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Impact of Feed Presentation Form and Feeding Strategy on Egg Quality

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Abstract: Egg production in Benin is subject to a several constraints that hinder its development despite the growing demand for animal proteins. Therefore, finding innovative means and techniques to guarantee quality and quantity of production would be advantageous. The aim of this work is to determine the influence of animal feed supplements on egg quality. A total of 144 Isa Brown laying hens randomly to six (6) groups and four (4) replicates with six (6) hens per group (for each feed treatment) formed the experimental design. The hens were housed in ventilated and lighted cages and the experiment lasted five (5) months of laying. Six (06) feed treatments were tested: ACF (Mealy completed food), ACG (Granular completed food), CGMc (Granular supplements mixed with cracked maize), Mc+CF (Cracked maize morning / Mealy supplement at 1:00 p.m.), CF+Mc (Mealy supplement morning / Cracked maize at 01:00 p.m.) and CG+Mc (Granular supplement morning / Cracked maize at 01:00 p.m.). The external and internal physical quality of the eggs was determined. The form of presentation and the mode of distribution significantly influenced the physical quality of the eggs ($p < 0.05$). ACF and CGMc showed good shell strength (7.80 ± 0.28; 7.70 ± 0.28). The Mc+CF treatment accumulated the best external and internal physical quality scores. This treatment would be recommended to poultry farmers to have eggs with the best quality.

Keywords: Food Supplement, Maize, Granular, Mealy, Sequential Distribution

1. Introduction

In Benin, chicken farming and its by-products play a very important role in the diet and economy of pastoral communities [1]. Eggs are an integral part of the human diet. National chicken egg production increased from 14746 tonnes (250,682,000 flat eggs) in 2015 to 16851 tonnes (331,715,000 flat eggs) in 2020 [2]. However, egg production in Benin continues to be subject to a several constraints that hinder its development despite the growing demand for animal protein. As a result, feed is one of the factors to be controlled in order to lower the cost of production and make the products available to the population [3]. Several authors have shown that it would be advantageous to use local feed resources and innovative means and techniques to ensure that eggs are produced in sufficient quantity and quality [4, 5]. For example, better egg-laying rates and good physical egg quality have been achieved by feeding different varieties of maize grains to layers [1]. Similarly, some authors have shown that the mode of distribution and the form of presentation of the feed could improve the laying performance and egg quality of hens fed rations based on dried cassava leaves (Manihot esculenta, Crantz) [6]. Thus, it is appropriate to make available to pastoral communities (most of which are producers of maize, the staple food of poultry) a feed supplement made from Benin's agricultural and agro-industrial by-products, with good instructions for use. However, very few studies have been conducted on the quality of eggs obtained from hens feeding with these feeds in Benin. It is therefore necessary to assess not only the effect of agricultural and agro-industrial by-products on egg quality, but also to determine the influence of the form of presentation and mode of distribution of this feed supplement on the external and internal characteristics of eggs. Hence the present study, whose objective was to evaluate the influence of the form of presentation and the mode of distribution of the feed on the internal and external physical characteristics of eggs.

2. Material and Methods

2.1. Study Area

The experimental study on laying hens was carried out with the material and technical support of the Laboratory of Aviculture Research and Zoo-Economy (LARAZE) on the application farm of the Faculty of Agronomic Sciences of the University of Abomey-Calavi (FSA) located in the commune of Abomey-Calavi (6° 21 and 6° 42 North and 2° 13 and 2° 25 East). The climate is sub-equatorial with two dry seasons (August to mid-September and December to March) and two rainy seasons (March to July and mid-September to early December). The study took place from August 2019 to January 2020.

2.2. Materials

2.2.1. Animal Material

The animal material consisted of 180 eggs fresh from the day of the Isa-Brown layer strain. The eggs were collected during five months of laying from twenty-four (24) to forty (40) weeks of age of the hens.

2.2.2. Plant Material

The feed used in this study was obtained from standard INRA formulas. It is a complete feed divided into two parts: crushed yellow maize and feed supplements (wheat bran, soybean meal, cottonseed meal, grain soybeans, red oil, oyster shells, etc.). Its composition is given in Table 1.

Table 1. *Composition of the feed rations.*

Matières premières	Quantités (%)
yellow maize	54.5
Wheat bran	2
Oil cake of soybean	8
Oilcacake of cotton	10
Soybean seed	9
Red oil	1.5
Oyster shells	9
Lysine	0.2
Methionine	0.2
Dicalcium phosphate	0.25
Nacl	0.3
Iron sulphate	0.05
Laying concentrate	5
Total	100

2.3. Method

2.3.1. Egg Production and Collection

The experiment involved 144 laying hens of the Isa-Brown strain fed with the same quality and quantity of complete feed (120 g per bird). The complete feed was presented in three forms (mealy, pelleted and a mixture of mealy and pellets) and distributed differently in two modes (continuous and sequential). Three treatments were tested to evaluate the influence of the presentation form: the control feed ACF (Mealy Completed Food), ACG (Granular Completed Food) and CGMc (Granular Supplement mixed with cracked Maize). These three forms of complete feed were fed to the animals continuously throughout the day. In addition to these, three other treatments where the two parts of the complete feed were fed separately and sequentially to assess the influence of the feeding method. These are: CF+Mc (Mealy supplement distributed in the morning; Cracked maize, distributed at 01:00 p.m.), CG+Mc (Granular supplements distributed in the morning; Cracked maize, distributed at 01:00 p.m.) and Mc+CF (Cracked maize distributed in the morning; Mealy supplement, distributed at 01:00 p.m.). Each month, thirty-six (36) eggs of the day are taken at random at a rate of six (06) eggs per feed treatment. A total of 180 eggs were collected after five months of laying. The external and internal physical characteristics of the eggs were determined.

