives (Adamse *et al.*, 2017). According to FAO and IFIF (2020), the maximum guideline values for these metals in animal feed are 100 mg/kg for

As, 40 mg/kg for Pb, 10 mg/kg for Hg, and Cd. The heavy metals concentrations in the feed samples in this study were below the guideline values.

Mycotoxin Concentration in Experimental Diets

The total aflatoxin (Aflatoxin B1, B2, G1 and G2) concentration as well as the Ochratoxin A concentration found in the formulated feed is shown in Table 3.5.

Table 3.5 Mycotoxin Concentration in Food Waste from Source Locations

Treatment	Total Aflatoxin (ng/ml) (Mean ± Stdev)	Ochratoxin A (ng/ml) (Mean ± Stdev)
Cntrl	9.95E-02 ± 3.70E-02	1.33E-01 ± 1.43E-03
T1	7.66E-02 ± 3.76E-02	1.87E-01 ± 2.93E-02
T2	1.04E-01 ± 3.83E-02	2.61E-01 ± 6.14E-03
T3	0.00E+00 ± 4.14E-02	2.00E-01 ± 7.27E-03
T4	1.55E-01 ± 0	2.21E-01 ± 1.41E-02
T5	0.00E+00 ± 7.77E-02	1.41E-01 ± 2.72E-03
T6	6.56E-02 ± 0	1.54E-01 ± 5.99E-03
T7	4.31E-02 ± 3.28E-02	1.54E-01 ± 2.62E-02
T8	9.49E-02 ± 2.15E-02	1.12E-01 ± 8.64E-03
Overall P-value	0.895	0.000

The primary Aflatoxins (AFs) found naturally in animal diets are Aflatoxin B1 (AFB1), Aflatoxin B2 (AFB2), Aflatoxin G1 (AFG1), and Aflatoxin G2 (AFG2). Varying concentration of Total AFs

and OTA were recorded in all the formulated diets. The maximum limit for aflatoxins in poultry feed per FDA regulatory levels is 300 µg/kg (NGFA., 2011).

The aflatoxins obtained in the diets fed to broilers in this study were below these values. The findings also indicated that concentration of OTA recorded for the diets were below the EU standard for the maximum limit of Ochratoxin A in cereals, 2 µg /kg (Kumar et al., 2020).

Biological factors (such as plant variety, insects, stress, and spore load), physical factors (such as moisture, temperature, relative mechanical damage, and humidity), and chemical factors (such as substrate

composition, oxygen, carbon dioxide, and pesticides), and all have an impact on how much toxin is created (Ukwuru et al., 2017).

Effect of Food Waste-Based Diets on Broiler Growth

Bodyweight of Broilers Fed With Food-Waste Based Diets

Table 3.6 below indicates the effect of food waste formulated feed consumed on the body weight of broilers.

Table 3.6 Body Weight of Broilers Fed Food Waste-Based Diets

Trt	Bodyweight (g)				
	Week 3	Week 4	Week 5	Week 6	Week 7
Cntrl	921.0 ± 15.6	1237.0 ± 1.4	1642.0 ± 67.9	2025.2 ± 182.9	2532.6 ± 378.1
T1	906.5 ± 31.8	1056.5 ± 96.9	1458.3 ± 203.3	1756.5 ± 297.8	2298.4 ± 511.3
T2	994.0 ± 50.9	1222.0 ± 56.6	1543.1 ± 122.9	1679.8 ± 15.7	2058.8 ± 160.3
T3	962.5 ± 23.3	1143.1 ± 15.7	1453.9 ± 55.6	1856.8 ± 68.5	2426.7 ± 150.8
T4	973.5 ± 17.7	1157.7 ± 19.0	1604.8 ± 28.6	2042.0 ± 26.7	2598.3 ± 200.4
T5	902.6 ± 37.5	1473.9 ± 33.7	1780.5 ± 7.8	2475.0 ± 388.9	2594.5 ± 275.1
T6	861.5 ± 30.9	1387.7 ± 76.8	1837.5 ± 113.1	2218.8 ± 61.9	2285.0 ± 21.2
T7	780.2 ± 41.2	1276.8 ± 15.2	1559.7 ± 21.6	1885.0 ± 21.2	2075.0 ± 35.4
T8	810 ± 41.2	1413.7 ± 30.7	1729.9 ± 63.8	2268.8 ± 26.5	2330.0 ± 0
Overall P-value	0.001	0.000	0.026	0.020	0.353

Trt – Treatment; Cntrl – Control; Stdev – Standard Deviation

The overall bodyweight of broilers fed food with waste-based diets ranged from 1294.8 g to 1691.9 g.

