

## Original Research Article

### **Partially fermented African Locust Bean (*Parkia biglobosa*) meal on laying performance, blood profile and carcass characteristics and economics efficiency of layer chickens**

#### **ABSTRACT**

**Aims:** Feeding trial was conducted to determine the effect of partially fermented African locust bean (*Parkia biglobosa*) meal (PFPBM) on the egg laying performance, egg quality, blood profile, and carcass characteristics and economics efficiency of feed in Lohmann Brown strain layer chickens (17-weeks old)

**Study design:** 5 by 3 factorial design.

**Place and Duration of Study:** Poultry Section of the Department of Animal Science Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong-Ashanti, Ghana for nine (9) months

**Methodology:** Five dietary treatments were formulated, such that the 0 % (control) contained no PFPBM whilst PFPBM was incorporated at 3 %, 5 %, 7 % and 9 % levels in the other diets. Each dietary treatment had 60 birds with 3 replicates of 20 birds each in a completely randomized design. Feed and water were supplied *ad libitum*.

**Results:** Egg weight was heavier ( $P < 0.05$ ) in birds fed 0% and 7 % PFPBM. Dietary PFPBM did not influence ( $P > 0.05$ ) external egg characteristics except shell thickness which was significantly ( $P < 0.05$ ) higher for birds fed 9% PFPBM. Yolk colour score was higher ( $P < 0.05$ ) for eggs of birds fed 0%, 3% and 7% PFPBM. Albumen height and Haugh unit were significantly ( $P < 0.05$ ) higher for birds fed 7% and 9% PFPBM. Hen-day egg production of birds fed 9% PFPBM (71.80%) was higher ( $P < 0.05$ ) but decreased to 67.90% for hen-housed egg production which was insignificant to other treatments except birds kept on 5% PFPBM. The haematological and biochemical responses were similar ( $P > 0.05$ ) except packed cells volume, serum albumin and cholesterol levels which were better ( $P < 0.05$ ) at 3%, 9% and 7% PFPBM. Dressed percentage was similar ( $P > 0.05$ ) for birds fed 0%, 3% and 9% PFPBM. Net

**Comment [Ma1]:** Are the % together with the numbers or separated. Change throughout the manuscript.

revenue per increased with increasing levels of PFPBM (GH¢ 22.29, GH¢ 20.03, GH¢20.26, GH¢ 24.45 and GH¢ 24.98 respectively for 0%, 3%, 5%, 7% and 9% PFPBM).

Comment [Ma2]: Per what? Specify.

Formatted: Highlight

**Conclusion:**PFPBM can be used as a non-conventional feed ingredient in layer chicken diets to potentially enhance various aspects of production, including laying performance, egg quality, haematological and biochemical indices, as well as carcass characteristics. These positive effects could contribute to maximizing profits in commercial egg production enterprises, indicating the potential value of incorporating PFPBM into layer chicken feed formulations.

**Key words:** blood profile, carcass characteristics, hen- day egg production, layer chicken, *Parkia biglobosa*.

## 1.0 INTRODUCTION

Keeping poultry makes a substantial contribution to household food security throughout the developing world [1]. Expanding poultry production particularly in northern Ghana could provide new livelihood opportunities and increased access to animal protein. The growth of the poultry industry is however challenged with a number of constraints including: the withdrawal of government subsidies to satisfy the requirement of the World Bank prescribed Structural Adjustment Programme[2] [3], massive importation of cheaper frozen chicken [4] [5], the outbreak of the highly pathogenic avian influenza (HPAI)[6], and Newcastle disease which discourage potential farmers [7] and in recent years, high feed cost [8].

Comment [Ma3]: The font size of the main text should be unified, it is 12 in some parts and 10 in the others.

Protein–energy malnutrition (PEM) and its associated micronutrient deficiencies, continues to be a major health burden in developing countries such as Ghana [9][10].The gap between the requirements and supply of four conventional feed ingredients: maize, soybean meal, fish meal and meat meal for feeding poultry in Ghana has resulted in high feed cost [11][12]. A possible solution to the escalating cost of these feed ingredients is to explore the potential of locally available cheap unconventional feed resources [13].

The bean from the African locust bean tree (*Parkia biglobosa*)has a potential for use as a non-conventional feed ingredient in the diet of layer chickens[14]. *Parkia biglobosa* has high protein and good

amino acid profile that makes it suitable as a protein substitute for human and animal feed [15][16]. The beans are known for their use in the production of local condiment known as "Dawadawa"[17]. Aside being a good source of plant protein to man, it serves as good source of protein for chicks [18]and fish [19][20]. The use of *Parkia biglobosa* beans as animal feed is however limited by the presence of anti-nutritional factors (ANFs) such as oxalate, phytate, trypsin inhibitors, tannins and hydrogen cyanide[21][22]. The biochemical and toxicological/adverse effects of these anti-nutritional factors on monogastric animals have been reviewed by Rajiet *al.* [23].Processing techniques such as soaking, boiling, dehulling and fermentation have been reported to enhance the nutritional quality by reducing or destroying the anti-nutritional factors [24][25].

Despite the considerable nutritive value of *Parkia biglobosa* bean, there is dearth of knowledge on its utilization in layer chicken's diets. Therefore, this study seeks to evaluate the effect of partially fermented African locust bean (*Parkia biglobosa*) meal (PFPBM) on the egg laying performance, egg quality, blood profile, carcass characteristics and economics efficiency of feed in the production of layer chickens.

## 2.0 MATERIALS AND METHODS

### 2.1 Location and Duration of Study

The study was carried out at the Poultry Section of the Department of Animal Science Education, AkentenAppiah-MenkaUniversity of Skills Training and Entrepreneurial Development (AAMUSTED),Mampong-Ashanti, Ghana, for a period of nine months.

### 2.2 Source and Processing of *Parkia biglobosa* beans

Unprocessed African locust beans were purchased from retailers at the Damongo market in the Northern region.The *Parkia biglobosa* beans were cooked for 6 hours, at 85°C in big pots on open fire using firewood to soften the bean coats. The cooked beans were lightly pounded with pestle and mortar to separate the bean coat from the beans. The decorticated beans were washed to remove impurities. The cleaned beans were wrapped in polythene bags, placed inside a basket and kept under roof for 72hours

**Comment [Ma4]:** \*instead of o in superscript, change throughout the manuscript.

as described by Adiaha[26] for microbial degradation. The partially fermented beans were removed and sun-dried for 36 hours at an ambient temperature of 32°C and relative humidity of 59mmHg. The dried partially fermented beans were milled to form; (PFPBM). Sample of the partially fermented *Parkia biglobosa* bean meal was analysed for proximate composition according to the procedure outlined by Adeloye[27]. The metabolizable energy (ME kcal/kg) was calculated according to the formula derived by Olajide[28]: ME kcal/kg = (37 x %CP) + (81.8 x %EE) + (35 x %NFE) (see Table 1).

