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Research Article
Effects of *Faidherbia albida* (Del.) Chev. Roasted on Egg Quality Parameters of ISA Brown Laying Chickens

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Abstract
Objective: An experiment was carried out in Maradi (Niger) at CERRA (Regional Agricultural Research Center), to evaluate the effect of roasted pods of *Faidherbia albida* on the egg quality parameters of Isa Brown laying hens. **Materials and Methods:** A total of 200 21-week-old hens were randomly assigned to four dietary treatments and four replicates per treatment. The hens were housed in a 5 m×10 m building with 10 hens per repetition in 1.71 m^2 blocks with ventilation and natural lighting. The ground was covered with peanut shells. Apart from the control feed (F0), the experimental foods successively contained 5, 10 and 15% crushed pods of *Faidherbia albida* roasted at 110°C. The feed was distributed over a period of three months. Every 2 weeks, all the eggs of the each day were collected in batches and weighed at 6 p.m. using an electronic scale (500 g) with a precision of 0.1 g. Two eggs of the day per repetition were taken at random for the assessment of egg quality, making forty eggs in total per weighing. All variables were analyzed with R software version 4.2.2 using multivariate analysis of variance (one way-ANOVA). **Results:** The incorporation of *Faidherbia albida* into chicken feed has been shown to be beneficial for egg production. And the best incorporation rate of roasted *Faidherbia albida* pods was 10%. **Conclusion:** The incorporation of roasted *Faidherbia albida* pods into the diet of layers had no negative effect on the egg quality parameters.

Key words: Egg production, egg quality, *Faidherbia albida*, poultry diet, roasted pods

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Eggs, rich in protein, vitamins and minerals and low in calories, are one of the most important foods[1]. The egg contains all the nutrients essential for the development of the embryo in an external environment. Variations in the composition of its constituents are observed, linked primarily to the hen itself depending on its genetic origin and its age but also to its diet and the production system[2]. The macro-constituents of the egg such as the contents of dry matter, lipids, proteins and mineral macro-elements vary very little. Indeed, the diet of pullets and then of hens significantly influences the overall egg mass via the number or weight of eggs but cannot affect the composition of the major constituents of the egg, modifying only very moderately the proportions of albumen and yolk[2].

In industrial egg production, it is necessary to evaluate and introduce new energy sources as alternatives to or completely replace the expensive traditional ingredients used in poultry feed[3]. Phytogenic feed additives have been widely studied to improve poultry performance. To the authors' knowledge, a number of studies have evaluated the nutritional value of raw cassava root flour and of whole pods of *Faidherbia albida* as a non-traditional energy source for poultry[3-6].

In response to the importance given to poultry feed, several feed formulas have been developed. Despite all these efforts, the problem is far from being definitively resolved. While the formulas offered to breeders may satisfy their economic aspects, the nutritional quality of the foods produced from these formulas is often not as good[7]. It is therefore necessary to find alternative foods to cereals that are readily available and nutritious in order to harmonize the development of poultry farming with local realities. Nouri *et al.*[8] studied the effect of roasted *Faidherbia albida* pods on the zootechnical performance of ISA brown laying hens. Based on the laying rate and the consumption index, this study showed that the best incorporation rate of roasted pods of Faidherbia albida is 10%. In order to provide additional information, this study was conducted to evaluate the effects of roasted Faidherbia albida pods on the egg quality parameters of ISA brown laying hens.

MATERIALS AND METHODS

Experimental device: This study was conducted at the experimental poultry farm of the Regional Agricultural Research Center of the National Institute of Agricultural Research of Maradi (Niger) and was lasted for 3 months. The experimental building has natural ventilation and lighting with a dimension of 5 m×10 m. Two hundred Isa Brown hens with an average weight of 1379 g±37 g and aged 21 weeks were used. The chickens were raised on ground covered with peanut shells. These hens were randomly distributed into 20 blocks of 1.71 m^2 each containing 10 chickens. Each dietary treatment was distributed to 5 groups (repetitions) chosen randomly. The experiment was took place in a building with a wind speed of 1.49±0.07 min/sec for the morning, 1.49±0.12 at noon and in the evening, temperature was maintained at 24.91±1.73°C for the morning, 33.85±3.02°C at midday and 34.26±3.36°C in the evening.

