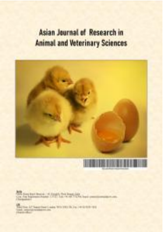

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Partially Fermented African Locust Bean (*Parkia biglobosa*) Meal on Laying Performance, Blood Profile, Carcass Characteristics and Economic Efficiency of Layer Chickens

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Authors' contributions

This work was carried out in collaboration among all authors. Author SAJ conducted the experiment. Author FRKB designed the experiment and wrote the protocols for the first draft of the manuscript. Authors JKKA and AKT supervised the experiment. Authors RAA and PA analysed the data. All authors read and approved the final manuscript.

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ABSTRACT

Incorporating African locust bean seed meal in the diet of layer chickens has been shown to improve their laying performance, blood profile, and carcass characteristics, while also promoting sustainable agriculture. This nutrient-rich ingredient can be a cost-effective alternative to conventional feed resources, improving the economic efficiency of poultry production. A nine (9) months feeding trial

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was conducted to determine the effects of partially fermented African locust bean (*Parkia biglobosa*) meal (PFPBM) on the egg laying performance, egg quality, blood profile, carcass characteristics and economic efficiency of feed in Lohmann Brown strain layer chickens (17-weeks old). The study was conducted at the Poultry Section of the Department of Animal Science Education at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong-Ashanti, Ghana.

The present study employed a completely randomized design to investigate the effects of dietary treatments on the nutrition of layer birds. Five distinct diets were formulated, with varying levels of PFPBM. The control diet contained no PFPBM, whereas the other diets included PFPBM at concentrations of 3%, 5%, 7%, and 9%. Each dietary treatment consisted of 60 birds, with three replicates of 20 birds randomly assigned to each diet. The experimental birds were provided with *ad libitum* access to clean water and feed. The study concluded that 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 ($P >0.05$) to other treatments except birds kept on 5% PFPBM. The haematological and biochemical responses were similar 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 revenue per capita 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).

The study concluded 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.

Keywords: Blood profile; carcass characteristics; hen-day egg production; layer chicken; Parkia biglobosa.

1. 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].

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]. *P. 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 *P. 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 Raji et 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].

Longer fermentation time reduces certain nutrient levels particularly total carbohydrate and thus making partial or shorter fermentation time worthwhile [24].

Despite the considerable nutritive value of *P. 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 (*P. 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. 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, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong-Ashanti, Ghana, for a period of nine months. Mampong is located about 58.5 Km north-east of the capital, Kumasi and it lies at latitude 7° 03ˈ 45.83˝ N and longitude 1° 24ˈ 0.36˝ W of the equator. The altitude of Mampong stands at 393 m. The annual mean rainfall is between 800 and 1500mm and the temperature ranges between 22-23 °C.

2.2 Source and Processing of *P. biglobosa* Beans

Unprocessed African locust beans were purchased from retailers at the Damongo market in the Northern region. The *P. 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 72 hours 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 59 mmHg. The dried partially fermented beans were milled to form; PFPBM. Sample of the partially fermented *P. 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).

2.3 Experimental Diets and Chemical Analysis

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

Five experimental diets (see Table 1) 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 *P. 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]:

Table 1. Ingredient and chemical composition of experimental diets

Ingredients	**T1 (0 % PFPBM)**	**T2 (3 % PFPMB)**	**T3 (5 % PFPMB)**	**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
Total	**100**	**100**	**100**	**100**	**100**
Chemical composition (% DM)					
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 energy (Kcal/kg)	2539.84	2598.6	2624.33	2650.07	2680.42

**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 Butylated Hydroxytoluene; partially fermented Parkia biglobosa bean meal (PFPBM)*

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

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 0.01 g 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 0.01 g 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 Imouokhome 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. Each egg was 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]:

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

Where: HU = Haugh unit; 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 tetra acetic 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 5 ml syringes.

2.8 Carcass Weight Determination

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

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. RESULTS AND DISCUSSION

3.1 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 Sani et 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 variations in the composition of the feed due to differences in sample preparation during partial fermentation. Regardless of the reason for the difference, it is important to note that a higher crude fiber value can reduce the digestibility and metabolizable energy density of the feed, so it is desirable to keep crude fibre values within acceptable limits for the target species. Notwithstanding the fact that partial fermentation increases protein digestibility, mineral availability, reduce anti-nutritional factors such as tannins, trypsin inhibitors and phytates, however complete fermentation of African locust beans can facilitate the degradation or escape of certain volatile nutrients, resulting in changes in the flavour, aroma, and nutrient composition of the fermented beans.

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].