2.3.2. Data Collected

The mass of the whole egg (W), the mass of albumen (Wa) and the mass of yolk (Wy) and shell (Ws) were determined by weighing with an electronic balance with the precision of 0.1 gram (g) [7]. The Length (L) and Diameter (GD) of the egg, the length and Diameter of albumen (Da), and the Diameter of yolk (Dy) were measured with a caliper and expressed in centimeters (cm). The Height of albumen (H) and the Height of yolk (Hy) were measured using an electric micrometer tripod (with the accuracy of 0.01 micrometres) and were expressed in millimeters (mm) [8, 9]. These data were used to calculate parameters such as Shape Index (IS), albumen Index (Ia), yolk Index (Iy), Haugh Unit (HU) by the formula of [10], shells surface (S) and shell Index (Is) by the following relationships:

1) Shape Index

$$IS = GD/L \quad (1)$$

2) Albumen Index

$$Ia = H/Da \quad (2)$$

3) Yolk Index

$$Iy = Hy/Dy \quad (3)$$

4) Haugh Unit

$$HU=100*\log (H +7,57-1,7\ W^{0,37}) \quad (4)$$

5) Shell surface

$$S\ (cm^2) = 4,518*L^{0,289} * GD^{0,3164} * W^{0,4882} \quad (5)$$

6) Shell index

$$Is\ (g/100\ cm^2) = Ws*100/S \quad (6)$$

The proportion of yolk, albumen and shell was calculated by dividing the mass of each component by the mass of the whole egg [11]. The percentage of edible matter (EM) was obtained by the relationship [12]:

$$EM = (Wb+Wj)*100 / W \quad (7)$$

The thickness of the shell without the shell membrane was measured using an electric micrometer with the precision of 0.001 mm. Shell thickness was taken at three different locations: at the pointed end (high), at the rounded end (middle) and at the equator (top). The thickness value is obtained by averaging these three measurements [13]. Determination of yolk coloration was carried out using the Roch fan on a scale of 1 to 15 [14].

2.4. Statistical Analysis

The effect of the feed presentation form and the mode of distribution on the internal and external physical quality of eggs was evaluated by performing an analysis of variance in the R 3.5.1 software environment (R Core Team, 2018). When the probability was significant ($p < 0.05$), a structuring of means is done with the SNK function of the "agricolae" package (from Mendiburu). The means of each parameter were presented in tables with their standard errors except for yolk color for which graphs were made.

3. Results and Discussion

3.1. Effect of the Form of Presentation on External and Internal Physical Quality of Eggs

3.1.1. External Physical Quality of Eggs

Table 2 presents the results of the external physical quality of eggs from animals feeding with the complete mealy feed (ACF), the complete granular feed (ACG) and the supplement granular mixed with cracked Maize (CGMc). The mass of the eggs varied from 56.07 ± 0.83 (ACF) to 58.10 ± 0.94 g (CGMc). The eggs in the CGMc treatment had the highest mass values. Similarly, the largest diameter (4.28 ± 0.03 cm) and length (5.48 ± 0.05 cm) were obtained by the CGMc treatment while the smallest diameter (4.21 ±0.05 cm) and length (5.46 ± 0.04 cm) were obtained by ACG. Thus, the hen feeding with CGMc and ACF got the largest eggs compared to ACG. However, statistical analysis did not find any significant difference between the mass, length and diameter of eggs from hens fed the same feed in different forms. Indeed, the feeding a fine meal compared to a coarser grind result in only a small reduction in egg mass (-0.9 g) [15]. The mass, index and shell thickness mean varied from 6.57 ± 0.27 (ACG) to 7.80 ± 0.28 g (ACF), from 9.59 ±0.01 (ACG) to 11.24 ± 0.01 (ACF), and from 0.491 ± 0.005 (ACG) to 0.496 ± 0.005 mm (ACF) respectively. Shell strength was significantly higher for ACF and CGMc eggs compared to ACG ($p<0.05$). This is because the mechanical strength of the shell is related to its thickness, shell mass and structural organization. It is very important that the shell of table eggs has a high mechanical strength in order to prevent fractures resulting from shocks or settling that occur throughout the production and transport chain [16]. The influence of the form of presentation of the feed was significant ($p<0.05$) on shell mass, shell proportion and shell index. Thus, ACF and CGMc feeds gave larger eggs with stronger shells in contrast to the ACG food which recorded the lowest values for egg mass and shell quality. However, hens always put the same amount of calcium (shell) on each egg they lay during their lifetime. When a hen lays an egg, she loses 2 to 2.5 g of calcium, regardless of the size of the egg [17]. Thus, when the egg is smaller, the shell per unit area is thicker, and when the egg is larger, the egg shell is thinner. Therefore, this difference in egg quality observed between the ACF, CGMc and ACG treatments could be due to the sanitary quality of the feed.

