ISSN 1819-1878

Asian Journal of Animal Sciences

http://knowledgiascientific.com

Knowledgia SCIENTIFIC
A Place to Publish Outstanding Research

OPEN ACCESS **Asian Journal of Animal Sciences**

ISSN 1819-1878
DOI: 10.3923/ajas.2023.46.55

Research Article

Borassus aethiopum Ripe Fruits' Dried Pulp as a Feed Additive for *Coturnix coturnix japonica* Egg Yolks Coloration

[1]Tagouèlbè Tiho, [2]Nahoulé Silué, [1]Yapo Magloire Yapi and [3]Nogbou Emmanuel Assidjo

[1]Department of Agriculture and Animal Resources, National Polytechnic Institute Félix Houphouët Boigny, Yamoussoukro, Côte d'Ivoire
[2]Agropastoral Management Institute, Péléforo GON Coulibaly University, Korhogo, Côte d'Ivoire
[3]Department of Food Sciences, National Polytechnic Institute Félix Houphouët Boigny, Yamoussoukro, Côte d'Ivoire

Abstract

Background and Objective: The acceptance of *Borassus aethiopum* (*Ba*) ripe fruits' dried pulp by laying *Coturnix coturnix japonica* hens and its capacity to color the egg yolks were assessed. **Materials and Methods:** Seven diets were made, and comprised of 60% yellow corn-based (YC), 60% white corn-based (WC) and following some white corn was substituted by 1, 2.5, 5, 7.5 and 10% of *Borassus aethiopum* mature fruits' dried pulp. Then, these diets were named WC+1, WC+2.5, WC+5, WC+7.5 and WC+10%*Ba*, respectively. Moreover, 140 laying *Coturnix coturnix japonica* hens of 68 week-old were grouped by 20 birds and each group was fed on a diet. From week 69 to week 74 of age, the eggs were collected and weighed according to the diets. Thereafter, on week 73, 3 eggs of similar weights per diet were selected for egg yolks color and their total cholesterol contents assessment. **Results:** The WC+10%*Ba* performed better than other diets. Indeed, WC+10%*Ba* diet allowed the best laying rate of 79.76% and this laying rate was 13.45% higher than that of YC, the good reference. Additionally, the egg yolks weighed 3.72 g and they were well yellow colored (b* = 66.69), following YC diet (b* = 121.57). Moreover, WC+10%*Ba* egg yolks average total cholesterol content was 19.56 mg g^{-1}, like that of YC for 18.49 mg g^{-1} ($p = 0.231$). **Conclusion:** *Coturnix coturnix japonica* laying hens peck *Borassus aethiopum* ripe fruits' dried pulps. Moreover, added at 10% to a white corn-based diet, it colors the egg yolk without increasing total cholesterol content.

Key words: *Borassus aethiopum*, *Coturnix coturnix japonica*, egg yolk color, L*, a*, b*, egg yolk cholesterol

Citation: Tiho, T., N. Silué, Y.M. Yapi and N.E. Assidjo, 2023. *Borassus aethiopum* ripe fruits' dried pulp as a feed additive for *Coturnix coturnix japonica* egg yolks coloration. Asian J. Anim. Sci., 17: 46-55.

Corresponding Author: Tagouèlbè Tiho, Department of Agriculture and Animal Resources, National Polytechnic Institute Félix Houphouët Boigny, Yamoussoukro, Côte d'Ivoire

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

In growing economy countries like Cameroun, Côte d'Ivoire, Ghana, Nigeria and Senegal, middle-income families, more and more people are taking care of what they eat. So, eating to get a full-belly is coupled with the food nutritional quality of home and far home foods distributed in restaurants and supermarkets. Moreover, because bread and many other bakery products are a lot consumed during midday lunches, far from home, their quality is more and more assessed. Besides, due to daily stress at work, oxidative stress is becoming more and more common. For this reason, many people reduce saturated fatty acid consumption with the aim of reducing bad dietary cholesterol intake. Better, they look for unsaturated fatty acid sources. For example, when Ianni *et al.*[1] enriched laying hens' diet with unsaturated fatty acids (ω-3, ω-6 and ω-9), the bakery products nutritional values were enhanced. Indeed, Ianni *et al.*[1] concluded that hens' rich diets in Polyunsaturated Fatty Acid (PUFA), allowed enriched bake products in PUFA. Moreover, Patil *et al.*[2] and Swelum *et al.*[3] recalled that egg yolks are very rich in unsaturated fatty acids. For this reason, egg yolks are important not only for their uses for making cakes but for meals cooked at home. Better still, egg yolks are also used in biotechnology for animals' semen conservation[3]. Under these conditions, eggs appear to be important and easily accessible sources of unsaturated fatty acids.

In Ivory Coast, eggs are sold either individually, per group of 2, 3, 5, or in trays of 30 eggs. Thus, this source of protein appears very accessible to a lot of people and families. Also, for rural households, poultry farming constitutes the most affordable livestock investment[4]. Indeed, by enabling rapid retail sales of eggs or broilers, poultry farming contributes to reducing poverty and improving the standard of living of rural families in Côte d'Ivoire[4]. Thus, according to Koné *et al.*[4], these combined factors could explain the high progress observed in poultry farming these last 10 years. In addition, in an option of diversifying the agricultural portfolios for poultry farmers, Danso-Abbeam *et al.*[5] concluded that more and more egg producers are raising more than one poultry species. Indeed, N'gatta *et al.*[6] reported that compared to chicken laying hens, *Coturnix coturnix japonica* laying hens are easy to feed. To clarify, 35 g of feed is enough for a quail, while a chicken laying hen requires 120 g.

Although, these eggs weigh barely 12 g, compared to chicken eggs which weigh 50 g on average, trays of 30 eggs of quail or chicken are sold at the same cost, about 2,200 CFA francs (≈3.55 USD). Thus, Adom *et al.*[7] assumed that, because laying quails require less feed, they yield better returns on investments than chicken laying hens. Under these combined conditions, quail eggs are mainly consumed by rich people. But, looking at Aygün and Olgun[8] findings, quail egg yolks contain higher total cholesterol levels than chicken laying hens. So, the need for diets with important unsaturated fatty acid percentages while allowing good coloration in quails' egg yolks is important. Thus, this work hypothesis was that laying quails would peck *Borassus aethiopum* (*Ba*) ripe fruits' dried pulp. Subsequently, the objectives were to evaluate *Ba* ripe fruits' dried pulp effects on laying quail eggs yolks' color and their total cholesterol content, in white corn-based diets.