There was no significant difference ($P \geq 0.05$) in the total weight gained by broilers fed with different treatments of the formulated feed (Figure 3.2).

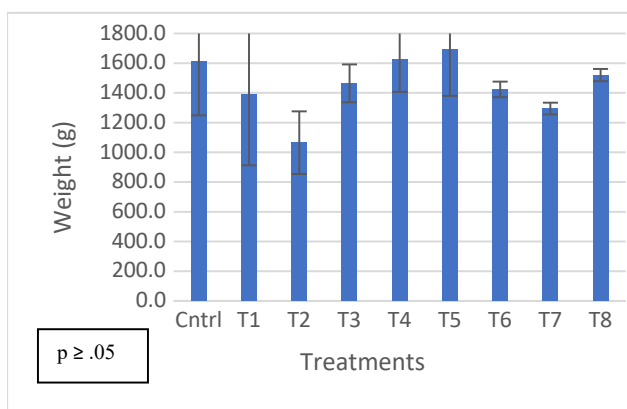


Figure 3.2 Overall bodyweight of broilers fed food waste-based diets

It was observed that the body weight of the broilers in week 3 (the start of the experiment), were not uniform. The body weight of some broilers (particularly those fed T6 (861.5g), T7 (780.2g) and T8 (810.0g)) were lower than the rest. This could be attributed to the fact that it took some broilers time to acclimatize to the feed. In successive weeks it was observed that all the birds gradually increased in bodyweight. By week 7, the values obtained for the bodyweight of the broilers fed with the diets were found to be similar as a statistical test revealed no significant difference between them. At the end of the study T4 (2598.3g) and T5 (2594.5g) were found to be the treatments that yielded the highest bodyweight and corresponding overall weight gains in broilers. T4 diets which contained 75% of cereals and enzymes and 25% maize, recorded the highest bodyweight of broilers. This could be attributed to the fact that cereals (consisting of mainly rice) served as an ideal replacement for the conventional maize diets.

Furthermore, the supplementation of enzymes contributed to breaking down of nutrients found in the diet. T4 diets contained a requisite repertoire of nutrients containing average amounts of 22.54% crude protein, 9.5% of moisture content, 8.08% of ash

content (mineral), 10.81% of crude fat, 3.99% of crude fibre and 45.55% of carbohydrate content. T5 diets which contained 50% of food waste (i.e. 50% of cereals, 40% of tubers and 10% vegetables) and 50% maize, recorded the second highest bodyweight gained by broilers. This may be due to the fact that the formulation in the diet contained a repertoire of nutrients from different sources of cereals, tubers, vegetables and the maize itself. T5 diets to a large extent contained a similar nutritional composition (22.61% crude protein, 9.6% of moisture content, 5.77% of ash content (mineral), 8.51% of crude fat, 5.77% of crude fibre and 48.88% of carbohydrate content) to that of T4.

In as much as some of the treatments fed to the broilers fared better than others in terms of the overall weight gained by the broilers, a statistical analysis revealed that feeding any of the diets to the birds is likely to yield similar weight gains in broilers. The results of this study indicated that enzyme supplementation in cereal diets (T4) yielded better bodyweights in broilers as compared to tuber diets (T2). The addition of enzymes to poultry rations improves the digestibility of the feed and boosts productivity and performance (Alagawany *et al.*, 2018).