3.1.2. Internal Physical Quality of Eggs

Table 3 shows the internal physical characteristics of eggs according to presentation form. Internal egg quality parameters such as albumen height, Haugh unit and edible fractions were significantly affected by feed form. Eggs from hens feeding with the ACF (control) had a higher albumen height (9.36 mm) compared to CGMc (supplement granular mixed with cracked Maize) (8.45 mm). However, the albumen height of the hen feeding with the completed granular food (8.67 mm) was similar ($p > 0.05$) to the other treatments. The same trend was observed at the Haugh unit. Thus, freshness was better with the mealy completed food (96.77 ± 1.09) compared to the completed granular feed (93.34 ± 1.38) and the supplement granular mixed with cracked Maize (91.70 ± 1.44). The results obtained for the ACF food treatment which alone recorded a high shell thickness added to a better freshness are in agreement with [18] who found a positive correlation between shell thickness and Haugh unit [18]. According to this author, the greater the shell thickness the higher the Haugh unit value. On the other hand, it is agreed that eggs with a Haugh Unit of more than

70 are considered to be of excellent quality, between 70 and 60 acceptable, while those with a Haugh Unit of fewer than 60 are poor quality eggs [19, 20]. Thus, all eggs produced can be considered of excellent quality. With regard to the consumable fraction of the egg, ACG offers a higher proportion (88.28±0.46%) than those obtained with ACF (86.34 ± 0.40%) and CGMc (86.75 ± 0.44%). Indeed, the percentage in edible fraction is widely used in the egg product industry to evaluate the yield in edible fractions. It has a nutritional interest for the consumer. The percentages in edible fraction found in this study are close to those obtained on eggs used in the egg product industry in Burkina Faso (88.17%) [21].

Table 2. *Effect of feed form on the external physical quality of eggs.*

Variables	Rations			P
	ACF	ACG	CGMc	
Mass of egg (g)	57.03±1.09	56.07±0.83	58.10±0.94	0.330
Diameter (cm)	4.26±0.04	4.21±0.05	4.28±0.03	0.453
Length (cm)	5.48±0.04	5.46±0.04	5.48±0.05	0.916
Mass of shell (g)	7.80[a]±0.28	6.57[b]±0.27	7.70[a]±0.28	0.004
Proportion of shell (%)	13.66[a]±0.40	11.72[b]±0.46	13.25[a]±0.44	0.005
Surface (cm²)	69.16±0.89	68.40±0.69	70.06±0.77	0.332
Shell Index	11.24[a]±0.01	9.59[b]±0.01	10.97[a]±0.01	0.004
Shape Index	0.78±0.01	0.77±0.01	0.78±0.01	0.436
Shell thickness high (mm)	0.495±0.005	0.499±0.006	0.498±0.007	0.497
Shell thickness low (mm)	0.503±0.007	0.495±0.005	0.496±0.006	0.615
Shell thickness middle (mm)	0.495±0.005	0.499±0.006	0.498±0.007	0.888
Shell thickness mean (mm)	0.496±0.005	0.491±0.005	0.494±0.006	0.835

ACF: Mealy Completed Food; ACG: Granular Completed Food; CGMc: Granular Supplement mixed with cracked maize. a, b on the same line: values with different letters are significantly different; P: Probability.

Table 3. *Effect of feed form on internal physical quality of eggs.*

Variables	Rations			P
	ACF	ACG	CGMc	
Height of albumen (mm)	9.38[a]±0.25	8.67[ab]±0.27	8.45[b]±0.255	0.035
Height of yolk (mm)	18.05±0.19	17.87±0.18	17.61±0.227	0.313
Diameter of albumen (cm)	6.26±0.09	6.36±0.11	6.48±0.12	0.343
Diameter of yolk (cm)	3.79±0.06	3.82±0.07	3.81±0.06	0.942
Albumen Index	1.26±0.04	1.13±0.05	1.11±0.05	0.058
Yolk Index	2.90±0.05	2.84±0.07	2.75±0.06	0.203
Haugh Unit	96.77[a]±1.09	93.34[ab]±1.38	91.70[b]±1.44	0.024
Mass of yolk (g)	14.23±0.31	14.27±0.34	14.23±0.31	0.997
Mass of albumen (g)	34.57±0.86	34.83±0.68	35.77±0.90	0.554
Proportion of abumen (%)	70.73±0.47	70.95±0.54	71.33±0.711	0.757
Proportion of yolk (%)	29.28±0.47	29.05±0.54	28.66±0.711	0.775
Edible matter (%)	86.34[b]±0.40	88.28[a]±0.46	86.75[b]±0.44	0.005

ACF: Mealy Completed Food; ACG: Granular Completed Food; CGMc: Granular supplement mixed with cracked maize. a, b on the same line: values with different letters are significantly different; P: Probability.