**Table 1: Ingredient and chemical composition of experimental diets.**

Ingredients	T1 (0% PFPBM)	T2 (3% PFPMB)	T3 (5%P FPMB)	T4 (7% PFPMB)	T5 (9 % PFPMB)
Maize	53	52	51	50	49.3
Wheat bran	18	18	19	20	21.0
Soya bean meal	9.0	7.0	5.0	3.0	0.0
Parkia seed meal	0.0	3.0	5.0	7.0	9.0
Anchovy	3.0	3.0	3.0	3.0	3.0
Tuna fish meal	8.0	8.0	8.0	8.0	8.7
Dicalcium	0.5	0.5	0.5	0.5	0.5
*Premix	0.5	0.5	0.5	0.5	0.5
Oyster shell	7.5	7.5	7.5	7.5	7.5
Salt	0.5	0.5	0.5	0.5	0.5
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
<b>Chemical composition (% DM)</b>					
Crude protein	17.18	17.34	17.29	17.23	17.06
Ether extract	2.78	3.65	4.25	4.84	5.44
Crude fibre	3.81	3.74	3.75	3.76	3.71
Calcium	3.55	3.54	3.54	3.53	3.53
Phosphorus	0.49	0.47	0.47	0.46	0.45

Metabolizable	2539.84	2598.6	2624.33	2650.07	2680.42
energy (Kcal/kg)					

\*Supplied per Kg of diet: Vitamin A, 8.000UI; Vitamin D3, 1.500.000UI; Vitamin E, 2.5000mg; Vitamin K, 1.000mg; Vitamin B2, 2.000mg; Vitamin B12, 5mg, folic acid 500mg; nicotinic acid, 800mg; calcium pantothenate, 2000mg; choline chloride, 5000mg. Compounds of trace element: E5 Magnesium, 500mg; E6 zinc, 40,000mg; E4 Copper, 4500mg; E3 Cobalt, 100mg; E2 iodine, 1000mg and E8 selenium, 100mg. Antioxidant: E321 ButylatedHydroxytoluene; partially fermented *Parkia biglobosa* bean meal (PFPBM)

### 2.3. Experimental diets and Chemical analysis

Samples of the partially fermented *Parkia biglobosa* bean meal were analysed for proximate composition according to the procedure outlined by Adeloye[27] prior inclusion in diets.

Five experimental diets (see Table1) were formulated and coded 0%PFPBM, 3%PFPBM, 5%PFPBM, 7%PFPBM and 9%PFPBM such that dietary treatments contained 0% (control), 3, 5, 7 and 9 % respectively of the partially fermented *Parkia biglobosa* beans meal (PFPBM). The diets were formulated to contain 17% CP and 2,600 kcal/kg ME [29][30]. Samples of the diets were analysed for proximate composition.

### 2.4 Experimental Procedure and Housing

Three hundred and seventy (370) day-old layer chicks (Lohmann Brown strain) were procured from the Hatchery Unit of Akate farms in Kumasi and raised for sixteen (16) weeks. At the beginning of week seventeen (17), three hundred (300) birds were selected purposively based on the size of the comb, wattle and vent, and brightness of the eyes to obtained good layers. The selected birds were weighed and randomly allotted to five treatment groups with three replicates in a completely randomized design (CRD) using the deep litter system of management. Each of the five treatments had 60 birds with 20 birds in each of the three replicates.

### 2.5 Data Collection

Data were collected on egg production, external and internal egg quality parameters, and economics of feed use, blood indices, and carcass and organs characteristics.

### 2.5.1 Daily feed intake(FI)

FI was calculated according to the formula provided by Shahid *et al.*[31]:

$$\text{FI g/bird/day} = \frac{\text{Weekly feed consumption by birds in a treatment}}{\text{No. of birds in the treatment during that week}} \times \frac{1}{7}$$

### 2.5.2 Hen-day egg production (HDEP)

HDEP was computed respectively using the formulae given by Singh *et al.* [32]:

$$\text{HDEP (\%)} = \frac{\text{Number of eggs laid on daily basis}}{\text{Number of hens available in the pen that day}} \times 100\%$$

### 2.5.3 Egg weight and shell weight

Egg weight measurement was taken daily from the age at first egg production till the end of the experiment. The eggs were individually weighed with an electronic digital balance from Zhejiang (China), with a range of 0.01g precision. The weight recorded for each treatment was used for egg mass determination. Egg shell weight was measured with the same balance, Zhejiang (China) with 0.01g precision. The values obtained for shell weight and egg weight were used to calculate the shell percentage using the equation by Hamilton[33]:

$$\text{Shell percentage (\%)} = \frac{\text{Shell weight}}{\text{Egg weight}} \times 100\%$$

### 2.5.4 Shell thickness

Shell thickness was measured with a micrometer screw gauge with 0.001-millimeter accuracy. The shell with the inner membrane was first cleaned with tissue paper and air-dried at room temperature for 24 hours according to Charbonneau and Tran[34]. To achieve accuracy, the shell thickness was taken from three points: the narrow, broad and middle of the shell as described by Imoukhome and Omastuli[35].

### 2.5.5 Internal egg quality traits

Internal egg quality traits: yolk weight (YW), yolk height (YH), yolk width (YWh), yolk percentage (YP), albumen weight (AW), albumen height (AH) and egg volume (EV) were determined bi-weekly. Individual eggs were broken out on a Petri dish for internal egg quality traits measurements as outlined by Alfadol[36]. Fresh eggs were collected and measured within 2 hours after being laid according to Hagan and Eichie[37].

### 2.5.6 The Haugh unit

The Haugh unit was calculated from the values obtained for albumen height and egg weight as described by Haugh[38]:

$$HU = 100 \log (H + 7.5 - 1.7W^{0.37})$$

Where: HU = Haughunit; H = height of albumen (mm) and W = egg weight (grams)

### 2.6 Egg mass

Egg mass was determined according to El-Saadany *et al.*[39]:

$$\text{Egg mass} = \text{Egg production (\%)} \times \frac{\text{Egg weight (g)}}{100}$$

### 2.7 Blood sample collection

Six hens from each treatment (two per replicate) were randomly selected at the end of the experiment for blood profile analysis. Blood samples were collected from the wing vein into tubes containing Ethylamine tetraacetic acid (EDTA) as anti-coagulant for packed cell volume and red blood cells analysis while blood for serum albumin and cholesterol analysis were collected into coagulated tubes using 5ml syringes.

### 2.8 Carcass weight determination

At the end of the experiment, two birds per replicate were taken at random. The birds were sacrificed, scalded, plucked and eviscerated. The carcass organs (crop, gizzard, liver and visceral fats) were removed, weighed and expressed as a percentage of live weight.

Comment [Ma5]: Slaughtered?

## 2.9 Economics of production

Economics of production were analyzed. The calculations were done using the prevailing unit price per kilogram of feed consumed and the unit price per kilogram of eggs produced at the time of the experiment, and uniform distribution of all other costs. The unit price of the *Parkia biglobosa* bean meal includes cost of processing. Net revenue was computed as:

Net revenue (GH¢) = Total revenue – Total cost of feed consumed.

Where: Total revenue (GH¢) = Price per Kg of eggs produced/hen x total number of Kg of eggs produced.