The birds require certain commercial exogenous enzymes in the diets to aid the digestion because they lack the necessary enzymes to completely digest some nutrients. Furthermore, crops with high concentrations of soluble non-starch polysaccharides (NSPs) can have their nutritional value increased by the addition of commercial enzymes (of NSPs). The NSPs' digestibility is extremely low in chicken, and a significant portion is eliminated through the excreta (Alagawany *et al.*, 2018). It was noticed in this study that in the earlier weeks (week 3 and 4), T2 recorded higher bodyweights as compared to T4. This could be attributed to the fact that broilers being fed T4 diets required more time to adapt to the diet. The onset of the 5th week however witnessed a marked increase in the bodyweight of T4 as compared to T2. This trend continued into

week 7. In comparison to broiler chicks that weren't supplemented, the synergistic usage of multienzymes and phytase improved the nutritional value and performance of broilers in a similar study by Rebello *et al.* (2019). Diets containing soybean oil (T6 and T8) did not yield the largest bodyweight. Birds consuming this diet were expected to be more energetic (due to the fact that they contained the highest metabolizable energy) and not necessarily translate into gaining more weight.

Food Waste-Based Diets Consumed by Broilers

Table 3.7 highlights the food waste formulated feed consumed by broilers over the experimental period.

Table 3.7 Food Waste-Based Diets Consumed by Broilers

Trt	Feed Consumed (kg)			
	Week 4	Week 5	Week 6	Week 7
Cntrl	0.59 ± 0	0.85 ± 0.1	0.72 ± 0.1	1.00 ± 0.1
T1	0.52 ± 0	0.65 ± 0	0.64 ± 0	1.38 ± 0.2
T2	0.57 ± 0	0.78 ± 0.1	0.73 ± 0.1	1.30 ± 0.2
T3	0.59 ± 0	0.84 ± 0.1	0.96 ± 0.1	1.41 ± 0
T4	0.57 ± 0	0.82 ± 0	0.91 ± 0.1	1.04 ± 0.2
T5	0.45 ± 0	0.68 ± 0	0.79 ± 0	1.38 ± 0.2
T6	0.48 ± 0	0.61 ± 0	0.55 ± 0.1	1.30 ± 0.2
T7	0.42 ± 0	0.55 ± 0.1	0.59 ± 0.1	1.41 ± 0
T8	0.46 ± 0	0.59 ± 0	0.55 ± 0	1.04 ± 0.2
Overall P-value	0.000	0.008	0.002	0.139

Trt – Treatment; Cntrl – Control

The total feed consumed by broilers ranged from 2640.4 g to 3803.7 g. There was a significant difference ($P \leq 0.05$)

in the total feed consumed by broilers fed with different treatments of the formulated feed (Figure 3.3).

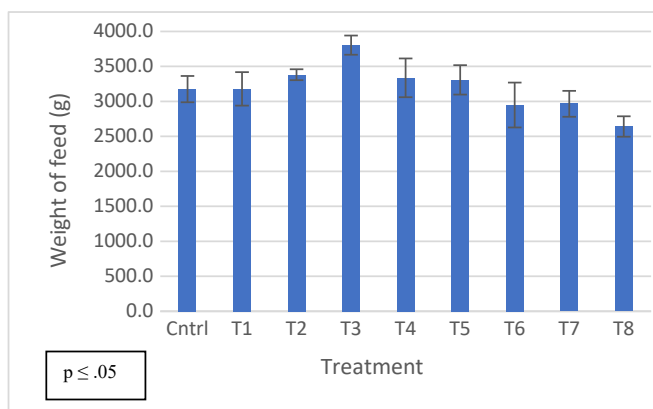


Figure 3.3 Total feed consumed by broilers

The broilers in this study consumed varying quantities of the different diets. The diet (T7) contained 100% food waste (without any maize component). This could have resulted in it being less consumed. Other formulations where a percentage of maize was included in the diets was observed to fare better in terms of consumption by broilers. The low quantities of T6 and T8 diets consumed may be due to the oily nature of the feed. The oilier the diet (T8), the less quantities of it were consumed. It was however noticed that the total experimental diets consumed (in all treatments) by broilers was below standard expectation of feed (4 kg)

that should be consumed (Scott, 2005; Tequia *et al.*, 2002; Zaman *et al.*, 2008). The relatively low consumption of feed in this study may be due to the feed not being pelletized (according to literature, pelletized feed has more feed intake by broilers), and the dry nature of feed (according to literature, wet feed has more feed intake by broilers (Baião & Lara, 2005; Mendes *et al.*, 2011; Sarfo, 2013).