MATERIALS AND METHODS

Experimental site, treatments and *Coturnix coturnix japonica*: The experiment took place at the National Polytechnic Institute Félix Houphouet-Boigny of Yamoussoukro (INP-HB) in Côte d'Ivoire (Ivory Coast). Specifically, it was set at the research station at the Laboratory of Animal Science at the Graduate School of Agronomy. The data were collected from May to June, 2023 (rainy season).

The 7 treatments were set for laying *Coturnix coturnix japonica* (Table 1), within which there were two reference tests made of white corn-based (WC) and yellow corn-based diets (YC). So, due to yellow corn carotenoids, the YC diet was the good reference, while the WC diet was the bad reference, to be enhanced, because of the lack of carotenoids in the white corn. Alongside these reference diets were 5 test diets containing 1, 2.5, 5, 7.5 and 10% of *Borassus aethiopum* (*Ba*) mature fruits' dried pulp and were named WC+1%*Ba*, WC+2.5%*Ba*, WC+5%*Ba*, WC+7.5%*Ba* and WC+10%*Ba*, respectively (Table 1). These pulps were dried at 70°C for 5 days, as deduced by Tiho *et al.*[9].

From an initial group of 253 *Coturnix coturnix japonica* laying hens 68 weeks old, reared at the Graduate School of Agronomy research station, 140 laying birds of similar weights, 228.38±12.32 g, were used. In addition to the weight conformity, the second selection criterium for retaining a laying *Coturnix coturnix japonica* was based on its cloacae observation. Only birds with well-opened cloacae, therefore still laying, were retained. So, quails with poorly opened cloacae were deemed non-laying and were discarded from the experimental group. Together, 10 birds constituted an experimental group and 2 replications for each diet were set. So, 20 quail laying hens were fed on a given diet and the data were collected for 6 weeks, covering weeks 69, 70, 71, 72, 73 and 74. Each group of 10 birds was reared in a wooden cage

Table 1: Experimental diets and their nutritional values

Diets	WC	YC	WC+1%*Ba*	WC+2.5%*Ba*	WC+5%*Ba*	WC+7.5%*Ba*	WC+10%*Ba*
White corn	60	-	59	57.5	55	52.5	50
Yellow corn	-	60			-	-	-
Borassus aethiopum (*Ba*)	-	-	1	2.5	5	7.5	10
Soya meal	12	12	12	12	12	12	12
Nutri-A premix	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Wheat bran	9.00	9.00	9.00	9.00	9.00	9.00	9.00
Fish meal	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Eggshell powder	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total	100	100	100	100	100	100	100
Analysis data							
Dried matter (%)	96.03	96.32	96.05	95.60	96.09	96.62	96.71
Ash (%)	8.61	8.60	8.63	8.73	9.00	9.12	9.40
Crude fat (CF%)	4.13	4.67	5.25	5.40	5.50	5.62	5.72
Crude protein (CP%)	15.08	15.20	15.30	15.80	16.15	16.17	16.25
Computed data							
Tot_Carb (%)	72.18	71.53	70.82	70.07	69.35	69.09	68.63
ME (kcal/kg. DM)	3,355.85	3,380.92	3,406.64	3,405.84	3,397.85	3,399.08	3,393.07
Lysine (%)	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Methionine (%)	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Meth+Cyst. (%)	0.9	0.9	0.9	0.9	0.9	0.9	0.9

YC: Yellow corn-based died, WC: White corn-based diet, WC+1%*Ba*: White corn-based diet enriched with 1% of *Borassus aethiopum* (*Ba*) mature fruits dried pulp and so on for 2.5, 5, 7.5 and 10%, Tot_Carb (%): Total carbohydrate percentage, Tot_Carb (%DM) = 100-[(CF (%DM) +CP (% DM)+Ash (% DM)] by Koné *et al.*[4]

measuring 50×50×100 cm (width×height×length) and the bottoms of cages were 50 cm above the ground. Furthermore, the cages were covered with old nylon fishing nets around the edges and the bottoms were covered with plastic mesh.

Also, throughout the essay, there was no light program. Thus, the animals were illuminated by sunlight during the day and rested at night. Daily, each quail received 35 g of feed and the drinking water was available ad libitum. Finally, the daily feed was distributed half at 8 AM and the second half was given at 4 PM[6].

***Coturnix coturnix japonica* hens' laying rates (week 69 to 74):** The week 68 was the transition and adaptation of *Coturnix coturnix japonica* laying hens to the experimental diets. So, from week 69 to 74, the eggs were collected daily and weighed according to the diet. For that issue, a precise balance (HRB-E 100, S/N: HR1505005, capacity 100 g, precision 0.001 g, Shenzhen, China), was used. So, by counting the eggs' number day by day, the laying rates were computed by considering two variables which were the week and the diets. So, Eq. 1 was used to compute the laying rate of the weeks. In each experiment group, there were 20 quails, 7 diets and 7 days of the week. Equation 2 was used to compute the laying rate of the birds based on the diet during the 6 weeks:

$$\text{Laying}_{\text{rate}}\ (\text{week})\ (\%) = \frac{\text{Number of eggs collected per week}}{20\ \text{quails}_{\text{diet}} \times 7_{\text{diets}} \times 7_{\text{days of the week}}} \times 100 \qquad (1)$$

$$\text{Laying}_{\text{rate}}\ (\text{diet})\ (\%) = \frac{\text{Number of eggs collected per week}}{20\ \text{quails}_{\text{diet}} \times 6_{\text{diets}} \times 7_{\text{days of the week}}} \times 100 \qquad (2)$$

So, egg weights' mean (μ) was computed on the total eggs laid (Σx_i) during each week per diet group (Eq. 3). In fact, according to Arslan *et al.*[10] quails' age affects their average egg weight. Moreover, Nowaczewski *et al.*[11] mentioned that laying hens' age has also an important effect on yolk total cholesterol content. Average egg weight per week was computed by weighing all the eggs laid each week, from week 69 to 74. Where, n is the total number of eggs collected per diet group, under the 20 laying hens fed on a given diet:

$$\mu = \frac{1}{n}\sum_{1}^{n}(x_i) \qquad (3)$$

Egg selection and yolk color analyses (L*, a*, b*): On the seventh day of each week, 3 eggs of similar weight were collected per diet. These eggs were selected by computing an average weight for the eggs laid on the seventh day of the week (Eq. 3). Thereafter, an absolute interval (I_w) was computed for each egg on the seventh day of the week. In detail, the average egg weight on the seventh day of the week was subtracted from each egg weight (Eq. 4). Then, the 3 eggs showing the smallest absolute interval values were selected for egg constituents' assessment. Importantly, during the experiment, no quail died. So, 6 analyses were run.