Total feed cost (GH¢) = Mean cost/kg of feed x mean total feed (kg/hen) consumed

## 2.10 Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) using the Statistical Analysing System [40], and means were separated by the Least Significant Difference (LSD) test at 5% ( $P < 0.05$ ) significant level.

## 3.0 RESULTS AND DISCUSSIONS

### 3.1 Results of Proximate Composition of PFPBM and Diets

Crude protein content of PFPBM obtained (38.5%) (see Table 2) is relatively high and approaches 40-45% of soybean meal [29][30]. The crude protein value obtained is relatively higher than 35.73% reported by Sanief *al.* [41] and Salman [42] for fermented African locust beans (FALB). The nitrogen free extractives which give indication of the energy level of PFPBM appears low (18.33%), however, the metabolisable energy level is high (4601.85 Kcal/kg) (see Table 2.). The higher levels of ether extractives recorded (31%) has the effect of increasing the metabolisable energy density of the PFPBM. The crude fibre obtained (3.17 %) is within acceptable limit [29][30], however Salman *et al.* [42] recorded higher crude fibre value (5.2 %) for FALB than that recorded in the current study. The difference observed in the values obtained could be attributed to the degree of fermentation of the parkia among other factors. Chemical

composition of the experimental diets (see Table 3) showed that crude protein levels of the five diets were within the recommended levels of 16-17% for layers [29][30]. The ether extract content did not show any trend. The values obtained in this study were similar to 6.95% reported by Obun[43] at 23% inclusion of fermented Parkia bean meal in broiler diet. The ash content decreased with increasing levels of PFPBM in the experimental diets, which was consistent with the observation made by Obun[43].

**Table 2: Chemical composition of PFPBM.**

Fraction	Percentage (%)
Crude protein	38.50
Crude fibre	3.17
Ether extract	31.00
Ash	2.50
Nitrogen free extract	18.33
Moisture	6.50
*Metabolisable energy (kcal/kg)	4601.85

\* Metabolisable energy (ME kcal/kg) was calculated according to the formula derived by Olajide[44]; ME kcal/kg = (37 x % CP) + (81.8 x %EE) + (35 x %NFE)

**Table 3: Results of Proximate composition (% DM) of experimental diets.**

Parameter	0% PFPBM	3% PFPBM	5% PFPBM	7% PFPBM	9 %PFPBM
<b>Moisture (%)</b>	18.17	21.62	18.16	18.51	15.17
Crude protein (%)	16.98	16.92	16.80	16.85	16.72
Nitrogen free extract (%)	51.50	47.94	49.83	51.34	53.75
Ether extract (%)	6.00	6.16	6.80	6.00	6.16
Crude fibre (%)	3.19	3.16	4.24	3.15	4.21
Ash content (%)	4.26	4.20	4.17	4.15	4.09
Metabolisable Energy	2,885.30	2,807.83	2,921.89	2,911.15	3003.78

---

(kcal/kg)

---

partially fermented *Parkia biglobosa* bean meal (PFPBM)

---

### 3.2 Results on the effects of PFPBM on Egg production

The results of the study showed different responses of layers to dietary levels of PFPBM (see Table 4). Dietary treatment had significant ( $P < 0.05$ ) effect on mean daily feed intake. In contrast, Obun [43] reported non-significant difference in feed intake when broiler finishers were fed fermented *Parkia biglobosa* bean meal. Aderemiet al. [21] observed significant differences among dietary treatment in daily and total feed intake of broilers. The reason for the contrary findings might be due to differences in the processing techniques and experimental birds used for these studies. Hen-day egg production among birds on the dietary treatments varied significantly ( $P < 0.05$ ).

For each treatment, the hen-day egg production curve, was observed to rise quickly after laying commenced, reached a maximum level after a short period, leveled off and declined gradually thereafter (Figure 1). There was no significant ( $P > 0.05$ ) decline in hen-day egg production as the birds were within the first cycle of the laying period. However, hen-day egg production was superior ( $P < 0.05$ ) for birds fed 9% PFPBM inclusion level indicating that PFPBM could be used as alternative plant protein source in commercial egg production enterprise to improve egg production. Egg mass output was significantly ( $P < 0.05$ ) lower at 3% and 5% PFPBM but higher for birds fed 7% and 9% PFPBM. Birds fed 7% PFPBM diet yielded more egg mass, 1.34 g on average, as compared to that of the control diet.

Egg weight differed significantly ( $P < 0.05$ ) among birds fed the five dietary treatments. Egg weight for birds fed 0% and 7% PFPBM were significantly ( $P < .05$ ) higher than those of their counterparts fed 5%, 3% and 9% PFPBM, respectively (see Table 5). Though egg weight was influenced by dietary treatments, nonetheless, all the egg weights recorded in this study were within the range (56 – 63g) and could be classified as large eggs. Egg shell thickness was statistically ( $P < 0.05$ ) superior in birds fed 9% PFPBM (see Table 5). This could be attributed to the fact that more calcium was available for eggshell calcification [45]. This is evident as increasing levels of PFPBM in the diets resulted in increased concentration of calcium in the diets. Yolk weight, yolk percentage and yolk colour were significantly ( $P < 0.05$ ) influenced by dietary treatments (see Table 6). Birds fed 0%, 3% and 5% PFPBM produced

eggs whose yolks were similar ( $P > 0.05$ ) in weight, with the highest occurring in those on 7% and 9% PFPBM, indicating that PFPBM could be incorporated at higher levels in the diets of layer chickens to improve yolk weight and nutritional quality of the egg. According to Wisaquillo[46], the nutritional quality of the egg has a direct link with percent yolk and yolk weight because these parameters are linked to the dry matter content of the egg and essential fatty acids content of the egg. The yolks obtained in this study were whiter/paler in birds fed the *Parkia* diets than that of birds fed the control diet.

The yellow/orange colour of the yolk is controlled by the bird's intake of xanthophyll pigments and in particular lutein, zeaxanthin and various synthetic pigments such as canthaxanthin and apocarotenoid esters. As the level of dietary xanthophyll increases, there is an increase in yolk colour[47]. The pale colour of the yolk of birds fed the parkia based diets might be due to the fact that the PFPBM had low xanthophylls and carotenoids content, which corroborates the report by Olujobi[48] that the orange carotenoid,  $\beta$ -carotene content in *Parkia biglobosa* is 158  $\mu\text{g}/100\text{g}$  which is lower than the value 200  $\mu\text{g}/100\text{g}$  reported in yellow maize by Berman *et al.*[49]. The albumen height and Haugh unit are important parameters for evaluating the quality of eggs [50]. The Haugh unit values are ranked from 0 – 130 as: AA = 72-130% (excellent), A = 60-71% (good), B = 31-59% (average) and C = 0-30% (poor) [51]. Lower Haugh unit reflects lesser freshness [52]. The higher the Haugh unit value, the better the quality of the egg. The Haugh unit values recorded in this study were within (72-130%) and could be fresh and of better quality (Table 6).