Figure 1 shows the effect of feed form on yolk coloration. The degree of yolk coloration of ACF was better than the other treatments throughout the trial. Indeed, at the start of the trial, yolk coloration of eggs from the ACF treatment scored 12 compared to 11 for ACG and 10 for CGMc. At 30 weeks of age, the degree of yolk coloration decreased in all treatments. The scores were 8 for ACF and CGMc and 7 for ACG. The different scores then increased after 30 weeks of age. At the end of collection, yolk of the mealy feed had a color of 11 compared to 9 and 10 for ACF, CGMc and ACG respectively. This decrease in color observed for all treatments is believed to be due to the carotenoid content of the raw materials, in this case that of the yellow maize, which is a function of several factors including storage time and conditions [22]. Indeed, yolk pigmentation, which is strongly influenced by intestinal absorption, plasma transfers, tissue export efficiency and carotenoid degradation metabolism, is also linked to the diet [23]. The difference in yolk color observed between treatments with and without pelleted feed could be due to pelleting, which is a heat treatment that can act on the thermolabile pigments and carotenoids contained in the feed responsible for yolk intensity.

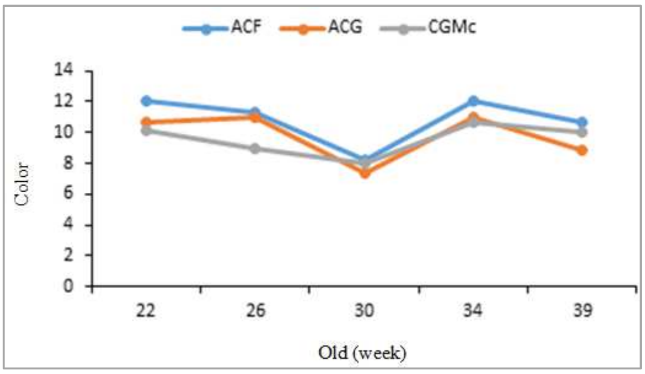

Figure 1. *Effect of the form of presentation of the food on the color of yolk.*

3.2. Effect of the Mode of Distribution on External and Internal Physical Quality of Eggs

3.2.1. External Physical Quality of Eggs

The effect of the mode of distribution on external physical quality was assessed by first comparing the CF+Mc (mealy supplement served in the morning with cracked maize at 01:00 p.m.) and Mc+CF (cracked maize served in the morning and then mealy supplement at 01:00 p.m.) and the control treatment ACF (completed mealy food) (Table 4). In a second step, CGMc (supplement granular mixed with cracked maize) and CG+Mc (granular supplement served in the morning and then cracked maize at 01:00 p.m.) were compared to ACF (complete mealy food) (Table 5). In the first case, the mode of feeding only affected the shape index of the eggs. The shape index of eggs from hens feeding with the cracked maize in the morning and then the supplement meal at 01:00 p.m. (0.80 ± 0.01) was higher than that of the completed meal food (0.78 ± 0.01). However, the egg shape index of hens fed the supplement mealy in the morning and with the cracked maize at 01:00 p.m. (0.79 ± 0.01) was similar to the other two treatments. Similarly, egg mass appeared to be higher with Mc+CF (cracked maize in the morning and then mealy supplement at 01:00 p.m.) (58.40 ± 0.74 g) than with eggs from hens fed the control diet (57.03 ± 1.09g) and CF+Mc (mealy supplement in the morning and then cracked maize at 01:00 p.m.) (57.23 ± 1.16 g). The same trend was observed for the large diameter, surface area and shell thickness. These results show that the supplement meal separated from the maize and fed to the animals improves egg size. This effect becomes significant when the animals are feeding with the supplement alone in the afternoon.

Table 4. *Effect of the mode of distribution on external physical quality: Meal supplement.*

Variables	Rations			P
	ACF	CF+Mc	Mc+CF	
Height of albumen (mm)	57.03±1.09	57.23±1.16	58.40±0.74	0.590
Height of yolk (mm)	4.26±0.04	4.26±0.05	4.34±0.04	0.281
Diameter of albumen (cm)	5.48±0.04	5.38±0.05	5.41±0.03	0.229
Diameter of yolk (cm)	7.80±0.28	7.60±0.24	7.57±0.18	0.755
Albumen Index	13.66±0.40	13.30±0.35	12.93±0.23	0.303
Yolk Index	69.16±0.89	69.34±0.96	70.32±0.60	0.570
Haugh Unit	11.24±0.01	10.94±0.01	10.74±0.01	0.443
Mass of yolk (g)	0.78^{b}±0.01	0.79^{ab}±0.01	0.80^{a}±0.01	0.013
Mass of albumen (g)	0.495±0.005	0.495±0.006	0.511±0.006	0.302
Proportion of abumen (%)	0.503±0.007	0.491±0.007	0.507±0.006	0.245
Proportion of yolk (%)	0.495±0.005	0.495±0.006	0.511±0.006	0.079
Edible matter (%)	0.496±0.005	0.491±0.006	0.506±0.005	0.118

ACF: Mealy completed food; CF+Mc: Mealy supplement morning + Cracked maize at 01:00 p.m.; Mc+CF: Cracked maize morning + Mealy supplement at 01:00 p.m.; a, b on the same line: values with different letters are significantly different; P: Probability.