$\mu_w = \frac{1}{n_w}\sum_1^n (x_i)$ (3') on the seventh day of the week (w).

Where, n_w is the total number of eggs collected during the week:

$$I_w = |x_i - \mu_w| \quad (4)$$

I_w an absolute interval computed between each egg weight and the average of all eggs.

After selecting 3 eggs of similar weight, they were broken and the constituents were separately weighed. So, the shell and the yolk were weighed and the albumen weight was derived by subtracting albumen, yolk and shell weights from the whole egg weight. Then, following CIE color assessment system[1], the yolk color was evaluated. So, each yolk was assessed for its black-white (L*), red-green (a*) and yellow-blue (b*) coordinates, with a colorimeter spectrophotometer (Precise Color Reader, CHN Spec, CS-10, Hangzhou, China), set at D65.

Egg yolks total cholesterol evaluations: For total cholesterol assessment, for each diet, a pool was made by mixing the 3 selected eggs' yolks. For total cholesterol evaluation the N'gatta *et al*.[6] protocol was followed. A UV 1901 spectrophotometer was used and the total cholesterol content was computed in mg dL^{-1} (Eq. 5 and 6). Thereafter, this content was converted in mg g^{-1} of fresh egg yolk by timing by 0.1:

$$\text{Tot}_{\text{Chol}}\left(\frac{\text{mg}}{\text{dl}}\right) = \frac{\text{Sample}_{\text{Absorption}}}{\text{Standard}_{\text{Absorption}}} \times \text{Standard}_{\text{Concentration}} = \frac{\text{Sample}_{\text{Absorption}}}{\text{Standard}_{\text{Absorption}}} \times 200 \quad (5)$$

$$\text{Tot}_{\text{Chol}}\left(\frac{\text{mg}}{\text{g of yolk}}\right) = \frac{\text{Sample}_{\text{Absorption}}}{\text{Standard}_{\text{Absorption}}} \times \text{Standard}_{\text{Concentration}} = \frac{\text{Sample}_{\text{Absorption}}}{\text{Standard}_{\text{Absorption}}} \times 200 \times 0.1 \quad (6)$$

Statistical analysis: During data collection, the results were generated in triplicate. Thereafter, for the statistical tests, the results were submitted to an Analysis of Variance (ANOVA), using XLSTAT 2014. The least-squares means were separated according to Newman-Keuls (SNK) multiple range tests in a 95% confidence interval.

RESULTS AND DISCUSSION

The main results reported were the eggs laying rates, eggs and their yolks' weights, egg yolk color for their L*, a* and b* components and their total cholesterol contents.

Laying rates (week 69 to 74): The laying rates from the weeks and diets were considered (Table 2). In total, 4088 eggs were collected during these 6 weeks. It was noted that the laying rate changed from one week to another. Environmental conditions such as hot days and cool days had different effects on quails' laying performance. Within a week, it was observed that during very hot days, when the ambient temperature was around 30°C in the rearing house, the laying rate dropped. But, after fresh days, the laying rate tended to increase. So, from one week to another and from one diet to another, the number of eggs collected differed. From week 69 to 74, the best laying rate was obtained in week 73 with 90%. In contrast, because of the colibacillosis attack, the laying rate dropped in week 74. In fact, during the experiment, no medical treatment was administrated from week 68 to 74.

Table 2: Summary statistics on eggs collected per diet, per week and computed laying rates

	Parameter	Eggs count	Percentage	Laying rate (%)	Eggs number
Week	69	698	17.07	71.22	4088
	70	728	17.81	74.29	
	71	548	13.41	55.92	
	72	676	16.54	68.98	
	73	882	21.58	90.00	
	74	556	13.60	56.73	
Diet	WC	503	12.30	59.88	4088
	WC+1%*Ba*	582	14.24	69.29	
	WC+2.5%*Ba*	585	16.39	69.64	
	WC+5%*Ba*	593	14.31	70.60	
	WC+7.5%*Ba*	598	14.51	71.19	
	WC+10%*Ba*	670	14.63	79.76	
	YC	557	13.63	66.31	

YC: Yellow corn-based died, WC: White corn-based diet, WC+1%*Ba*: White corn-based diet enriched with 1% of *Borassus aethiopum* (*Ba*) mature fruits dried pulp and so on for 2.5, 5, 7.5 and 10%

Looking at the diets, beginning with WC diet, *Coturnix coturnix japonica* laying rates were improved alongside an increased incorporation rate of *Borassus aethiopum* mature fruits' dried pulp. As an illustration, looking at WC, WC+1%*Ba*, WC+2.5%*Ba*, WC+5%*Ba*, WC+7.5%*Ba* and WC+10%*Ba* diets, the laying rates were 59.88, 69.29, 70.60, 71.19 and 79.76, respectively. Therefore, WC diet laying rate was improved by 15.75; 16.30; 17.89; 18.89 and 33.20%, with WC+1%*Ba*; WC+2.5%*Ba*, WC+5%*Ba*; WC+7.5%*Ba* and WC+10%*Ba*, respectively. So, the best improvement was obtained with WC+10%*Ba* for 33.20% and this diet expressed 79.76% of the laying rate. Elsewhere, similar laying rates were obtained by François *et al.*[12]. For example, they observed that at 6 months of production, the laying rate fluctuated between 74 and 78.75%[13]. Clearly, sorting the layers by observing the cloaca, made it possible to improve the laying rate.