**Table 4: Effect of PFPBM on the production performance of layers.**

Parameter	0% PFPBM	3 % PFPBM	5 % PFPBM	7 % PFPBM	9 % PFPBM	LSD	SEM
MIBW (g/bird)	938.33	938.33	940.00	941.66	938.33	4.86	1.49
MFI (g/bird)	111.80 <sup>a</sup>	108.66 <sup>a</sup>	102.66 <sup>b</sup>	111.00 <sup>a</sup>	107.66 <sup>a</sup>	5.16	1.37
MFBW (g/bird)	1923.33 <sup>bc</sup>	1856.67 <sup>c</sup>	2000.00 <sup>ab</sup>	2066.67 <sup>a</sup>	2100.00 <sup>a</sup>	132.70	40.70
MBWG (g/bird)	985.00 <sup>bc</sup>	918.33 <sup>c</sup>	1060.00 <sup>ab</sup>	1125.00 <sup>a</sup>	1161.67 <sup>a</sup>	132.60	40.70
HHEP (%)	66.86 <sup>bc</sup>	65.40 <sup>bc</sup>	64.50 <sup>c</sup>	69.60 <sup>a</sup>	67.90 <sup>ab</sup>	2.57	0.79
HDEP (%)	67.70 <sup>c</sup>	67.30 <sup>cd</sup>	65.50 <sup>d</sup>	69.60 <sup>b</sup>	71.80 <sup>a</sup>	1.87	0.57

FCR	2.69 <sup>ab</sup>	2.77 <sup>a</sup>	2.68 <sup>ab</sup>	2.59 <sup>b</sup>	2.55 <sup>b</sup>	0.15	0.05
MEM (g/bird)	41.52 <sup>b</sup>	39.19 <sup>c</sup>	38.17 <sup>c</sup>	42.86 <sup>a</sup>	42.16 <sup>ab</sup>	1.10	0.34
MAFE (days)	162.67	159.33	162.33	155.33	152.33	13.61	4.17
MWFE (g)	41.33 <sup>c</sup>	48.67 <sup>b</sup>	50.00 <sup>ab</sup>	54.67 <sup>a</sup>	42.33 <sup>c</sup>	5.53	1.70
MAFPL (days)	204.00 <sup>a</sup>	202.00 <sup>a</sup>	201.00 <sup>ab</sup>	201.00 <sup>ab</sup>	197.00 <sup>b</sup>	4.67	1.43
MT (%)	1.66	3.33	1.66	0.00	6.66	7.39	2.27

Means within rows with different superscripts are significantly different ( $P < 0.05$ ). PFPBM = Partially fermented parkia bean meal, LSD = Least significance difference, SEM = Standard error of the mean, MIBW = Mean initial live body weight, MFBW = Mean final live body weight, MFI = Mean feed intake, MBWG = Mean body weight gain, HHEP = Hen house egg production, HDEP = Hen day egg production, FCR = Feed conversion ratio, MEM = Mean egg mass, MAFE = Mean age at first egg, MWFE = Mean weight of first egg, MAFPL = Mean age at 50% lay and MT = Mortality %.

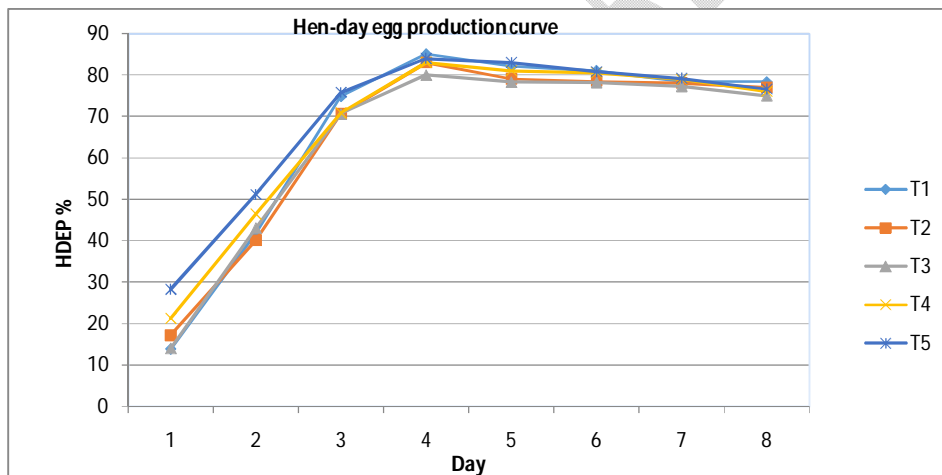


Figure 1: Dietary PFPBM effect on hen-day egg production curve. T1, T2, T3, T4 and T5 are the diet formulation for treatment 1, 2, 3, 4 and 5 respectively

Table 5: Effect of PFPBM on external egg quality traits

Parameter	T1 (0% PFPBM)	T2 (3% PFPBM)	T3 (5% PFPBM)	T4 (7% PFPBM)	T5 (9%PFPB M)	LSD	SEM
Mean egg weight (g/bird)	61.33 <sup>a</sup>	58.23 <sup>b</sup>	58.20 <sup>b</sup>	61.60 <sup>a</sup>	58.73 <sup>b</sup>	0.63	0.19
Mean egg length (cm)	5.59 <sup>ab</sup>	5.58 <sup>b</sup>	5.59 <sup>ab</sup>	5.65 <sup>a</sup>	5.57 <sup>b</sup>	0.06	0.02
Mean egg width (cm)	4.28	4.27	4.31	4.36	4.33	0.09	0.03
Shape index	76.53	76.57	77.11	77.23	77.77	1.91	0.59
Mean shell weight (g)	6.77	6.83	6.23	6.50	6.16	0.92	0.28
Shell thickness (mm)	0.28 <sup>c</sup>	0.32 <sup>b</sup>	0.33 <sup>b</sup>	0.29 <sup>c</sup>	0.36 <sup>a</sup>	0.02	0.06
Shell (%)	11.03	11.73	10.70	10.57	0.50	1.59	0.49

Means within rows with different superscripts are significantly different ( $P < .05$ ). PFPBM = Partially fermented parkia bean meal, LSD = Least significance difference, SEM = Standard error of the mean.