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 *P. biglobosa* bean meal. Aderemi et 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 ($P < 0.05$). The observed difference in hen-day egg production among birds on the dietary treatments can be attributed to the impact of the partial fermentation of *Parkia* beans meal (PFPBM) on the birds' reproductive performance. Partial fermentation of PFPBM could have improved its nutrient availability, which may have led to better egg production. The inclusion of PFPBM in the birds' diet could have provided additional nutrients, such as protein, energy, and minerals that are essential for egg production. These nutrients may have also been more easily digestible and available to the birds due to the partial fermentation process.

For each treatment, the hen-day egg production curve, was observed to rise quickly after laying commenced, reached a maximum level, leveled off and declined gradually thereafter (Fig. 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 ($P < .05$) 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.

The hen-day egg production curve observed in the study also supports the idea that the inclusion of PFPBM in the birds' diet had a positive impact on egg production. The rapid rise in egg production after laying commenced and the subsequent leveling off and marginal decline are typical patterns observed in birds' egg production. The higher hen-day egg production observed in birds fed 9% PFPBM inclusion level

Table 2. Chemical composition of unfermented and partially fermented *Parkia* Bean Meal

Fraction	Unfermented	Partially Fermented	Nutrient Gained/Loss
Crude protein (**%**)	33.97	38.50	+4.53
Crude fibre (**%**)	5.68	3.17	+2.51
Ether extract (**%**)	33.12	31.00	-2.12
Ash (**%**)	2.30	2.50	+0.20
Nitrogen free extract (**%**)	19.21	18.33	-0.88
Moisture (**%**)	5.72	6.50	- 0.78
*Metabolisable energy (kcal/kg)	4638.46	4601.85	-36.61

** Metabolisable energy (ME kcal/kg) was calculated according to the formula described by Gboshe [44]; ME kcal/kg = (37 x % CP) + (81.8 x % EE) + (35 x % NFE); Positive (+) value indicates nutritional gain and negative (-) indicates nutritional loss*

Table 3. Results of proximate composition (% DM) of experimental diets

Parameter	0 % PFPBM	3 % PFPBM	5 % PFPBM	7 % PFPBM	9 % PFPBM
Moisture (%)	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 (kcal/kg)	2,885.30	2,807.83	2,921.89	2,911.15	3003.78

Partially fermented P. biglobosa bean meal (PFPBM) suggests that the nutrients provided by PFPBM were better utilized by the birds, leading to improved egg production.

Egg mass output was significantly ($P < 0.05$) lower at 3% and 5% PFPBM but higher for birds fed % 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 ($P < 0.05$) 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 – 63 g) and could be classified as large eggs. Egg shell thickness was statistically ($P < 0.05$) superior in birds fed 9 % PFPBM (see Table 5).

The observed difference in eggshell thickness among birds fed different dietary treatments can be attributed to the nutrient composition of the diets, particularly the inclusion levels of PFPBM. PFPBM is a rich source of essential minerals, such as calcium (9.01 mg/100mg) and phosphorus (73mg/100mg) [45] which are essential for eggshell formation. The partial fermentation of *Parkia* could have improved the bioavailability of these minerals, making them more easily digestible and available for the birds. These relatively high calcium and phosphorus levels are hidden in the crude ash provided by proximate analysis. Variations in eggshell thickness among birds fed the PFPBM could be due to level of PFPBM used and differences in fermentation by the microbes

This could be attributed to the fact that more calcium was available for eggshell calcification [46]. 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 [47], 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 apocarotenoic esters. As the level of dietary xanthophyll increases, there is an increase in yolk colour [48]. 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 [49] that the orange carotenoid, β-carotene content in *P. biglobosa* is 158 ug/100g which is lower than the value 200ug/100g reported in yellow maize by Berman et al. [50]. 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).

3.3 Haematological Characteristics

Packed cells volume (PCV) was statistically similar ($P > 0.05$) for birds fed with *Parkia* based diets but decreased as the inclusion level increased. PCV differed significantly between birds fed 3% PFPBM and the control (see Table 7). Nutrition plays a crucial role in maintaining proper Packed Cell Volume (PCV) levels, which is a measure of the proportion of red blood cells in whole blood. Iron is an essential nutrient required for the formation of red blood cells, and low iron intake can lead to a decrease in PCV levels.

Table 7 presents data showing the impact of Parkia Bean Meal (PBM) inclusion on the PCV levels of layer birds. According to Olalude et al. [45], PBM has a low iron content (3.31 mg/100mg), which means that diets containing high levels of PBM may not provide enough iron for optimal red blood cell formation.