For example, from week 9 to 12 of age, Ouaffai *et al.*[13] announced the laying rates between 50 and 54% for *Coturnix coturnix japonica*. Also, when Isa Brown laying hens' white corn-based diets were enriched with 7.5, 10, 12 and 15% of *Borassus aethiopum* ripe fruits' dried pulp diets, Silué *et al.*[14] got 62.14, 62.80, 76.19 and 74.70% for the laying rates, respectively. Compared to Silué *et al.*[14] experiments with Isa Brown layers, *Coturnix coturnix japonica* layers performed better under the same diets. Again, alongside an increasing incorporation rate of *Ba* dried pulp, the Isa Brown laying rate was improved to a maximum of 76.19% with WC+12.5%*Ba* and dropped to 74.70% with WC+15%*Ba*[14].

Eggs' weights according to the week and diet: From week 69 to 74, the weekly egg average weight moved from the smallest of 10.68±0.09 g to the highest of 11.25±0.08 g. So, this weighted mean increased by 0.57 g, thus 5.36% (Fig. 1). Step by step, from week 69 to 74, the weekly mean weight increased by 0.88% from 10.68 to 10.77g; 0.59% from 10.77 to 10.84 g; 2.36% from 10.84 g to 11.09 g and 1.44% from 11.09 to 11.25 g, respectively in weeks 70, 71, 72 and 73. Unfortunately, in week 74, colibacillosis attacks were observed on the eggs' shells and the consequence was a 1.90% loss in eggs' weights, from 11.25 to 11.04 g. In fact, medical prophylaxis was done in week 68 during the quails' adaptation to the diets and from week 69 to 74, no further medication was given. Looking at this progressive weekly egg' weight gain, similar results were announced by Nhan *et al.*[15]. In detail, Patricio *et al.*[16] observed that eggs weighed 11.43 g at week 10, 11.61 g at week 26 and 11.62 g at week 30. Similarly, Ouaffai *et al.*[13] announced 10.9, 11.8, 11.1 and 11.6 g for the egg average weights at weeks 9, 10, 11 and 12, respectively.

Based on the diets effect on the eggs' weights (Table 3), these weights fluctuated between 11.70±0.09 and 10.50±0.11 g according to the diets. Mainly, 3 distinct groups were observed, among those was the leading group with

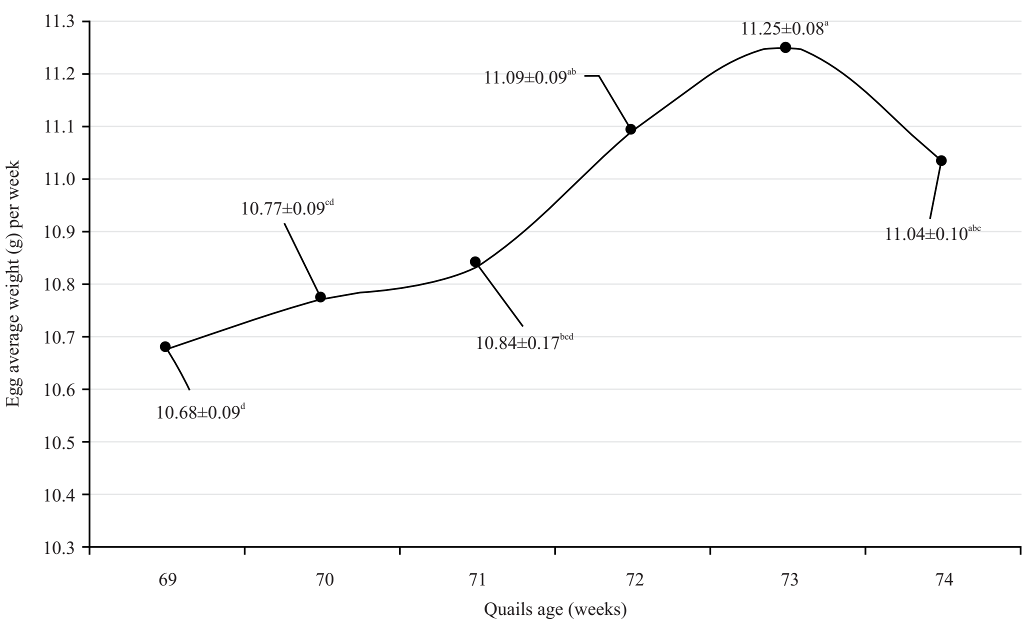

Fig. 1: Average egg weight (g) from week 69 to 74 (N = 4088 eggs)

Means with different superscripts [abcd] significantly differ, by Newman-Keuls (SNK) multiple ranges test at 95% interval of confidence

Table 3: Average egg weight according to the diets

Diets	μ±σ (g)	Comparison, gap between average, p-value
(1) WC+1%*Ba*	11.70±0.09[a]	
(2) WC+10%*Ba*	11.05±0.11[b]	(1) vs (2), 0.65, <0.0001***
(3) WC+7.5%*Ba*	11.00±0.11[b]	(2) vs (3), 0.05, 0.745[ns]
(4) WC	10.87±0.19[b]	(3) vs (4), 0.13, 0.292[ns]
(5) YC	10.77±0.09[bc]	(4) vs (5), 0.10, 0.444[ns]
(6) WC+2.5%*Ba*	10.73±0.08[bc]	(5) vs (6), 0.04, 0.763[ns]
(7) WC+5%*Ba*	10.50±0.11[c]	(6) vs (7), 0.23, 0.086[ns]
		(5) vs (7), 0.37, 0.109[ns]
		(4) vs (7), 0.37, 0.028**

YC: Yellow corn-based died, WC: White corn-based diet, WC+1%*Ba*: White corn-based diet enriched with 1% of *Borassus aethiopum* (*Ba*) mature fruits dried pulp and so on for 2.5, 5, 7.5 and 10%, μ±σ: Mean±Standard error, ns: Non-significant, **Significant, ***Highly significant, (N = 4088 eggs), [abc]Means within a column, with different superscript significantly differ, by Newman-Keuls (SNK) multiple ranges test at 95% interval of confidence