Table 5. *Effect of the mode of distribution on external physical quality: granular supplement.*

Variables	Rations			P
	ACF	CGMc	CG+Mc	
Mass of egg (g)	57.03±1.09	58.10±0.94	57.70±0.99	0.750
Diameter (cm)	4.26±0.04	4.28±0.03	4.26±0.05	0.926
Length (cm)	5.48±0.04	5.48±0.05	5.43±0.05	0.731
Mass of shell (g)	7.80±0.28	7.70±0.28	7.80±0.31	0.961
Proportion of shell (%)	13.66±0.40	13.25±0.44	13.57±0.52	0.799
Surface (cm^2)	69.16±0.89	70.06±0.77	69.73±0.82	0.740
Shell Index	11.24±0.01	10.97±0.01	11.19±0.01	0.864
Shape Index	0.78±0.01	0.78±0.01	0.78±0.01	0.693
Shell thickness high (mm)	0.495±0.005	0.498±0.007	0.504±0.007	0.998
Shell thickness low (mm)	0.503±0.007	0.496±0.006	0.499±0.010	0.819
Shell thickness middle (mm)	0.495±0.005	0.498±0.007	0.504±0.007	0.651
Shell thickness mean (mm)	0.496±0.005	0.494±0.006	0.497±0.007	0.946

ACF: Mealy completed food; CGMc: Granular supplement mixed with cracked maize; CG+Mc: Granular supplement distributed in the morning + Cracked maize, distributed at 01:00 p.m. a, b on the same line: values with different letters are significantly different; P: Probability.

In the second case, the method of feed distribution had no effect on the external physical quality parameters of the eggs. However, hens feeding with the supplement granular mixed with cracked maize (CGMc) gave the largest eggs (58.10 ± 0.94 g) followed by those feeding with the supplement granular in the morning and the cracked maize at 1.00 pm (57.70 ± 0.99 g) and those feeding the completed mealy food (57.03 ± 1.09 g). The same trend was observed with large diameter and surface. These results indicate that egg mass was improved when the supplement was pelleted and fed continuously throughout the day. This is because poultry always choose to consume the largest particle sizes first, regardless of the raw material composition [24]. Also, the ingestion of coarse particles allows the development of the gizzard, which results in a significant improvement in mechanical grinding of the feed (making nutrients more available for digestion and thus assimilation) [24]. This improved nutrient uptake explains why layers fed the Mc+CF, CGMc and CG+Mc feeds produced larger eggs than the other treatments. The Mc+CF feed in particular gave the largest eggs compared to CGMc and CG+Mc. Indeed, some authors had found an increase in feed conversion when feeding wheat or whole maize in the morning and a protein and calcium rich supplement in the afternoon [25].

3.2.2. Internal Physical Quality of Eggs

The effect of the mode of distribution on the physical parameters of internal egg quality was evaluated by first comparing the mealy supplement served in the morning with the cracked maize at 13:00 (CF+Mc) and the cracked maize served in the morning followed by the supplement mealy at 13:00 (Mc+CF) and the completed mealy food (Table 6). In a second step, the supplement granular mixed with cracked maize (CGMc) and the supplement granular served in the morning followed by cracked maize at 1 p.m. (CG+Mc) were compared to the completed mealy food (Table 7). In the first case, the mode of feeding had no effect on the internal physical quality parameters (p>0.05). In the second case, the mode of distribution had an effect only on albumen height and Haugh units. Thus, albumen height was significantly higher with the completed mealy food (9.38±0.25 mm) compared to the granular supplement mixed with cracked maize (8.45±0.25 mm). However, albumen height and Haugh units for the hens feeding with the pelleted supplement in the morning followed by the cracked maize at 01:00 p.m. (8.70±0.26 mm and 93.05±1.44) were similar to those from the other treatments. The Haugh unit was significantly higher with the completed mealy food (96.77±1.09) compared to 91.70±1.44 for the granular supplement mixed with cracked maize and 93.05±1.44 for the granular supplement served in the morning followed by cracked maize at 01:00 p.m. Thus, the freshness of eggs was better with the ACF food. This agrees with the observations of [18] which states that the greater the shell thickness the higher the Haugh unit value. Thus, ACF gave better egg freshness because the same foo ration gave greater shell thickness.