The results of Table 7 indicate that as the level of PBM in the diets increased, the PCV levels decreased, which suggests that the low iron content of PBM may have contributed to the decrease in PCV. This is consistent with the principle of nutrient-density, which states that diets should contain sufficient levels of all essential nutrients to meet the animal's needs. However, birds fed 3% PFPBM diet had a relatively higher ($P < 0.05$) PCV compared to the control due to lower levels of the PFPBM. PCV values were within the range of 24.9% and 45.2% reported by Alkhalf [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 ($P > 0.05$) by PFPBM. Blood cholesterol levels were similar ($P > 0.05$) 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 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^{a}	108.66^{a}	102.66^{b}	111.00^{a}	107.66^{a}	5.16	1.37
MFBW (g/bird)	1923.33^{bc}	1856.67^{c}	2000.00^{ab}	2066.67^{a}	2100.00^{a}	132.70	40.70
MBWG (g/bird)	985.00^{bc}	918.33^{c}	1060.00^{ab}	1125.00^{a}	1161.67^{a}	132.60	40.70
HHEP (%)	66.86^{bc}	65.40^{bc}	64.50^{c}	69.60^{a}	67.90^{ab}	2.57	0.79
HDEP (%)	67.70^{c}	67.30^{cd}	65.50^{d}	69.60^{b}	71.80^{a}	1.87	0.57
FCR	2.69^{ab}	2.77^{a}	2.68^{ab}	2.59^{b}	2.55^{b}	0.15	0.05
MEM (g/bird)	41.52^{b}	39.19^{c}	38.17^{c}	42.86^{a}	42.16^{ab}	1.10	0.34
MAFE (days)	162.67	159.33	162.33	155.33	152.33	13.61	4.17
MWFE (g)	41.33^{c}	48.67^{b}	50.00^{ab}	54.67^{a}	42.33^{c}	5.53	1.70
MAFPL (days)	204.00^{a}	202.00^{a}	201.00^{ab}	201.00^{ab}	197.00^{b}	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 < .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 %