Table 4: Average egg yolk weight according to the diets

Diets	μ±σ (g)	Comparison, gap between averages (g), p-value
(1) WC+1%*Ba*	3.96±0.09[a]	
(2) YC	3.82±0.09[a]	(1) vs (2), 0.14, 0.229[ns]
(3) WC	3.76±0.09[a]	(2) vs (3), 0.06, 0.591[ns]
(4) WC+7.5%*Ba*	3.75±0.09[a]	(3) vs (4), 0.01, 0.919[ns]
(5) WC+10%*Ba*	3.72±0.09[a]	(4) vs (5), 0.03, 0.817[ns]
(6) WC+2.5%*Ba*	3.71±0.09[a]	(5) vs (6), 0.01, 0.978[ns]
(7) WC+5%*Ba*	3.40±0.09[b]	(6) vs (7), 0.31, 0.013**
		(1) vs (7), 0.56, 0.000**

YC: Yellow corn-based died, WC: White corn-based diet, WC+1%*Ba*: White corn-based diet enriched with 1% of *Borassus aethiopum* (*Ba*) mature fruits dried pulp and so on for 2.5, 5, 7.5 and 10%, μ±σ: Mean±Standard error, ns: Non-significant, **Significant, n = 18 (3 eggs/diet/week for 6 weeks), [ab]Means within a column, with different superscript significantly differ, by Newman-Keuls (SNK) multiple ranges test at 95% interval of confidence

WC+1%*Ba* only. Following, the second group was the largest with WC+10%*Ba*, WC+7.5%*Ba*, WC, YC and WC+2.5%*Ba* diets. Finally, the third group, the queue having the poorest result was 5%*Ba* diet. For example, WC+1%*Ba* diet eggs weights were significantly heavier than those from the WC+10%*Ba* diet.

Compared to WC+10%*Ba* diet, the leading WC+1%*Ba* diet eggs weighed 0.65 g more (p<0.0001). In the second and largest group, the egg's average weights fluctuated between 11.05±0.11 g under WC+10%*Ba* and 10.73±0.08 g under WC+2.5%*Ba* (0.292≤p≤0.763). These average egg weights were like those reported by Núñez-Torres *et al.*[16]. In fact, from week 2 to 8, the quail average eggs weighed between 11.30 to 13.20 g. Similarly, with 51 weeks old *Coturnix coturnix japonica* laying hens, the eggs collected by N'gatta *et al.*[6] weighed between 10.30 and 11.31 g.

Though WC+5%*Ba* delivered the weightless eggs for 10.50±0.11 g. Compared to the second group diets for 10.88±0.12 g, this performance was like those of YC and WC+2.5%*Ba*, whose were 10.77±0.09 and 10.73±0.08 g, respectively (0.109≤p≤0.763). Considering many factors such as laying *Coturnix coturnix japonica* age, the season (dry or rainy), from the beginning to the top laying rate, coccidiosis and colibacillosis effects, quail average egg weights vary between 9 to 13 g. Moreover, these average laying rates were higher than those of week 1, 6 and 10 of production and the average egg weight was 10.42±0.48 g. Again, Nowaczewski *et al.*[11] observed that in week 15, 23 and 31 of the quails' age, their average eggs' weight was 11.59, 11.66 and 11.67 g, respectively. So herein, egg weights were good.

Egg yolk weights according to the diet: Like the eggs' weights, the yolk weights were diet dependent (Table 4). But the uniformity was higher than the differences because just one diet behaved differently to the others. As the egg weights, WC+5%*Ba* diet delivered the poorest result for 3.40±0.09 g (p = 0.013). Specifically, in the order WC+1%*Ba*, WC+7.5%*Ba* and WC+10%*Ba*, the amount of natural carotenoid was increased progressively in the diets, but the yolk weights decreased alongside. Altogether, for the largest group composed of WC+1%*Ba*, YC, WC, WC+7.5%*Ba*, WC+10.5%*Ba* and WC+2.5%*Ba*, the average yolk weight was 3.79±0.09 g, for these 6 diets. This average egg yolk weight could be considered as good. Because the average egg weight depends on the quails' age, consequently, the average egg yolk weight varies accordingly. For instance, over 150 quails' eggs, Ouaffai *et al.*[13] got 3.50±0.41 g average weight for the egg yolks, when the quails were between week 9 and 12 old.

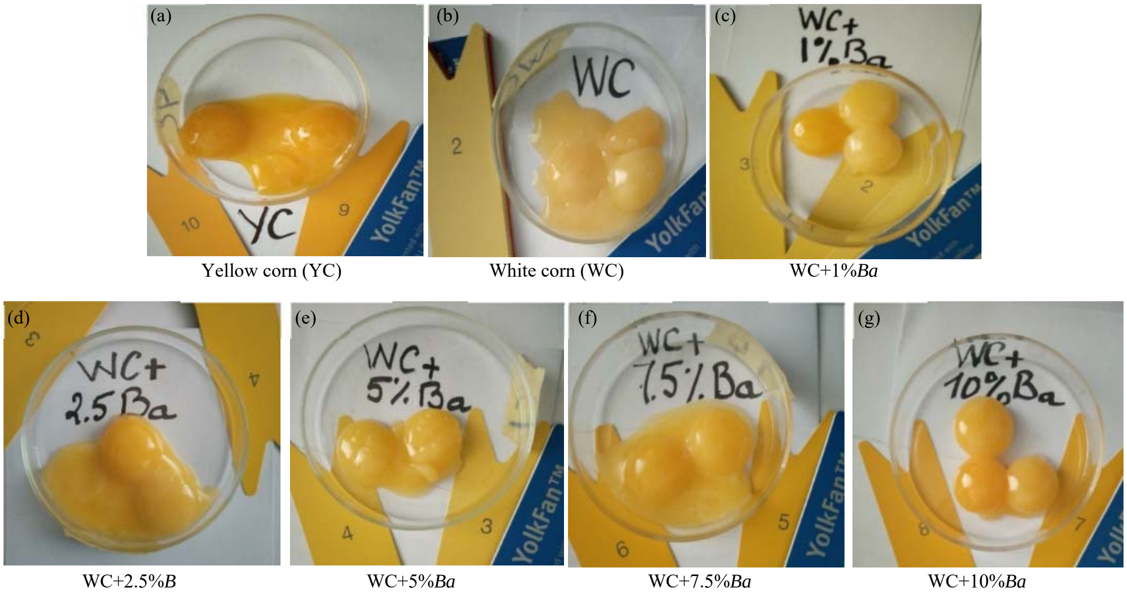

Fig. 2(a-g): Egg yolks color measured with egg yolk fan, according to the diets

YC: Yellow corn-based died, WC: White corn-based diet, WC+1%*Ba*: White corn-based diet enriched with 1% of *Borassus aethiopum* (*Ba*) mature fruits dried pulp and so on for 2.5, 5, 7.5 and 10%

Similarly, N'gatta *et al.*[6] registered average egg yolks between 3.22 and 3.78 g, when the quails were between week 51 and 59 old.