**Table 6: Effect of PFPBM on internal egg quality traits**

Parameter	T1 (0% PFPBM)	T2 (3% PFPBM)	T3 (5% PFPBM)	T4 (7% PFPBM)	T5 (9% PFPBM)	LSD	SEM
Yolk weight (g)	13.30 <sup>bc</sup>	12.83 <sup>c</sup>	12.93 <sup>c</sup>	13.97 <sup>ab</sup>	14.67 <sup>a</sup>	0.84	0.26
Yolk height (cm)	1.47	1.47	1.47	1.43	1.47	0.11	0.35
Yolk width (cm)	3.70	3.67	3.70	3.73	3.70	0.19	0.06
Yolk (%)	21.67 <sup>b</sup>	22.01 <sup>b</sup>	22.20 <sup>b</sup>	22.67 <sup>b</sup>	24.97 <sup>a</sup>	1.31	0.40
Yolk index (%)	39.67	40.03	39.6	38.37	39.63	4.52	1.38
Yolk colour	3.08 <sup>a</sup>	2.42 <sup>ab</sup>	2.25 <sup>b</sup>	2.58 <sup>ab</sup>	2.17 <sup>b</sup>	0.69	0.21
Albumen weight (g)	41.27 <sup>a</sup>	38.57 <sup>bc</sup>	39.03 <sup>b</sup>	41.13 <sup>a</sup>	37.9 <sup>c</sup>	1.11	0.34
Albumen width (cm)	6.54 <sup>ab</sup>	6.44 <sup>b</sup>	6.42 <sup>b</sup>	6.83 <sup>a</sup>	6.47 <sup>b</sup>	0.34	0.10
Albumen height (mm)	7.73 <sup>c</sup>	8.20 <sup>bc</sup>	8.43 <sup>b</sup>	9.47 <sup>a</sup>	9.57 <sup>a</sup>	0.49	0.15
Haugh unit (%)	87.10 <sup>c</sup>	90.50 <sup>b</sup>	91.83 <sup>b</sup>	96.13 <sup>a</sup>	97.23 <sup>a</sup>	2.64	0.81
Total protein (g/dl)	9.20	11.03	9.10	7.57	9.73	4.60	1.41
Cholesterol level (mg/dl)	29.4	17.93	20.47	26.9	21.73	12.43	3.81
Albumen (%)	67.3 <sup>a</sup>	66.10 <sup>ab</sup>	67.07 <sup>a</sup>	66.73 <sup>a</sup>	64.47 <sup>b</sup>	1.75	0.54
Egg volume (cm <sup>3</sup> )	51.73 <sup>a</sup>	48.20 <sup>b</sup>	47.67 <sup>b</sup>	53.50 <sup>a</sup>	53.00 <sup>a</sup>	2.63	0.81

Means within rows with different superscripts are significantly different ( $P < 0.05$ ). PFPBM = Partially fermented parkia bean meal, LSD = Least significance difference. SEM = Standard error of the mean.

### 3.3 Haematological characteristics

Packed cells volume (PCV) was similar ( $P > 0.05$ ) for birds fed the Parkia based diets but decreased as the inclusion level increased. PCV differed significantly between birds fed 3% PFPBM and the control (see Table 7). PCV values were within the range of 24.9% and 45.2% reported by Alkhalaf [53] for healthy birds and are also similar to 29.88% and 31.81% reported by Obun [43] in broiler finishers. The RBC, WBC and haemoglobin were not influenced by PFPBM. Blood cholesterol levels varied ( $P < 0.05$ ) among birds fed the dietary treatments. The serum cholesterol values are however within the reference values 129-297 mg/dl reported by Adewole et al. [54].

**Table 7: Dietary PFPBM on haematological and biochemical characteristics of laying hens**

Parameter	0 % PFPBM	3 % PFPBM	5 % PFPBM	7 % PFPBM	9 % PFPBM	LSD	SEM
<b>Haematological characteristics</b>							
Packed cell volume (%)	29.20 <sup>b</sup>	34.13 <sup>a</sup>	33.50 <sup>ab</sup>	32.53 <sup>ab</sup>	30.60 <sup>ab</sup>	4.53	1.39
Red blood cell ( $\times 10^6 \text{ mm}^{-3}$ )	2.25	2.39	2.38	2.30	2.16	0.33	0.10
White blood cells ( $\times 10^6 \text{ mm}^{-3}$ )	23.96	24.49	24.15	23.35	23.40	2.33	0.72
Haemoglobin (g/dl)	13.43	14.10	13.93	13.33	13.27	1.77	0.54
<b>Biochemical characteristics</b>							
Total serum protein (g/dl)	2.50	2.83	3.17	2.23	3.27	2.07	0.63
Globulin (g/dl)	1.00	1.30	1.30	0.80	1.30	1.78	0.55
Albumin (g/dl)	1.47 <sup>bc</sup>	1.53 <sup>bc</sup>	1.87 <sup>ab</sup>	1.43 <sup>c</sup>	2.00 <sup>a</sup>	0.41	0.12

Cholesterol (mg/dl)	134.9	150.00 <sup>a</sup>	146.13 <sup>a</sup>	121.77	139.73 <sup>ab</sup>	23.0	7.06
	3 <sup>ab</sup>			b		2	

Means within rows with different superscripts are significantly ( $P < .05$ ) different. PFPBM = Partially fermented parkia bean meal, LSD = Least significance difference, SEM = Standard error of the mean.

### 3.4 Carcass characteristics

Carcass cut-up parts (head, neck and shank) and filled crop and gizzard expressed as a percentage of the final live weight of layer chickens did not improve with the incorporation of PFPBM at 7% and 9% levels (see Table 8). Contrary to this result, Tamburawa[55] observed that gizzard percentage increased linearly with increasing levels of fermented Parkia bean meal in broiler finisher diets.

The main objectives of the poultry industry are to increase the carcass yield and to reduce carcass fatness, mainly the abdominal visceral fat [56]. The percent visceral fat recorded in this study are lower than 1.59 % and 1.95 % reported by Obun[57]. The low visceral fat deposition in the birds fed the dietary treatments could be attributed to the quality of protein in the diets and dietary energy level. Lambert *et al.* [58] showed that increasing dietary protein content improves the average daily gain, carcass yield, and carcass quality but with reduced body fat deposition.

Formatted: Font: 12 pt

**Table 8: Effect of PFPBM on carcass and organ weight**

Parameter	0% PFPBM	3% PFPBM	5% PFPBM	7 % PFPBM	9% PFPBM	LSD	SEM
<b>Carcass Weight</b>							
Head (%)	3.12 <sup>a</sup>	2.94 <sup>a</sup>	3.38 <sup>a</sup>	2.65 <sup>b</sup>	2.80 <sup>b</sup>	0.58	0.18

Neck (%)	2.97 <sup>a</sup>	3.17 <sup>a</sup>	2.93 <sup>a</sup>	2.82 <sup>a</sup>	2.38 <sup>b</sup>	0.40	0.12
Shank (%)	2.49 <sup>a</sup>	2.46 <sup>a</sup>	2.43 <sup>a</sup>	2.08 <sup>b</sup>	2.29 <sup>ab</sup>	0.22	0.07
<b>Organ Weight</b>							
Filled crop (%)	1.56 <sup>ab</sup>	1.45 <sup>ab</sup>	1.81 <sup>a</sup>	1.06 <sup>bc</sup>	0.71 <sup>c</sup>	0.53	0.16
Filled gizzard (%)	2.50 <sup>a</sup>	2.20 <sup>b</sup>	2.20 <sup>b</sup>	2.08 <sup>bc</sup>	1.95 <sup>c</sup>	0.25	0.08
Liver (%)	1.57 <sup>b</sup>	2.21 <sup>a</sup>	1.90 <sup>ab</sup>	1.59 <sup>b</sup>	1.93 <sup>ab</sup>	0.54	0.17
Filled intestines (%)	5.58 <sup>b</sup>	7.04 <sup>a</sup>	5.38 <sup>b</sup>	5.79 <sup>ab</sup>	5.48 <sup>b</sup>	1.29	0.40
Visceral fat (%)	1.40	0.92	0.98	0.94	1.18	0.60	0.18
Dressed (%)	80.17 <sup>a</sup>	75.47 <sup>ab</sup>	65.00 <sup>c</sup>	66.05 <sup>bc</sup>	70.70 <sup>abc</sup>	9.58	2.94

Means within rows with different superscripts are significantly ( $P < .05$ ) different. PFPBM - Partially fermented *Parkia biglobosa* bean meal, SE - Standard error of the mean, LSD - Least significance difference.