Food and rationing: The *Faidherbia albida* pods were purchased and sorted to remove any impurities. Before incorporation, the pods were roasted and crushed. The crusher used was Hammer Mill type. F0 (control) contained 0% pods. F5, F10 and F15 contained 5, 10 and 15% pods, respectively. The percentage composition of the four foods tested and their nutritional values were recorded in Table 1. During the experiment, the food was distributed twice a day, with 700 g in the morning and 400 g in the evening for each repetition, for a duration of 3 months.

Evaluation of egg quality parameters: Every two weeks, all eggs of the day were collected in batches and weighed at 6 p.m. using an electronic scale (500 g) with a precision of 0.1 g. Two eggs of the day per repetition were taken at random for the assessment of egg quality, making forty eggs in total per weighing. Albumen height was measured with a caliper ruler by cracking the eggs on a flat surface.

The evaluation of the freshness of the egg was carried out by calculating the Haugh unit (UH) which is based on the formula proposed by Haugh in 1937[9].

$$UH = 100 \times \log (H - 1.7W^{0.37} + 7.57)$$

UH : Haugh Unit
H : Height of thick blank in mm
W : Weight of the egg in grams

The length (L) and large diameter (GD) of the eggs were measured using a caliper ruler to calculate the shape index (FI)[10]:

$$IF = \frac{GD}{L} \times 100$$

The shell was weighed after removal of the shell membrane[11], using an electronic balance with a sensitivity of 0.1 g.

Table 1: Ingredient and nutrient composition of feed for Isa brown laying chicken (from 21 to 30 weeks) containing different levels of *Faidherbia albida* pods per 100 kg

Ingredients (%)	F0 (control)*	F5*	F10*	F15*
Millet	69.00	66.00	61.50	57.50
Wheat bran	8.00	6.10	5.50	4.00
Peanut meal	7.50	6.50	6.25	6.50
Fishmeal	7.00	7.00	6.50	6.50
Calcined bone	8.00	8.00	8.00	8.00
Salt	0.30	0.30	0.30	0.30
Premix[1]	0.20	0.20	0.20	0.20
Peanut oil[2]	0.00	0.50	1.25	1.50
D-L methionine	0.00	0.20	0.25	0.25
Lysine HCl	0.00	0.20	0.25	0.25
Roasted pods of *Faidherbia albida*	0.00	5.00	10.00	15.00
TOTAL	100.00	100.00	100.00	100.00
Calculated nutritional composition				
ME (kcal/kgMS)[3]	2812.00	2798.00	2766.00	2719.00
Crude protein (%)	19.25	18.89	18.24	17.97
Crude fiber (%)	2.96	4.26	5.90	7.39
Calcium (%)	2.31	2.30	2.27	2.26
PNP[4] (%)	1.19	1.18	1.16	1.15
Calcium/PNP[4]	1.93	1.94	1.95	1.95

*Feeds that contain Faidherbia albida pods are incorporated at 0% (F0), 5% (F5), 10% (F10) and 15% (F15), [1]Premix containing per kg: Vitamins A: 4000000 IU, D3: 800000 IU, E: 2000 mg; K: 800 mg, B1: 600 mg, Niacin: 3600 mg, B6: 1200 mg, B12: 4 mg, Choline chloride: 80000 mg, Minerals: Cu 8000 mg, Mn: 64000 mg, Zn: 40,000 mg, Fe: 32000 mg, Se: 160 mg, [2]Unrefined peanut oil, [3]Metabolizable energy in kilocalories per kilogram of dry matter, [4]PNP: Non phytic phosphorus

The thickness of the shell without membrane was measured using a caliper ruler. For an egg, three measurements were taken at the equatorial region of the shell and an average was calculated.

The coloring of the eggs was determined using the Roche fan made of different levels varying from light yellow to dark orange-yellow in ascending order of numbers (1-15). The level of egg yolk coloring was determined by taking the average of 3 observations made by three different people.

Statistical analyzes: All variables were analyzed with R software version 4.2.2 using multivariate analysis of variance (one way-ANOVA) followed by Tukey test for comparisons among means with a significance level of 5%. Data was presented as mean±SE.