Feed Conversion Ratio

The feed conversion ratio obtained in the study is outlined in Table 3.8.

Table 3.8 Feed Conversion Ratio

Feed Conversion Ratio			
Trt	Week 4	Week 5	Week 6
Cntrl	1.88 ± 0.1	2.13 ± 0.2	1.95 ± 0.4
T1	3.79 ± 1.6	1.65 ± 0.3	2.20 ± 0.5
T2	2.50 ± 0.1	2.44 ± 0	11.87 ± 12.9
T3	3.35 ± 0.8	2.72 ± 0.1	2.53 ± 0.9
T4	3.10 ± 0	1.83 ± 0	2.07 ± 0
T5	0.80 ± 0.1	2.25 ± 0.3	1.35 ± 0.7
T6	0.91 ± 0	1.36 ± 0.1	1.47 ± 0.4
T7	0.84 ± 0.1	1.94 ± 0.2	1.82 ± 0
T8	0.77 ± 0.2	1.92 ± 0.4	1.04 ± 0.1
Overall P-value	0.002	0.009	0.385

Trt – Treatment; Cntrl – Control

The feed conversion ratio ranged from 2.0 to 4.0. There was no significant difference ($P \geq 0.05$) in the feed conversion ratio by broilers fed with different treatments of the formulated feed. The feed conversion ratio (FCR) is the amount of feed consumed per unit weight gain of the bird's body weight. FCR denotes the efficiency of feed to convert to body weight (Siyal *et al.*, 2016), highlighting the performance of the bird's metabolic activity. The statistical analysis revealed that the feed conversion ratio obtained by broilers was significantly different across the weeks with the exception of the last week where they were similar. The variation in the earlier weeks can be attributed to the acclimatization of broilers to their diets (Siyal *et al.*, 2016). Further analysis revealed that the overall FCR measured for the diets were within the same range.

However, there was still some notable differences. The conventional maize diet (Control (2.0)) obtained the ideal FCR for broilers. T4 (2.1) obtained a near ideal FCR for broilers. The highest FCR values were recorded in birds fed T5 (3.8), T6 (4.0), T7 (3.8) and T8 (3.8). Broilers fed diets T4 had a near efficient FCR of 2.07. The acceptable FCR standard for broilers is 2.0. This means an FCR of 2.0 means the average bird is required to consume 2 kg of feed to gain 1 kg body weight. This means the lower the FCR, the efficient the birds are at converting feed into weight.

CONCLUSIONS

This study was conducted to determine the effect of utilizing treated food waste processed into formulated diets on broiler growth. The study revealed that the various formulated diets contained a repertoire of requisite nutritional content. Furthermore, it was also observed that there was the presence of various microbial groups, heavy metals and mycotoxins, albeit in minimal concentrations,

thereby forestall the instance of occurrence of diseases.

Minimal concentrations of antinutrients in the formulated feed indicated that they did not play a significant role in inhibiting the absorption of nutrients. The formulated diets were therefore deemed safe for consumption. Diets containing the food waste-maize component of 75% cereals with enzyme and 25% maize was deemed to be the most efficient in broiler production as it yielded the highest bodyweight in broilers, was efficiently consumed by broilers and had a better feed conversion ratio. Thus, this diet is most efficient as feed for broiler production. Other research should also be conducted on the conversion of food waste for the starter feed for broilers.

Declaration of Competing Interest

The article is an original work of the authors. This statement is to certify that all Authors have seen and approved the manuscript being submitted. All the Authors contributed significantly to the work and agree to its submission to the Journal. This paper has not been submitted for publication nor has it been published in whole or in part elsewhere. We declare that the article has not been published or is not under consideration for publication elsewhere. We declare that there is not conflict of interest in this publication.

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