### 3.5 Economic efficiency on feeding

The mean cost per kilogram of feed consumed was similar for the dietary treatments. The cost benefit analysis (see Table 9) revealed that the highest net revenue was obtained from the eggs of birds fed 9% PFPBM. The results showed that birds with efficient feed conversion ratio recorded the highest net revenue. This agrees with the findings of Clark *et al.*[59] that birds which are efficient in feed conversion provide the greatest return on money invested.

**Table 9: Effect of PFPBM on economics of production.**

Parameter	0%	3%	5%	7%	9%
	PFPBM	PFPBM	PFPBM	PFPBM	PFPBM
Mean total feed intake (Kg/hen)	26.61	25.86	24.44	26.44	25.63
Mean cost/Kg feed GH¢	1.39	1.39	1.40	1.39	1.39
Total feed cost GH¢ (per/bird)	36.99	35.95	34.22	36.75	35.63

Price/Kg of eggs GH¢ (per/bird)	6.00	6.00	6.00	6.00	6.00
Total Kg of eggs (per/bird)	9.88	9.33	9.08	10.20	10.04
Feed conversion ratio	2.69	2.77	2.68	2.59	2.55
Total revenue GH¢ (per/bird)	59.28	55.98	54.48	61.20	60.61
Net revenue GH¢ (per/bird)	22.29	20.03	20.26	24.45	24.98

*PFPBM = Partially fermented Parkia bean meal.*, \$ 1 = □ GH¢5.90

### Conclusion

In conclusion, the findings of this study suggest that PFPBM can be used as a non-conventional feed ingredient in layer chicken diets to potentially enhance various aspects of production, including laying performance, egg quality, haematological and biochemical indices, as well as carcass characteristics. These positive effects could contribute to maximizing profits in commercial egg production enterprises, indicating the potential value of incorporating PFPBM into layer chicken feed formulations.

### Consent

All authors declared that 'written informed consent was obtained from the approved parties for publication of this article and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

### REFERENCES

- [1] Sariyev, O., & Zeller, M. Crossbred poultry adoption and impact: Evidence from Ethiopia. *Social Sciences & Humanities Open*, 7(1), 100394. 2023. <https://doi.org/10.1016/j.ssaho.2022.100394>

- [2] Ipinnaiye, O., & Olaniyan, F. An exploratory study of local social innovation initiatives for sustainable poverty reduction in Nigeria. *Sustainable Development*. (2023). <https://doi.org/10.1002/sd.2502>
- [3] Rana, A. W., Gill, S., & Akram, I. *Policy framework for contract farming: An alternate to Aarhi system in Pakistan*. *Intl Food Policy Res Inst.* (2023)
- [4] Assefa, A., Dione, M., Ilboudo, G., Lallogo, V., Gameda, B. A., Grace, D., & Knight-Jones, T. J. Quantitative analysis of knowledge, attitude and practice of workers in chicken slaughter slabs toward food safety and hygiene in Ouagadougou, Burkina Faso. *Frontiers in Sustainable Food Systems*, 6, 708. (2023). <https://doi.org/10.3389/fsufs.2022.1091209>
- [5] Mohamed, M. A., Kassem, G. M., Zahran, D. A., Emara, M. T., & Mansour, N. K. Impact of mechanically recovered poultry meat (MRPM) on proximate analysis and mineral profile of traditional Egyptian luncheon. *Journal of Radiation Research and Applied Sciences*, 16(1), 100521. (2023). <https://doi.org/10.1016/j.jrras.2022.100521>
- [6] Yang, X. Y., Gong, Q. L., Li, Y. J., Emad, B. A., Hu, M. J., Sun, Y. Y., ... & Wang, C. F. The global prevalence of highly pathogenic avian influenza A (H5N8) infection in birds: A systematic review and meta-analysis. *Microbial Pathogenesis*, 106001. ISSN 0882-4010, 2023. <https://doi.org/10.1016/j.micpath>
- [7] Niqueux, É., Flodrops, M., Allée, C., Lebras, M. O., Pierre, I., Louboutin, K., & Eterradosi, N. Evaluation of three hemagglutinin-based vaccines for the experimental control of a panzootic clade 2.3. 4.4 b A (H5N8) high pathogenicity avian influenza virus in male ducks. *Vaccine*, 41(1), 145-158. (2023). <https://doi.org/10.1016/j.vaccine.2022.11.012>
- [8] Kariuki, J. W., Jacobs, J., Ngogang, M. P., & Howland, O. Antibiotic use by poultry farmers in Kiambu County, Kenya: exploring practices and drivers of potential overuse. *Antimicrobial Resistance & Infection Control*, 12(1), 1-11. (2023). <https://doi.org/10.1186/s13756-022-01202-y>
- [9] Tran, I. C., Gregory, C., O'Connor, P., Imohe, A., Do, L. A. H., & Suchdev, P. S. A scoping review on the associations and potential pathways between malnutrition and measles. *medRxiv*, 2023-01. (2023). <https://doi.org/10.1101/2023.01.21.23284872>
- [10] Thomas, L., Baral, T., Miraj, S. S., Varma, M., Reddy, B. S., Munisamy, M., ... & Rao, M. Nutritional status in tuberculosis: A comprehensive problem to be addressed. In *Viral, Parasitic, Bacterial, and Fungal Infections* (pp. 525-545). Academic Press. 2023 <https://doi.org/10.1016/B978-0-323-85730-7.00016-3>
- [11] Hamani, B., Moula, N., Taffa, A. G., Leyo, I. H., Mahamadou, C., Detilleux, J., & Van, Q. C. D. Effect of housefly (*Muscadomestica*) larvae on the growth performance and carcass

characteristics of local chickens in Niger. *Veterinary World*. (2022).  
10.14202/vetworld.2022.1738-1748