Meanwhile, this increasing natural carotenoid sources, leading to decreasing egg yolk weights was reported by Tiho *et al.*[17] when they incorporated 10 and 20% of *Borassus aethiopum* ripe fruits' dried pulp in Isa Brown layers' diets. In this case, yolk average weights decreased from 14.16 to 13.91 g, meaning 1.76% weight loss. Similarly, when Silué *et al.*[14] increased *Ba* mature fruits' dried pulp in Isa Brown layer's diets, WC+7.5%*Ba*, WC+10%*Ba* and WC+15%*Ba*, the results were 14.92, 14.65 and 14.59 g for egg yolks weights, respectively.

Nevertheless, due to *B. aethiopum* mature fruits' dried pulp nutritional value, it could be concluded that the yolk's nutritional values have been improved. Indeed, Tiho *et al.*[18] found that *B. aethiopum* mature fruits' dried pulp contains 76.35-78.67% unsaturated fatty acids, according to the drying temperature. Moreover, Swelum *et al.*[3] showed that Japanese quail egg yolks are richer in monounsaturated fatty acids, such as Oleic (C18:1, n-9) than chicken hens. Better still, *Coturnix coturnix japonica* egg yolks contain more copper, selenium, zinc and iron contents than that of chicken hens[3]. Likewise, Nowaczewski *et al.*[11] reported 52.02% for monounsaturated and 12.26% for polyunsaturated fatty acids, thus 64.028% for the unsaturated fatty acids, in *Coturnix coturnix japonica* egg yolks.

Egg yolk color according to the diet: The yolk colors were evaluated through the coordinate L* for black and white tendency, a* for green and red tendency and b* for blue and yellow tendency[1,6] (Table 5). Also, the visual color was judged by trained students with a Roche yolk color fan (Fig. 2). The two systems were used because human eye judgment is sometimes confusing. Simultaneously, looking at L* and b* tendencies revealed that well-colored egg yolk was darker, bearing low L* values, while b* values were higher. For example, Fig. 2a represented the good reference and *Borassus aethiopum* pulp progressively improved the white corn-based diet yolk from Fig. 2(b-g).

So, the YC diet which had the best yellow colored egg yolk for a* b* value of 121.57, had the lowest L* value of 76.87 ($p<0.0001$). Of course, the lightness (L*) decreased with gradually denser carotenoid contents.

But, due to *B. aethiopum* mature fruits' dried pulp with 8.89% fat content when it dried at 70°C, *B. aethiopum* pulp colored the egg yolk and kept high L* values. Not only at 5, 7.5 and 10% *Ba* ripe fruits' dried pulps incorporation rates, the egg yolks b* values were 64.34, 68.16 and 66.69, but also the lightness values were grouped together for 81.38, 80.58 and 81.11 ($0.195\leq p\leq 0.700$), respectively. Hence, increasing *B. aethiopum* dried pulp incorporation increased the yellowness, but the yolks kept high lightness values. This observation was reported by Silué *et al.*[14]. Similarly, while *Ba* dried pulp was incorporated at 10, 12.5 and 15% in Isa Brown

Table 5: Average egg yolk lightness (L*) and yellowness (b*) according to the diets

L*			b*		
Diets	μ±σ	Comparison, p-value	Diets	μ±σ	Comparison, p value
(1) WC+2.5%*Ba*	82.15±0.22[a]		(1) YC	121.57±0.94[a]	
(2) WC+5%*Ba*	81.38±0.22[b]	(1) vs (2), 0.019**	(2) WC+7.5%*Ba*	68.16±0.94[b]	(1) vs (2), <0.0001***
(3) WC+1%*Ba*	81.25±0.22[b]	(2) vs (3), 0.665[ns]	(3) WC+10%*Ba*	66.69±0.94[bc]	(2) vs (3), 0.276[ns]
(4) WC+10%*Ba*	81.11±0.22[b]	(3) vs (4), 0.678[ns]	(4) WC+5%*Ba*	64.34±0.94[cd]	(3) vs (4), 0.081[ns]
(5) WC	80.99±0.22[b]	(4) vs (5), 0.700[ns]	(5) WC+1%*Ba*	62.89±0.94[de]	(4) vs (5), 0.700ns (3) vs (5), 0.016** (1) vs (5), <0.0001***
(6) WC+7.5%*Ba*	80.58±0.22[b]	(5) vs (6), 0.195[ns] (1) vs (6), <0.0001***	(6) WC+2.5%*Ba*	60.58±0.94[e]	(5) vs (6), 0.088[ns] (4) vs (6), <0.017**
(7) YC	76.87±0.22[c]	(6) vs (7), <0.0001***	(7) WC	43.79±0.94[f]	(6) vs (7), <0.0001***

YC: Yellow corn-based died, WC: White corn-based diet, WC+1%*Ba*: White corn-based diet enriched with 1% of *Borassus aethiopum* (*Ba*) mature fruits dried pulp and so on for 2.5, 5, 7.5 and 10%, μ±σ: Mean±Standard error, ns: Non-significant, **Significant, ***Highly significant, n = 18 (3 eggs/diet/week for 6 weeks), [abcdef]Means within a column, with different superscript significantly differ, by Newman-Keuls (SNK) multiple ranges test at 95% interval of confidence

Table 6: Average egg yolk total cholesterol content (mg/g) according to the diets