RESULTS

Egg weight: Statistical analysis showed that the average egg weight (g) during the entire test period did not differ significantly ($p = 0.323$) (Table 2). In month 3, there was a significant difference in average egg weight ($p = 0.054$). A greater average weight was found with F15 (56.65±2.77), F10 (55.69±2.11) and F0 (55.15±1.74) and followed by F5 (53.92±1.68).

Shape index: The inclusion of *Faidherbia albida* pods in the rations of the layers did not affect the shape index significantly in the first month of the trial with $p = 0.537$ (Table 3). At the second and third months, egg shape indices tended to be the same with a p-value of 0.262 and 0.329, respectively. In months 1, 2 and 3 there was a non-significant difference ($p = 0.925$).

Albumen height: Table 4 shows that the height of the albumen was depending on the rations consumed by the hens. On average, the difference was not significant ($p = 0.338$). This result showed that the treatments had no effect on the height of the albumen.

Haugh unit: The results of the statistical analysis indicated that the Haugh Unit for the eggs did not change significantly for all treatments ($p = 0.148$) during the entire period of the experiment. It should be noted that this index changed significantly in the third month ($p = 0.041$) (Table 5). F0, F5 and F15 had the largest Haugh Unit values with respectively 104.19±4.53, 108.57±12.87 and 102.81±4.17 followed by F10 (101.95±3.58).

Shell thickness: The incorporation of roasted *Faidherbia albida* pods had a highly significant impact on the thickness of the egg shells of layers in general ($p = 0.000$) (Table 6). The average egg shell thicknesses were 0.51 mm for F0 which were the thickest followed by F15 (0.48 mm), F5 (0.48 mm) and F10 (0.45 mm).

Shell weight: Table 7 shows that the average weight of the shells was not significantly different ($p = 0.411$). Results showed that the incorporation of *Faidherbia albida* pods had no effect on the variation in shell weight.

Table 2: Average egg weights depending on rations

Months	F0 **	F5 **	F10 **	F15 **	p-value
1	53.61±3.51	52.94±1.35	51.72±2.76	53.34±4.67	0.586
2	53.84±2.18	51.39±1.77	53.28±1.38	52.74±3.81	0.151
3	55.15±1.74[a]	53.92±1.68[b]	55.69±2.11[a]	56.65±2.77[a]	0.054*
Mean	54.20±1.68	53.56±0.96	54.24±1.56	52.75±3.22	0.323

[a,b]Means followed by the same letter on the line are not statistically different from each other at risk alpha: 0.05, *Significant, **Foods that contain *Faidherbia albida* pods incorporated at 0% (F0), 5% (F5), 10% (F10) and 15% (F15)

Table 3: Variation in egg shape index depending on food rations

Months	F0 *	F5 *	F10 *	F15 *	p-value
1	76.52±3.55	78.31±6.74	77.45±3.21	76.42±3.25	0.537
2	77.14±2.80	77.34±2.29	78.78±3.66	78.14±2.18	0.262
3	78.32±2.13	77.21±1.82	77.00±3.29	78.11±3.04	0.329
Mean	77.32±1.67	77.62±2.42	77.74±1.91	77.56±1.31	0.925

*Foods which contain *Faidherbia albida* pods incorporated at 0% (F0), 5% (F5), 10% (F10) and 15% (F15)

Table 4: Average albumen height depending on rations

Months	F0 *	F5 *	F10 *	F15 *	p-value
1	11.53±1.68	10.80±1.15	10.78±1.40	11.65±1.41	0.129
2	11.74±1.24	11.35±1.09	11.39±1.46	11.71±1.16	0.680
3	11.10±1.15	12.95±6.87	10.50±0.79	10.82±0.95	0.170
Mean	11.45±0.76	11.70±2.37	10.89±0.71	11.39±0.64	0.338

*Foods that contain *Faidherbia albida* pods incorporated at 0% (F0), 5% (F5), 10% (F10) and 15% (F15)

Table 5: Average Haugh units according to ration type

Months	F0 **	F5 **	F10 **	F15 **	p-value
1	106.10±6.02	103.60±4.45	103.63±5.61	106.99±4.44	0.118
2	107.22±4.52	106.23±4.14	105.71±5.77	106.86±4.11	0.769
3	104.19±4.53[a]	108.57±12.87[a]	101.95±3.58[b]	102.81±4.17[a]	0.041*
Mean	105.83±2.93	106.14±4.54	103.76±3.11	105.55±2.33	0.148