- [12] Kumar, P., Kamle, M., & Mahato, D. K. (Eds). *Mycotoxins in Food and Feed: Detection and Management Strategies*. CRC Press. (2023)
- [13] Banday, M. T., Adil, S., Sheikh, I. U., Hamadani, H., Qadri, F. I., Sahfi, M. E., ...& Abd El- Hack, M. E. The use of silkworm pupae (*Bombyx mori*) meal as an alternative protein source for poultry. *World's Poultry Science Journal*, 1-16. (2023).  
<https://doi.org/10.1080/00439339.2023.2163955>.
- [14] N'gbo, M. L. K., Koné, F. M. T., Soro, P. L., Dabonné, S., & Kouamé, P. L. Potential use of fish meal (*Sardinella maderensis*), snail meal (*Achatina fulica*) and African Locust Beans (*Parkia biglobosa*) in Japanese quails diets: zootechnical and nutritional performance. *World Journal of Advanced Research and Reviews*, 14(2), 414-422. (2022). <https://doi.org/10.30574/wjarr.2022.14.2.0423>
- [15] Alrosan, M., Tan, T. C., Easa, A. M., Gammoh, S., Alu'datt, M. H., Aleid, G. M., ...& Maghaydah, S. Evaluation of quality and protein structure of natural water kefir-fermented quinoa protein concentrates. *Food Chemistry*, 404, 134-614. (2023).  
<https://doi.org/10.1016/j.foodchem.2022.134614>
- [16] Aremu, M. O., Awala, E. Y., Opaluwa, O. D., Odoh, R., & Bamidele, T. O. Effect of processing on nutritional composition of African locust bean (*Parkia biglobosa*) and mesquite bean (*Prosopis africana*) seeds. *Communications in Applied Sciences*, 3(1). (2015).
- [17] Nyadanu, D., Adu Amoah, R., Obeng, B., Kwarteng, A. O., Akromah, R., Aboagye, L. M., & Adu-Dapaah, H. Ethnobotany and analysis of food components of African locust bean (*Parkia biglobosa* (Jacq.) Benth. in the transitional zone of Ghana: implications for domestication, conservation and breeding of improved varieties. *Genetic Resources and Crop Evolution*, 64, 1231-1240. 2017. <https://doi.org/10.1007/s10722-016-0432-x>
- [18] Banse, O., Henri, K., & Laya, S. Use of nr seeds, *Parkia biglobosa* (Jacq.) Benth as a partial substitute for roasted soybeans in diet of broiler chickens. *African Journal of Agricultural Research*, 18 (7), 555-561. (2022). <https://doi.org/10.5897/AJAR2022.16054>
- [19] Akegbejo-Samsons, Y., Oyewole, O. B., Olayinka, S. O., & Olaniyan, T. O. Chemical composition and binding power of dried pulp wastes produced from the African locust bean (*Parkia Biglobosa*) in low-cost fish diets. *Ife Journal of Science*, 6(1), 30-34. (2004).  
<https://doi.org/10.4314/ijfs.v6i1.32119>

- [20] Oso, J. A., Idowu, E. O., & Agoi, O. F. Growth response of *Clarias gariepinus* fingerlings fed *Parkia biglobosa* diet as protein source. *Indian Journal of Science and Technology*, 4(2), 82-84. (2011). <https://doi.org/10.17485/ijst/2011/v4i2.7>.
- [21] Aderemi, F. A., Ayoola, M. O., Alabi, O. M., & Oyelami, L. O. Evaluation of fermented Locust bean meal (*Parkia biglobosa*) as replacement to soybean meal in production performance, blood profile and gut morphology of broiler chicken. *Journal of Animal Science and Veterinary Medicine*, 2(6), 164-170. (2017). <https://doi.org/10.31248/JASVM2017.063>.
- [22] Soetan, K. O., Akinrinde, A. S., & Adisa, S. B. Comparative studies on the proximate composition, mineral and antinutritional factors in the seeds and leaves of African locust bean (*Parkia biglobosa*). *Annals of Food Science and Technology*, 15(1), 70. (2014)
- [23] Raji, M.O., Abegunde, P. T., Adams, T. O., Fasasi, M. O., Salako, A. I., Oso, A. O., & Bamgbose, A. M. Evaluation of nutrients composition, anti-nutritional factors and amino acid profiles of sundried cassava starch extract pulp. *Nigerian Journal of Animal Science and Technology (NJAST)*, 4(1), 111 - 118. (2021). <http://njast.com.ng/index.php/home/article/view/138>
- [24] Mohammed, M. S., Shimelis, H. A., Laing, M. D., & Usman, A. Progress and opportunities on Bambara groundnut (*Vigna subterranea*[L.]Verdc.): genetic improvement and product development. In *Neglected and Underutilized Crops* (pp. 617-645). Academic Press. (2023). <https://doi.org/10.1016/B978-0-323-90537-4.00013-2>
- [25] Ujong, A. E., & Emelike, N. J. T. Improvement of the Nutritional Quality and HCl Extractability of Minerals of Dehulled Sesame Seeds and their Acceptance for Culinary Purpose by Parboiling, Boiling and Roasting. *Applied Food Research*, 100267. (2023). <https://doi.org/10.1016/j.afres.2023.100267>
- [26] Adiaha, M. S. Complete guide to agricultural product processing and storage. *World Scientific News*, 81(1), 1-52. (2017). EISSN 2392-2192
- [27] Adeloye, J. B., & Agboola, O. R. Bioactive properties, chemical composition, and sensory acceptance of juice blends from orange and African locust bean (*Parkia Biglobosa*). *Journal of Culinary Science & Technology*, 20(1), 33-50. (2022). <https://doi.org/10.1080/15428052.2020.1808135>
- [28] Olajide, R., Akinsoyinu, A. O., Babayemi, O. J., Omojola, A. B., Abu, A. O., & Afolabi, K. D. Effect of processing on energy values, nutrient and anti-nutrient components of wild cocoyam (*Colocasia esculenta*(L.)Schott) corm. *Pakistan journal of nutrition*, 10(1), 29-34. (2011).
- [29] Jobling, M. National Research Council (NRC): Nutrient requirements of fish and shrimp. *Aquacult. Int.* 20, 601–602 (2012). <https://doi.org/10.1007/s10499-011-9480-6>.