Table 6. *Effect of the mode of distribution on internal physical quality: Meal supplement.*

Variables	Rations			P
	ACF	CF+Mc	Mc+CF	
Height of albumen (mm)	9.38±0.25	9.73±0.30	9.51±0.28	0.668
Height of yolk (mm)	18.05±0.19	18.20±0.18	18.15±0.21	0.844
Diameter of albumen (cm)	6.26±0.09	6.06±0.11	6.18±0.08	0.304
Diameter of yolk (cm)	3.79±0.06	3.68±0.06	3.80±0.06	0.316
Albumen Index	1.26±0.04	1.34±0.04	1.27±0.05	0.465
Yolk Index	2.90±0.05	3.04±0.07	2.95±0.06	0.297
Haugh Unit	96.77±1.09	98.18±1.29	96.89±1.27	0.665
Mass of yolk (g)	14.23±0.31	14.03±0.25	14.10±0.24	0.867
Mass of albumen (g)	34.57±0.86	35.50±0.89	36.43±0.60	0.256
Proportion of albumen (%)	70.73±0.47	71.52±0.42	72.04±0.46	0.122
Proportion of yolk (%)	29.28±0.47	28.48±0.42	27.96±0.46	0.132
Edible matter (%)	86.34±0.40	86.70±0.35	87.07±0.23	0.303

ACF: Mealy completed food; CF+Mc: Mealy supplement morning + Cracked maize at 01:00 p.m.; Mc+CF: Cracked maize morning + Mealy supplements at 01:00 p.m.; a, b on the same line: values with different letters are significantly different; P: Probability.

Table 7. *Effect of the mode of distribution on internal physical quality: granular supplement.*

Variables	Rations			P
	ACF	CGMc	CG+Mc	
Height of albumen (mm)	9.38^{a}±0.25	8.45^{b}±0.255	8.70^{ab}±0.26	0.039
Height of yolk (mm)	18.05±0.19	17.61±0.227	17.77±0.21	0.337
Diameter of albumen (cm)	6.26±0.09	6.48±0.12	6.17±0.14	0.166
Diameter of yolk (cm)	3.79±0.06	3.81±0.06	3.82±0.05	0.947
Albumen Index	1.26±0.04	1.11±0.05	1.16±0.05	0.108
Yolk Index	2.90±0.05	2.75±0.06	2.93±0.09	0.133
Haugh Unit	96.77^{a}±1.09	91.70^{b}±1.44	93.05^{ab}±1.44	0.024
Mass of yolk (g)	14.23±0.31	14.23±0.31	14.20±0.25	0.996
Mass of albumen (g)	34.57±0.86	35.77±0.90	35.40±0.89	0.617
Proportion of albumen (%)	70.73±0.47	71.33±0.711	71.16±0.57	0.761
Proportion of yolk (%)	29.28±0.47	28.66±0.711	28.84±0.57	0.760
Edible matter (%)	86.34±0.40	86.75±0.44	86.43±0.52	0.799

ACF: Mealy completed food; CGMc: Granular supplement mixed with cracked maize; CG+Mc: Granular supplement distributed in the morning + Cracked maize, distributed at 01:00 p.m. a, b on the same line: values with different letters are significantly different; P: Probability.

Figures 2 and 3 show the change in yolk color when CF+Mc and Mc+CF were feeding sequentially, and CGMc and CG+Mc were fed sequentially, all compared to the ACF control. The yolk color of the mealy supplement served in the morning followed by a maize meal in the evening (CF+Mc) and creased maize in the morning followed by mealy supplements in the evening (Mc+CF) was similar to the complete mealy feed (ACF) throughout the experiment. The color scores of the different treatments decreased at the 30th week of age of the hens and increased after this period. At the end of the trial period, yolk color was the same (11) in the different treatments.

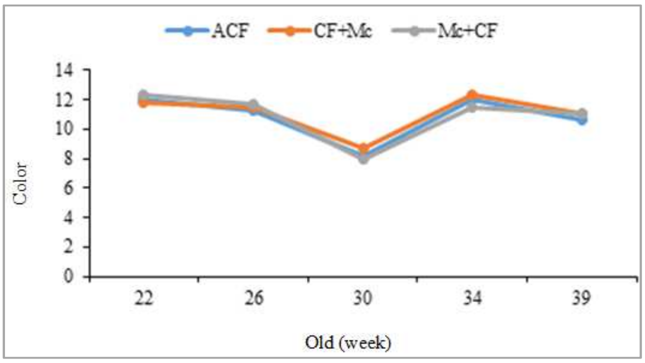

Figure 2. *Effect of the mode of distribution on yolk coloration: mealy supplement.*

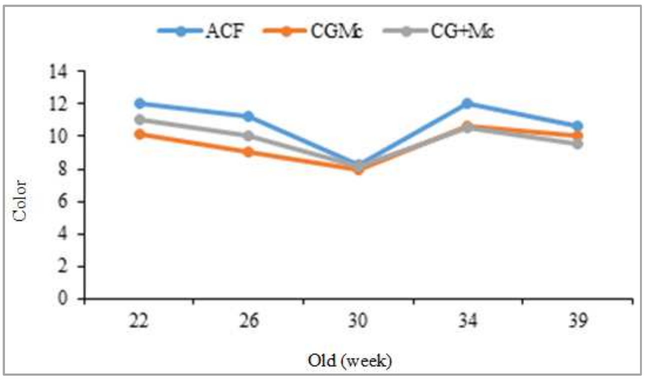

Figure 3. *Effect the mode of distribution on yolk coloration: granular complement.*