[a,b]Means followed by the same letter on the line are not statistically different from each other at risk alpha = 0.05, *Significant, **Foods that contain *Faidherbia albida* pods incorporated at 0% (F0), 5% (F5), 10% (F10) and 15% (F15)

Table 6: Variation in shell thickness according to dietary treatments

Months	F0 *	F5 *	F10 *	F15 *	p-value
1	0.43±0.07[a]	0.36±0.08[b]	0.34±0.06[b]	0.37±0.06[b]	0.000***
2	0.30±0.05	0.31±0.06	0.23±0.09	0.30±0.08	0.729
3	0.79±0.06[a]	0.77±0.08[a]	0.72±0.08[b]	0.78±0.05[a]	0.008**
Mean	0.51±0.04[a]	0.48±0.05[a]	0.45±0.03[b]	0.48±0.04[a]	0.000***

[a,b]Means followed by the same letter on the line are not statistically different from each other at risk alpha = 0.05, *Foods that contain Faidherbia albida pods incorporated at 0% (F0), 5% (F5), 10% (F10) and 15% (F15), **Highly significant, ***Very highly significant

Table 7: Weight of egg shells depending on treatments

Months	F0 *	F5 *	F10 *	F15 *	p-value
1	4.33±0.75	4.19±0.71	4.05±0.44	4.17±0.58	0.600
2	4.47±0.45	4.73±0.7	4.77±0.68	4.79±0.57	0.356
3	4.64±0.78	4.79±0.70	4.63±0.64	5.06±0.72	0.255
Mean	4.48±0.39	4.57±0.40	4.48±0.35	4.67±0.40	0.411

*Foods that contain *Faidherbia albida* pods incorporated at 0% (F0), 5% (F5), 10% (F10) and 15% (F15)

Table 8: Coloring of yolk depending on food rations

Months	F0 *	F5 *	F10 *	F15 *	p-value
1	2.21±0.50[b]	1.88±0.60[b]	2.80±0.78[a]	2.35±0.65[a]	0.000**
2	3.86±0.47[b]	3.52±0.60[b]	4.13±0.66[a]	3.71±0.56[ab]	0.000**
3	3.56±0.57	3.18±0.37	3.37±0.48	3.33±0.59	0.148
Mean	3.21±0.29[b]	2.86±0.40[b]	3.43±0.24[a]	3.13±0.39[ab]	0.000**

[a,b]Means followed by the same letter on the line are not statistically different from each other at risk alpha = 0.05, *Foods which contain *Faidherbia albida* pods incorporated at 0% (F0) , 5% (F5), 10% (F10) and 15% (F15), **Very highly significant

Coloring the egg yolk: The difference in the mean coloring of the egg yolk (Table 8) was highly significant (p = 0.000). The eggs of the layers fed with F10 had the best coloring of the egg yolk with an average of 3.43 followed by F0 (3.21) then F15 (3.13) and at the end the eggs of F5 with the smallest average (2.86).

DISCUSSION

Egg weight with age: The incorporation of *Faidherbia albida* pods did not significantly affect the average egg weight. Our results are in agreement with the study of Bovans Brown layers[12]. But in contrast, Houndonougbo *et al.*[10], noted an improvement in egg weight of Isa brown hens with rations containing 5 and 10% of dried cassava leaves. Furthermore, at the third month, the egg weight of hens fed diets containing 10 and 15% of *Faidherbia albida* pods was significantly the same as that of hens fed with the control diet. This change in egg weight may be linked to the age of the chicken. Bouvarel et al.[2]. reported that the weight of the egg mainly depends on the genetic origin, age and diet of the hens during the laying period.

The fitness index with age: The incorporation of *Faidherbia albida* pods did not affect the egg shape. The average shape index values in this trial are similar to those obtained by Brah *et al.*[6]. According to these researchers, there was a superiority of index for eggs of hens fed feed containing 15% *Faidherbia albida*. The eggs produced in this experiment have a shape index higher than the required standard of 75 which must be packaged in standardized packaging as reported by Smith (1992) cited by Dahloum *et al.*[13].