- [30] Rao, S. R., Ravindran, V., Srilatha, T., Panda, A. K., & Raju, M. V. L. N. Effect of dietary concentrations of energy, crude protein, lysine, and methionine on the performance of White Leghorn layers in the tropics. *Journal of Applied Poultry Research*, 20(4), 528-541. (2011). <https://doi.org/10.3382/japr.2011-00355>
- [31] Shahid, I., Sharif, M., Yousaf, M., Ahmad, F., Virk, M. R., Bilal, M. Q., ...& Rahman, M. A. Effect of exogenous emulsifier (lyso-phospholipid) supplementation in the broiler diet, on the feed intake and growth performance during grower phase. *Brazilian Journal of Poultry Science*, 23. (2021). <https://doi.org/10.1590/1806-9061-2020-1354>
- [32] Singh, M., Mollier, R. T., Rajkhowa, D. J., & Kandpal, B. K. Performance evaluation of the parents of the improved backyard poultry germplasm in sub-tropical condition of Northeastern Hill Region of India. *Tropical Animal Health and Production*, 53, 1-11. (2021). <https://doi.org/10.1007/s11250-021-02681-8>
- [33] Hamilton, R. M. G. A comparison of the various equations published for the estimation of characteristics of hen's eggs, the importance of reporting the compression rate for shell strength measurements, and distinction between egg specific gravity and density. *World's Poultry Science Journal*, 78(2), 447-466. (2022). <https://doi.org/10.1080/00439339.2022.2026202>
- [34] Charbonneau, A. M., & Tran, S. D. 3D cell culture of human salivary glands using nature-inspired functional biomaterials: the egg yolk plasma and egg white. *Materials*, 13(21), 4807. (2020). <https://doi.org/10.3390/ma13214807>
- [35] Imouokhome, J. I., & Omastuli, M. O. Principle component analysis of egg quality traits of indigenous chicken genotypes in Edo State. *BIU Journal of Basic and Applied Sciences* 7:(1): 33, 42. (2022).
- [36] Alfadol, M. F. M. Response of Broiler Chickens to Partial Substitution of Groundnut Cake by Non-conventional Protein Sources Fortified with Enzyme Supplementation (Doctoral dissertation, University of Gezira) (2019).
- [37] Hagan, J. K., & Eichie, F. O. Egg quality of two-layer strains as influenced by extended storage periods and storage temperatures. *Livestock Research for Rural Development*, 31(9), 1-8. (2019).
- [38] Haugh, R. R. The Haugh unit for measuring egg quality. *United States Egg Poultry Magazine*, 43, 552-555. (1937).
- [39] El-Saadany, A. S., El-Barbary, A. M., Shreif, E. Y., Elkomy, A., Khalifah, A. M., & El-Sabrou, K. Pumpkin and garden cress seed oils as feed additives to improve the physiological and productive traits of laying hens. *Italian Journal of Animal Science*, 21(1), 1047-1057. (2022).

- [40] Lohr, S.L. SAS® Software Companion for Sampling: Design and Analysis, Third Edition (1st ed.). Chapman and Hall/CRC. (2021)
- [41] Sani, N. A., Hassan, L. G., Dangoggo, S. M., Ladan, M. J., Alibaba, I., & Umar, K. J. Effect of fermentation on the nutritional and antinutritional composition of *Lagenariasiceraria* seeds. *IOSR Journal of Applied Chemistry*, 5(2), 1-6. (2013)
- [42] Salman, A. *Modification and Optimisation Processes of a Motorised Locust Beans Cubing Machine* (Doctoral dissertation, Kwara State University (Nigeria). (2021)
- [43] Obun, C. O. Performance and some haematological response of finisher broilers fed wanged levels of fermented locust bean (*Parkia biglobosa*) seedsmeal. *Asian Journal of Agricultural Research*, 1(3): 125-130. (2007).
- [44] Olajide, R., Akinsoyinu, A. O., Babayemi, O. J., Omojola, A. B., Abu, A. O., & Afolabi, K. D. Effect of processing on energy values, nutrient and anti-nutrient components of wild cocoyam (*Colocasia esculenta* (L.) Schott) corm. *Pakistan journal of nutrition*, 10(1), 29-34. (2011).
- [45] Avicola, E. S., Porcino, E. S., & America, S. The importance of nutrition on eggshell quality in broiler breeders' Poor eggshell quality and contaminated eggs are often the main factors to poor hatchability. *Outlook*, 11, 2. (2023)
- [46] Wisaquillo, M. C. A. *Nutrient Intake and Growth Dynamics During Rearing on the Reproductive Performance of Broiler Breeders*. North Carolina State University. (2022)
- [47] Miao, Q., Yang, Y., Du, L., Tang, C., Zhao, Q., Li, F., ... & Zhang, J. Development and application of a SFC-DAD-MS/MS method to determine carotenoids and vitamin A in egg yolks from laying hens supplemented with  $\beta$ -carotene. *Food Chemistry*, 135376. (2023).
- [48] Olujobi, O. J. Comparative evaluation of nutritional composition of African locust bean (*Parkia biglobosa*) fruits from two locations. *Nigerian Journal of Basic and Applied Sciences*, 20(3), 195-198. (2012).
- [49] Berman, J., Zorrilla-López, U., Farré, G., Zhu, C., Sandmann, G., Twyman, R. M., ... & Christou, P. Nutritionally important carotenoids as consumer products. *Phytochemistry Reviews*, 14, 727-743. (2015).
- [50] de Oliveira-Boreli, F. P., Pereira, D. F., Gonçalves, J. A., da Silva, V. Z., & de Alencar Nääs, I. Non-destructive assessment of hens' eggs quality using image analysis and machine learning. *Smart Agricultural Technology*, 4, 100161. (2023)

- [51] Wan, Y., Wang, Z., Wang, J., Su, H., Guo, X., Wu, J., ...& Jiang, R. Genetic parameters of the thick-to-thin albumen ratio and egg compositional traits in layer-type chickens. *British poultry science*, 60(5), 517-521. (2019).
- [52] Yuan, L., Fu, X., Yang, X., Chen, X., Huang, G., Chen, X., ...& Li, L. Non-Destructive Measurement of Egg's Haugh Unit by Vis-NIR with iPLS-Lasso Selection. *Foods*, 12(1), 184. (2023).
- [53] Alkhalaf, A., Alhaj, M., and Al-Homidan, I. Influence of probiotic supplementation on blood parameters and growth performance in broiler chickens. *Saudi journal of biological sciences*, 17(3), 219-225. (2010).
- [54] Adewole, F. A., Egbeyale, L. T., Ekunseitan, D. A., Bello, K. O., Lala, O. A., & Famakinde, S. A. Effect of strain and sex on haematological and serum biochemical indices of tropical indigenous chickens. *Nigerian Journal of Animal Production*, 48(2), 18-26. (2021).
- [55] Tamburawa, M. S., Ogundipe, S. O., Tegbe, T. S. B., Olugbemi, T. S., Ibrahim, U., Sa'idu, S. S., & Abdullahi, A. Y. Effect of graded levels of toasted African locust bean (*Parkia biglobosa*) seed meal on performance and carcass characteristics of broiler chickens at finishing stage. *Nigerian Journal of Animal Science*, 21(3), 315-324. (2019)
- [56] Fouad, A. M., & El-Senousey, H. K.. Nutritional factors affecting abdominal fat deposition in poultry: a review. *Asian-Australasian journal of animal sciences*, 27(7), 1057-1068. (2014)
- [57] Obun, C. O. Performance, digestibility and carcass and organ weight of finisher broiler-chicks fed graded levels of fermented locust bean (*Parkia biglobosa*) seed meal. *Asian Journal of Poultry Science*, 2(1): 12-23. (2008).
- [58] Lambert, W., Berrocoso, J. D., Swart, B., van Tol, M., Bruininx, E., & Willems, E. Reducing Dietary Crude Protein in Broiler Diets Positively Affects Litter Quality Without Compromising Growth Performance Whereas A Reduction in Dietary Electrolyte Balance Further Improves Litter Quality But Worsens Feed Efficiency. *Animal Feed Science and Technology*, 115571. (2023).
- [59] Clark, C. E., Akter, Y., Hungerford, A., Thomson, P., Islam, M. R., Groves, P. J., and O'Shea, C. J. The intake pattern and feed preference of layer hens selected for high or low feed conversion ratio. *PLoS one*, 14(9), e0222304. (2019)