Thus, the sequential distribution of CF+Mc and Mc+CF maintained the intensity of yolk color. In the CGMc and CG+Mc sequential distribution, the yolk of the complete mealy feed was better colored (12) compared to the pelleted supplement mixed with cracked maize (10) and the pelleted supplement served in the morning and then the cracked maize served at 1:00 p.m. (11). Also, this coloration decreased at the 30th week of age of the hens and increased after this period. At the end of collection, the complete mealy feed (ACF) had better colored eggs (11) than the other treatments (10 and 9 respectively for CGMc and CG+Mc). These results from the sequential distribution mode of the Granular supplement confirm those obtained above on the presentation form. Therefore, granulations may be the reason for the low yolk staining.

4. Conclusion

This study aims to contribute to the provision of feed supplements to pastoralist communities with maize stocks in order to reduce their production costs and make the products accessible to the population. The results revealed that it would be advantageous to present the food in the granular supplement mixed with crushed maize that permits to have good physical qualities internal and external of the eggs. Also, the crushed maize served in the morning and the complement served in the mealy form to 13H can be recommended to the poultry farmers in sequential distribution. However, it would be interesting to continue this work with further research on the chemical composition of feed supplements produced from agricultural and agro-industrial by-products and the impact of granulation technology on yolk color.

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References

[1] Guédou, M. S. E., Kouato, G. O., Houndonougbo, M. F., Chrysostome, C. A. A. M., and Mensah, G. A. (2018). Performances de ponte et qualité des œufs de poules pondeuses nourries avec des aliments à base de différentes variétés de grains de maïs [Laying performance and egg quality of laying hens fed with different varieties of maize grains]. International Journal of Biological and Chemical Sciences, 12 (6), 2846-2855.

[2] FAOSTAT, Data base of the FAO. (2022), www.FAOSTAST.org. Consulted June 01, 2022 to 20h45.

[3] Babatounde, S., Saïdou, A., Guidan, M. and Mensah, G. A. (2009). Effet d'une complémentation alimentaire à base de légumineuses fourragères cultivées (*Chamaecrista rotundifolia* et *Aeschynomene histrix*) sur les performances des ovins Djallonké [Effect of feed supplementation with cultivated forage legumes (*Chamaecrista rotundifolia* and *Aeschynomene histrix*) on the performance of Djallonke sheep]. Renc Rech Ruminants. 16.

[4] Brah, N., Houndonougbo, M. F., and Issa, N., (2015). Etapes et méthodes de formulation d'aliment de volaille: une synthèse bibliographique [Steps and methods of poultry feed formulation: a literature review]. International Journal of Biological And Chemical Sciences, 9 (6), 2924-2931.

[5] Tchibozo, S. V., Dossa, L. H., Houndonougbo, M. F., Koura, I. B., Houinato, B. M. (2017). Effets de l'incorporation du son de maïs à différents doses sur les performances de croissance des lapereaux et la rentabilité de l'élevage [Effects of incorporating maize bran at different doses on the growth performance of young rabbits and the profitability of breeding]. European Scientific Journal. 13 (24), 1857-7881.

[6] Houndonougbo, M. F., Chrysostome, C. A. A. M. and Houndonougbo, V. P., (2012). Performances de ponte et qualité des œufs des poules pondeuses ISA Brown alimentées avec des rations à base de feuilles séchées de manioc (Manihot Esculenta, Crantz) [Laying performance and egg quality of ISA Brown laying hens fed with dried cassava (Manihot Esculenta, Crantz) leaf rations]. Intenational Journal of Biological and Chemistry Sciences, 6 (5), 1950-1959.

[7] Tougan, U. P., Yayi-Ladekan, E., Alassani, A.-M., Adanlin, P. M., Koutinhouin, B. G. and Soumanou, M. M. (2019). Influence du Promoteur de Croissance 'DI Grow' Vert sur les Caractéristiques Physico-Chimiques et Nutritionnelles des Œufs de Poules Lohman Brown Elevées à Sokode. International [Influence of Green 'DI Grow' Growth Promoter on the Physico-Chemical and Nutritional Characteristics of Eggs from *Lohman Brown* Hens Raised in Sokode]. Journal of Progressive Sciences and Technologies. 17 (1), 01-09.

[8] Houndonougbo, P. V., Chrysostome, C. A. A. M., Houndonougbo, M. F., Hammami, H., Bindelle, J. and Gengler, N. (2014). Evaluation de la qualité interne et externe des œufs de cinq variétés de pintades (*Numida meleagris*) locales élevées au Bénin [Assessment of the internal and external egg quality of five local guinea fowl (*Numida meleagris*) varieties raised in Benin]. Le CAMES, Sciences de la vie, de la terre et Agronomie 2 (2), 42-47.

[9] Tossou, M. L., Chrysostome, C. A. A. M., Houndonougbo, M. F., Tougan, P. U., Behingan, M. B., Salifou, S. and Abiola, A. F. (2015). Effet de la souche et du système sur la qualité des œufs de trois souches de poules pondeuses élevées au sud du Bénin [Effect of strain and system on egg quality of three strains of laying hens raised in southern Benin]. Afrique SCIENCE 11 (5), 294-30.