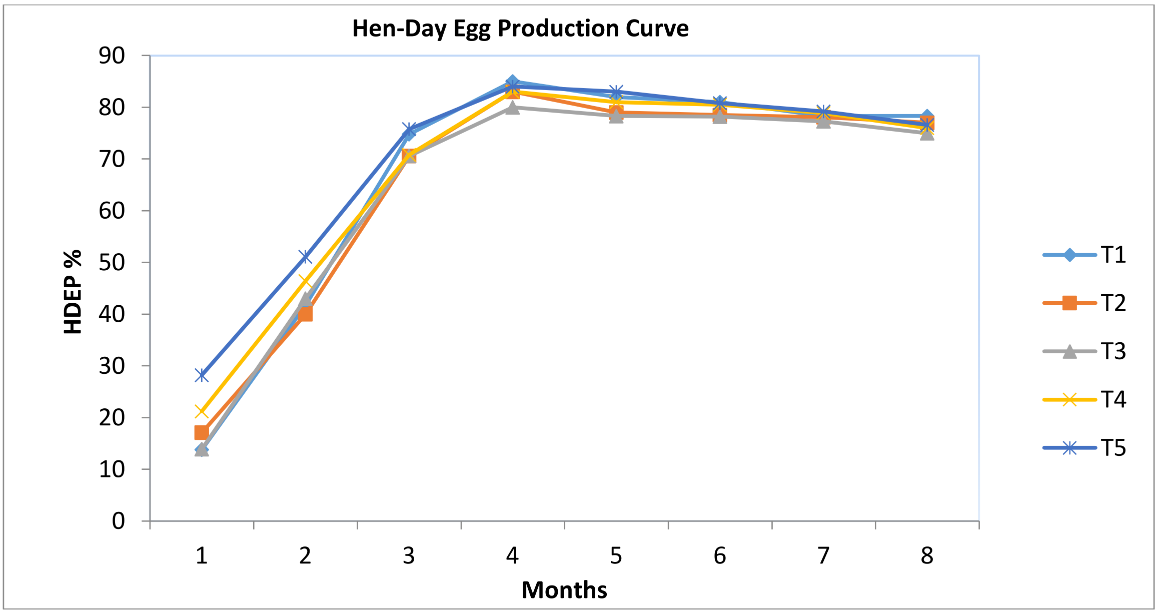

Fig. 1. Dietary PFPBM effect on hen-day egg production curve

**T1, T2, T3, T4 and T5 are the diets containing 0 %, 3 %, 5 %, 7 % and 9 % graded levels of PFPBM 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 % PFPBM)**	**LSD**	**SEM**
Mean egg weight (g/bird)	61.33^{a}	58.23^{b}	58.20^{b}	61.60^{a}	58.73^{b}	0.63	0.19
Mean egg length (cm)	5.59^{ab}	5.58^{b}	5.59^{ab}	5.65^{a}	5.57^{b}	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^{c}	0.32^{b}	0.33^{b}	0.29^{c}	0.36^{a}	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^{bc}	12.83^{c}	12.93^{c}	13.97^{ab}	14.67^{a}	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^{b}	22.01^{b}	22.20^{b}	22.67^{b}	24.97^{a}	1.31	0.40
Yolk index (%)	39.67	40.03	39.6	38.37	39.63	4.52	1.38
Yolk colour	3.08^{a}	2.42^{ab}	2.25^{b}	2.58^{ab}	2.17^{b}	0.69	0.21
Albumen weight (g)	41.27^{a}	38.57^{bc}	39.03^{b}	41.13^{a}	37.9^{c}	1.11	0.34
Albumen width (cm)	6.54^{ab}	6.44^{b}	6.42^{b}	6.83^{a}	6.47^{b}	0.34	0.10
Albumen height (mm)	7.73^{c}	8.20^{bc}	8.43^{b}	9.47^{a}	9.57^{a}	0.49	0.15
Haugh unit (%)	87.10^{c}	90.50^{b}	91.83^{b}	96.13^{a}	97.23^{a}	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^{a}	66.10^{ab}	67.07^{a}	66.73^{a}	64.47^{b}	1.75	0.54
Egg volume (cm^{3})	51.73^{a}	48.20^{b}	47.67^{b}	53.50^{a}	53.00^{a}	2.63	0.81

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 7. Effect of Dietary PFPBM on haematological and biochemical characteristics of laying hens

Parameter	**0 % PFPBM**	**3 % PFPBM**	**5 % PFPBM**	**7 % PFPBM**	**9 % PFPBM**	**LSD**	**SEM**
Haematological characteristics							
Packed cell volume (%)	29.20^{b}	34.13^{a}	33.50^{ab}	32.53^{ab}	30.60^{ab}	4.53	1.39
Red blood cell (x10^{6} mm^{-3})	2.25	2.39	2.38	2.30	2.16	0.33	0.10
White blood cells (x10^{6} 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
Biochemical characteristics							
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^{bc}	1.53^{bc}	1.87^{ab}	1.43^{c}	2.00^{a}	0.41	0.12
Cholesterol (mg/dl)	134.93^{ab}	150.00^{a}	146.13^{a}	121.77^{b}	139.73^{ab}	23.02	7.06

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.

The cost-effectiveness of using PFPBM as a feed ingredient was evaluated in the study. The mean cost per kilogram of feed consumed was similar for all the dietary treatments, indicating that the cost of producing feed with PFPBM was comparable to that of producing feed with soybean meal.

However, the cost-benefit analysis presented in Table 9 revealed that the highest net revenue was obtained from the eggs of birds fed 9% PFPBM. This suggests that although the cost of feed production was similar across treatments, there was a difference in the performance and profitability of the birds.

The study further showed that birds with efficient feed conversion ratio recorded the highest net revenue. This finding is consistent with the principle of feed efficiency, which states that the birds that convert feed into body weight gain or egg production more efficiently are more profitable.

Table 8. Effect of PFPBM on carcass and organ weight

Parameter	0% PFPBM	3% PFPBM	5% PFPBM	7 % PFPBM	9% PFPBM	LSD	SEM
Carcass Weight							
Head (%)	3.12^{a}	2.94^{a}	3.38^{a}	2.65^{b}	2.80^{b}	0.58	0.18
Neck (%)	2.97^{a}	3.17^{a}	2.93^{a}	2.82^{a}	2.38^{b}	0.40	0.12
Shank (%)	2.49^{a}	2.46^{a}	2.43^{a}	2.08^{b}	2.29^{ab}	0.22	0.07
Organ Weight							
Filled crop (%)	1.56^{ab}	1.45^{ab}	1.81^{a}	1.06^{bc}	0.71^{c}	0.53	0.16
Filled gizzard (%)	2.50^{a}	2.20^{b}	2.20^{b}	2.08^{bc}	1.95^{c}	0.25	0.08
Liver (%)	1.57^{b}	2.21^{a}	1.90^{ab}	1.59^{b}	1.93^{ab}	0.54	0.17
Filled intestines (%)	5.58^{b}	7.04^{a}	5.38^{b}	5.79^{ab}	5.48^{b}	1.29	0.40
Visceral fat (%)	1.40	0.92	0.98	0.94	1.18	0.60	0.18
Dressed (%)	80.17^{a}	75.47^{ab}	65.00^{c}	66.05^{bc}	70.70^{abc}	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

Table 9. Effect of PFPBM on economics of production

Parameter	0% PFPBM	3% PFPBM	5% PFPBM	7 % PFPBM	9% 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

It is important to note that the cost of PFPBM was not cheaper than soybean meal. However, the study suggests that PFPBM could provide an advantage as an alternative protein source, with the added value of processing (fermentation). This highlights the potential for using alternative protein sources in poultry diets, which can provide cost-effective options and improve sustainability in the feed industry.

4. 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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