Diets	μ±σ (mg g^{-1})	Comparison, p-value, significance
(1) WC+10%*Ba*	19.56±0.46[a]	
(2) WC+1%*Ba*	19.01±0.46[a]	(1) vs (2), 0.398[ns]
(3) YC	18.49±0.46[a]	(2) vs (3), 0.424[ns]
(4) WC+5%*Ba*	18.01±0.46[ab]	(3) vs (4), 0.462[ns]
(5) WC+7.5%*Ba*	16.81±0.46[bc]	(4) vs (5), 0.067[ns] (3) vs (5), 0.031**
(6) WC+2.5%*Ba*	16.67±0.46[bc]	(5) vs (6), 0.837[ns] (3) vs (6), 0.033**
(7) WC	15.82±0.46[c]	(6) vs (7), 0.190[ns] (4) vs (7), 0.007**

YC: Yellow corn-based died, WC: White corn-based diet, WC+1%*Ba*: White corn-based diet enriched with 1% of *Borassus aethiopum* (*Ba*) mature fruits dried pulp and so on for 2.5, 5, 7.5 and 10%, μ±σ: Mean±Standard error, ns: non-significant, **Significant, n = 18 (3 eggs/diet/week for 6 weeks), [abc]Means within the column, with different superscript significantly differ, by Newman-Keuls (SNK) multiple ranges test at 95% interval of confidence

layers' diets, b* values were 88.28, 90.17 and 81.36, respectively and the differences were not significant. Alongside these b* values, L* values were 81.46, 81.21 and 81.44, in the same diets' order and these L* values were also similar[15].

Diets WC+7.5%*Ba* and WC+10%*Ba* had similar impacts on egg yolk average yellowness. To enumerate, their derived egg yolks b* values were 68.16 and 66.69, respectively (p = 0.276) and they got the second good color group following YC diet. The human eyes' confusing results were illustrated with Roche fan yolk. In detail, WC+7.5%*Ba* was graded between 5 and 6 and WC+10%*Ba* received a grade between 7 and 8. Conversely, the L*, a*, b* system revealed that WC+7.5%*Ba* diet egg yolks had a higher b* value than that of WC+10% *Ba* diet. In short, adding *Borassus aethiopum* ripe fruits' dried pulps in white corn-based diets importantly improves *Coturnix coturnix japonica* egg yolks yellowness.

Egg yolk total cholesterol contents according to the diet: When the diet's effect on egg yolks' total cholesterol contents was assessed, it appeared that the results were diet dependent (Table 6). The outputs were put into 3 groups. So, the leading group composed of WC+10%*Ba*, WC+1%*Ba*, YC and WC+5%*Ba* delivered 19.56, 19.01, 18.49 and 18.01 mg of total cholesterol per gram of yolk, respectively ($0.398 \leq p \leq 0.462$). Generally, when the incorporation rate was doubled, the total cholesterol content considerably increased. Namely, WC, WC+2.5%*Ba*, WC+5%*Ba* and WC+10%*Ba* diets outputs were 15.82, 16.67, 18.01 and 19.56 mg per gram of egg yolk, respectively. These content increases of 0.85, 1.34 and 1.55 mg g^{-1}, represented 0.37, 8.04 and 8.6% augmentation, respectively. Diet WC which showed the highest lightness (L* = 80.99) and the poorest yellowness (b* = 43.79), delivered egg yolks with the lowest total cholesterol content for 15.82 mg per gram of yolk.

Compared to the leading diet, dietary cholesterol's effect on food nutritional values is still under debate. Instead of looking for a reduction in the total cholesterol content in egg yolk, like Ianni *et al.*[1] it may be useful to combine total cholesterol reduction and charge egg yolk with a dietary cholesterol rich in mono and polyunsaturated fatty acids. For example, Swelum *et al.*[3] mentioned that compared to other avian species, *Coturnix coturnix japonica* egg yolks were richer in mono and polyunsaturated fatty acids than chickens. So, because *Borassus aethiopum* mature fruits' dried pulps are rich in unsaturated fatty acids, its increasing incorporation continued to raise up total cholesterol contents.

Conversely, when Isa Brown layers were fed on WC+5%*Ba*, WC+7.5%*Ba*, WC+10%*Ba*, WC+12.5%*Ba* and WC+15%*Ba*, compared to WC diet, only WC+15%*Ba* increased total cholesterol contents in egg yolks[14]. Silué *et al.*[14] found that, from WC+5%*Ba* to WC+12.5%*Ba*, average egg yolks total cholesterol contents decreased, while WC+15%*Ba* induced its increase. It may be deducted that, above 12.5% of *Ba* incorporation rate, egg yolk average total cholesterol content increased, while below, the dried pulp induced total cholesterol reduction in Isa Brown layers egg yolks. Similarly, when *Coturnix coturnix japonica* layers were fed on WC+1%*Bo* (*Bixa orellana*), average egg yolk cholesterol content was significantly reduced[6]. Again, when Ahmed[19] introduced 4, 8 and 12 g of *Salvia hispanica* grains in one kilogram of laying quails' feedstuffs, he observed a reduction in average total cholesterol in egg yolks. In fact, these incorporation percentages were 0.4, 0.8 and 1.2%, respectively. *Salvia hispanica* grains incorporation in quails' feed induced ω-3 fatty acid increase in the blood strain[19], thus improving the animals' health status.

CONCLUSION

Increasing *Borassus aethiopum* mature fruits' dried pulp incorporation percentage in white corn-based diets enhanced the egg yolk yellowness. Thus, due to their yellow-orange richness in natural carotenoids and their content of unsaturated fatty acids, *Borassus aethiopum* mature fruits' dried pulps can be used for egg yolk coloration. So, if the farmer can afford any colorless grain such as millet, sorghum, or white corn, adding 10% of *Borassus aethiopum* ripe fruits' dried pulp can lead to good egg yolk coloration. However, the limit of this work is still the egg yolks' fatty acids profile and their HDL and LDL cholesterols' content assessments.