[10] Haugh, R. R. (1937). The Haugh unit for measuring egg quality. U S Egg Poultry Magazine. 43, 552-555; 572-573.

[11] Dahloum, L., Halbouche, M. and Arabi, A. (2015). Evaluation de la qualité des œufs chez deux phénotypes de poules locales: cou nu- frisées et normalement emplumées comparaison avec les œufs de souche commerciale [Egg quality traits of two phenotypes of local chickens Comparison with eggs of commercial strain]. Revue Agriculture, Revue semestrielle, Université Ferhat Abbas Sétif 1 (9), 10-18.

[12] Nys, Y., Sauveur, B. (2004). Valeur nutritionnelle des œufs INRA Production Animale [Nutritional value of eggs]. 17, 385-393.

[13] Abd El-Hack, M. E., Alagawany, M., Laudadio, V., Demauro, R. and Tufarelli V. (2017). Dietary inclusion of raw faba bean instead of soybean meal and enzyme supplementation in laying hens: Effect on performance and egg quality. Saudi Journal of Biological Sciences. 24, 276–285.

[14] Sauveur, B., Zybko, A., Colas, B., Garreau, M. and Rocard, J. (1979). Protéines alimentaires et qualité de l'œuf, l'Effet de quelques protéines sur la qualité interne de l'œuf et les propriétés fonctionnelles [Food proteins and quality of the egg, the effect of some proteins on the internal quality of the egg and the functional properties]. Annales de zootechnie, INRA/EDP Sciences, 28 (3), 271-295.

[15] Joly, P. (2004). Niveaux énergétiques des aliments pour pondeuses: influence sur les performances et l'ingéré [Energy levels in layer feeds: influence on performance and intake]. ISA (Ed). June 2004, Bulletin Technique. 10, 1-10.

[16] Bain, M. M., Dunn, I. C., Wilson, P. W., Joseph, N., De Ketelaere, B., De Baerdemaeker, J. and Waddington D. (2006). Probability of an egg cracking during packing can be predicted using a simple non-destructive acoustic test British Poultry Science. 47, 462-469.

[17] Nau, F., This, H., Anton, M., Baron, F., Guyot, N., Rehault Godbert S., Brossard, C., Nys, Y., Gautron, J., Lechevalier V, and Lescoat P. (2013). L'œuf aux trésors [egg with treasures]. Dossier de presse INRA. 24p.

[18] King'ori, A. M. (2012). Poultry egg external characteristics: Egg weight, Shape and Shell Color. Resaerch Journal of Poultry Science. 5, (2), 14-17.

[19] Akouango, P. (2014). Evolution qualitative et quantitative des composantes de l'œuf pendant les 3 phases de ponte chez la poule [Qualitative and quantitative evolution of egg components during the 3 phases of egg laying in hens]. Journal of Applied biosciences. 74 (1), 6080-6085.

[20] Monira, K. N., Salahuddin, M. and Miah, G. (2003). Effect of breed and holding period on egg quality characteristics of chicken International Journal of Poultry Science. 4, 261-263.

[21] Samandoulougou, S., Iiboudo, A. J., Ouédraogo, G. S., Bagre, T. S., Tapsoba, F. W., Compaoré, H., Dao, A., Zoungrana, A., Savadogo, A. and Traoré, A. S. (2016). Qualité physico-chimique et nutritionnelle des œufs de poule locale et de race améliorée consommés à Ouagadougou au Burkina Faso [Physicochemical and nutritional quality of local and improved breed eggs consumed in Ouagadougou, Burkina Faso]. International Journal of Biological Chemistry Science. 10, 2, 737-748.

[22] Bouvarel, I., Nys, Y., Panheleux M and Lescoat P. (2010). Comment l'alimentation des poules influence la qualité des œufs? [How does chicken feed influence egg quality?]. INRA Productions animales. 23 (2), 167-182.

[23] Nys, Y. (2010), Structure et formation de l'œuf. In: Science et technologie de l'œuf et des ovoproduits [Structure and formation of the egg. In: Science and technology of the egg and by-products]. Nau F., Guérin-Dubiard C., Baron F., Thapon J. L. (Eds). Editions Tec et Doc Lavoisier, Paris, France. 1 (5), 161-249.

[24] Wauters, A. M., Guibert, G., Bourdillon, A., Richard, M. A., Melcion, J. P. and Picard, M. (1997). Choix de particules alimentaires chez le poussin: effet de la taille et de la composition [Choice of feed particles in chicks: effect of size and composition]. 2èmes JRA Tours. 201-204.

[25] Umar Faruk, M., Bouvarel, I., Meme, N., Rideau, N., Roffidal, L., Tukur, H. M., Bastianelli, D., Nys, Y. and Lescoat, P. (2010). Sequential feeding using whole wheat and a separate protein mineral concentrate improved feed efficiency in laying hens. Poultry Science. 89, 785-796.