Albumen height with age: The albumen height of the eggs of the layers increased from the first to the second month in all treatments. According to Bouvarel *et al.*[14], the increase in the proportions of the albumen is mainly linked to the age of the layers. According to Zita *et al.* [15], in Isa brown hens, between the periods of 20-26 weeks and 54-60 weeks, the proportion of albumen decreases from 63.8 to 59.2%. According to Sauveur[16], the drop in albumen quality mainly occurs in the first months of laying. Due to the independent laying of layers in this trial, the results of this research can justify the difference in albumen height among treatments. The albumen height changed significantly by treatment during the first month of the trial, i.e., at the 22nd week of age.

Increase in Haugh unit with age: During the two months of testing, the Haugh unit did not change significantly. In a previous study, similar results have been reported by Dahloum *et al.*[13] who assessed egg quality in two phenotypes of local chickens. In the present study, the average value of the Haugh unit (105.83±2.93) with the control chicken (F0) is slightly higher than those obtained by Gnikpo *et al.*[17] who observed a maximum value (104.73±0.92) with the control birds. This could be due to the difference in the strains used during the two experiments. The level of improvement in the performance varies depending on the strain used[17].

Shell thickness with age: During the whole experimental period, a significant variation was observed in the thickness of the shells. This corroborates the study of Girma *et al.*[18] who noted a change in the thickness of egg shells in Bovans Brown layers after incorporating *Prosopis juliflora* pods into their diet up to a rate of 30%. However, the thickness of the shells in our study was greater than that measured by Girma *et al.*[18]. The quality of the thickness of the shells in this study can be explained by the fact that the water was distributed at will to all the layers. Robert[19] reported that water have influence on the quality of egg shells. Furthermore, it has been shown that the quantity of calcium and/or phosphorus contained in a ration has a major impact on the formation of the shell. Robert[19] reported that heat stress reduces food consumption and limits the availability of blood calcium for shell formation. This hypothesis could justify the significance of the variation in the thickness of the shells, because the temperatures recorded went up to 38.5°C.

Shell weight with age: Results showed that from the first to the third month of the trial as well as on the average of the cumulative months, there was a non-significant difference in the weight of the shells at all the levels of dietary treatments. Houndonougbo *et al.*[10] achieved similar results with the Isa Brown strain fed rations based on dried cassava leaves (Manihot esculenta, Crantz). Adouko *et al.*[20] incorporated Moringa oleifera powder into the rations of Isa Brown layers at different rates and reported similar results for eggshell weight. However, the shell weights measured in this trial are lower than those observed by Adouko *et al.*[20].

Coloring of egg yolk with age: During this trial, the yellow coloring of the yolk changed significantly. Brah *et al.*[6] fed Isa Brown layers with unroasted pods of *Faidherbia albida* under the same environmental conditions and with the same rates and observed a gradual increase in the color of the egg yolk as

the quantity of *Faidherbia albida* in the rations was increased. They concluded that *Faidherbia albida* pods contain pigments that improve the coloring of egg yolk. According to Moula *et al.*[21] the chicken's diet determines the coloring and more particularly the presence of two xanthophyll carotenoid pigments: lutein and zeaxanthin. The egg yolk was better colored when F10 was used in this test, on the other hand F5 colored the egg yolk the least in proportion to the rock grid. This result may be due to the heat treatment that the pods underwent before their addition into the different rations, unlike those of Brah *et al.*[6] who did not heat the pods before their incorporation. This result allowed us to put forward the hypothesis that roasting inhibits the pigments responsible for the coloring of the egg yolk contained in the pods of *Faidherbia albida*.

CONCLUSION

The incorporation of roasted *Faidherbia albida* pods into the diet of layers had no negative effect on the egg quality parameters throughout the experiment. In fact, the results of the statistical test showed the non-significance of the variations of all the egg quality parameters for the cumulative averages of the three months of testing with the exception of the variation in the thickness of the shells and the coloring of the egg. The control food (F0) only showed better performance on the variation in shell thickness in relation to all the egg quality parameters studied. An in-depth study on the chemical composition and/or a separate diet is necessary to understand the determining factors for optimizing the incorporation of unconventional foods.

SIGNIFICANCE STATEMENT

This study showed that the incorporation of roasted *Faidherbia albida* pods into the diet of layers does not alter egg quality parameters. Thus, producers of laying chicken can integrate roasted *Faidherbia albida* pods into the hens' feed and have eggs with the same quality parameters as eggs of chickens fed with conventional feed.

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