SIGNIFICANCE STATEMENT

Laying *Coturnix coturnix japonica* hens peck *Borassus aethiopum* ripe fruits' dried pulp. When this pulp was incorporated at 2.5, 5, 7.5 and 10% in the feed made of white corn-based, it colored the egg yolks. Moreover, increasing the dried pulp incorporation enhanced the laying rate and the egg yolks were more and more yellowish colored. Compared to the white corn-based diet, the total cholesterol content increased in egg yolks. But it was like that of the yellow corn-based diet. Thus, *Borassus aethiopum* ripe fruits' dried pulp is a good natural carotenoid source for coloring egg yolk while using colorless grains.

ACKNOWLEDGMENT

We, the authors, are thankful to KOUAME Manfegbin Henri Joel, an occasional trainee, for taking care of the laying *Coturnix coturnix japonica* hens. Firstly, he helped with the feed distribution to the birds, collecting and weighing the eggs daily. Secondly, he transported the eggs from the experimental site to the laboratory.

REFERENCES

1. Ianni, A., F. Palazzo, L. Grotta, D. Innosa, C. Martino, F. Bennato and G. Martino, 2020. Chemical-nutritional parameters and volatile profile of eggs and cakes made with eggs from ISA Warren laying hens fed with a dietary supplementation of extruded linseed. Asian-Australas. J. Anim. Sci., 33: 1191-1201.
2. Patil, S., B. Rao, M. Matondkar, P. Bhushette and S.K. Sonawane, 2022. A review on understanding of egg yolk as functional ingredients. J. Microbiol. Biotechnol. Food Sci., Vol. 11. 10.55251/jmbfs.4627.
3. Swelum, A.A., H.A. Ba-Awadh, I.O. Olarinre, I.M. Saadeldin and A.N. Alowaimer, 2022. Effects of adding mixed chicken and quail egg yolks to the cryodiluent on the quality of ram semen before and after cryopreservation. Front. Vet. Sci., Vol. 9. 10.3389/fvets.2022.1013533.
4. Koné, G.A., M. Good and M. Kouba, 2020. Performance of guinea fowl fed hevea seed meal or cashew nut meal as a partial substitute for soya bean meal. Animal, 14: 206-214.
5. Danso-Abbeam, G., G. Dagunga, D.S. Ehiakpor, A.A. Ogundeji, E.D. Setsoafia and J.A. Awuni, 2021. Crop-livestock diversification in the mixed farming systems: Implication on food security in Northern Ghana. Agric. Food Secur., Vol. 10. 10.1186/s40066-021-00319-4.
6. N'gatta, Z.R., T. Tiho, G.A. Kone, M. Gbane and K.H. Tani, 2023. *Bixa orellana* grains and *Curcuma longa* rhizomes powders for *Coturnix coturnix japonica* egg yolks' coloration. Asian J. Poult. Sci., 17: 1-8.
7. Adom, E., C. Bir and L.H. Lambert, 2023. A financial comparison of small-scale quail and laying hen farm enterprises. Poult. Sci., Vol. 102. 10.1016/j.psj.2023.102507.
8. Aygün, A. and O. Olgun, 2019. Comparison of egg quality, yolk cholesterol and fatty acid contents of chicken, quail, partridge and pheasant eggs. Akademik Ziraat Dergisi, 8: 323-328.

9. Tiho, T., N.J.C. Yao, Y.C. Brou and A.A. Adima, 2017. Drying temperature effect on total phenols and flavonoids content, and antioxidant activity of *Borassus aethiopum* Mart ripe fruits' pulp. J. Food Res., 6: 50-64.
10. Arslan, E., S. Güler, O. Çetin, M.M. Sarı and H. Yonar, 2023. Egg weight estimation and the effect of age and plumage colors on some egg quality traits in Japanese quails (*Coturnix coturnix japonica*). Emir. J. Food Agric., 35: 569-576.
11. Nowaczewski, S., T. Szablewski, R. Cegielska-Radziejewska, K. Stuper-Szablewska and M. Rudzińska *et al*., 2021. Effect of age of Japanese quail on physical and biochemical characteristics of eggs. South Afr. J. Anim. Sci., 51: 120-127.
12. François, D.K., A.E. Akana, R.M. Radu-Rusu, A. Teodorescu, M.G. Usturoi, F. Ngoula and A. Teguia, 2021. Effect of the quail phenotype and breeding age on egg laying and characteristics. Open J. Anim. Sci., 11: 208-221.
13. Ouaffai, A., L. Dahloum, A. Fassih, M. Milagh and M. Halbouche, 2018. Growth, laying performance and egg quality traits in Japanese quail (*Coturnix coturnix japonica*) [In French]. Arch. Zootecnia, 67: 168-176.
14. Silué, N., T. Tiho, K.A. Yao, A.K. Ouattara and N.E. Assidjo, 2023. *Borassus aethiopum* ripe fruits' dried pulp powder optimum incorporation rate in white corn-based diets for egg yolk colouration. Am. J. Agric. For., 11: 161-168.
15. Nhan, N.T.H., L.T.T. Lan, N.T.K. Khang, P.N. Du, T.N. Dung and N.T. Ngu, 2018. Effects of layer age and egg weight on egg quality traits of Japanese quails (*Coturnix coturnix japonica*). J. Anim. Plant Sci., 28: 978-980.
16. Patricio, N.T.O., D.Á.V. Elizabeth, A.S.R. Ismael and C.Q.S. Margarita, 2021. Ginger supplementation in quail as a nutritional alternative in egg production and quality. J. Selva Andina Anim. Sci., 8: 90-101.
17. Tiho, T., Z.R. Ngatta, G.A. Kone and K.B. Kouadio, 2020. *Borassus aethiopum* ripe fruits' dried pulp as egg yolk coloration agent. Anim. Vet. Sci., 8: 133-138.
18. Tiho, T., A.A. Amissa, Y.C. Brou, N. Traore, G.F. Kouassi, T.R. Kouame and M. Kouba, 2018. *Borassus aethiopum* mart ripe fruits' parts and drying temperature effect on its pulp protein, fat, sugars, metabolizable energy and fatty acids profile. Am. J. Food Nutr., 6: 67-75.
19. Ahmed, S.K., 2019. Egg yolk fatty acids, blood parameters and some reproductive measurements of Japanese quail supplemented with chia seeds (*Salvia hispanica* L.). Int. J. Poult. Sci., 18: 129-135.