

Egg quality of laying hens fed with cassava (*Manihot esculenta*), moringa (*Moringa oleifera*) and bocaiuva (*Acrocomia aculeata*) in semi-intensive rearing system

Qualidade de ovos de poedeiras alimentadas com mandioca (*Manihot esculenta*), moringa (*Moringa oleifera*) e bocaiúva (*Acrocomia aculeata*) criadas em sistema semi-intensivo

Calidad de huevos de ponedoras alimentadas con yuca (*Manihot esculenta*), moringa (*Moringa oleifera*) y bocaiuva (*Acrocomia aculeata*) criadas en un sistema semi-intensivo

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Abstract

This study aimed to evaluate the introduction of cassava flour, moringa leaf meal and bocaiuva pulp in laying hens' diets on egg quality. Nine hundred eggs from Dekalb® White laying hens between 34 and 54 weeks of age rearing in semi-intensive system were used in the experiment. The laying hens were submitted to the following diets: 1 - diet control: maize and soybean meal base diet; 2 - diet with inclusion of 18% of cassava root meal+4% moringa leaf meal+4% of bocaiuva pulp; 3 - diet with the inclusion of 24% of cassava root meal+6% of moringa leaf meal+6% of bocaiuva pulp; 4 - diet with the inclusion of 30% of cassava root meal+8% of moringa leaf meal+8% bocaiuva pulp. The inclusion of higher levels of alternative ingredients intensified yolk color; it improved the percentage of albumen, yolk index, specific gravity and reduced yolk percentage. The association of 30% de cassava root meal+8% de moringa leaf meal+8% de bocaiuva pulp does not decrease the egg quality; it gives the yolk an orange yellow tone and it can be used in diets of laying hens with 34 and 54 weeks of age in semi-intensive systems.

Keywords: Alternative ingredients; Non-conventional diets; Yolk color; Specific gravity.

Resumo

O estudo foi conduzido com o objetivo de avaliar a inclusão de farelo de mandioca, farinha de folhas de moringa e polpa de bocaiuva em dietas de galinhas poedeiras sobre a qualidade dos ovos. Novecentos ovos de galinhas poedeiras Dekalb® White entre 34 e 54 semanas de idade criadas em sistema semi-intensivo foram utilizados no experimento. As galinhas poedeiras foram submetidas às seguintes dietas: 1 – dieta à base de milho e farelo de soja; 2 - dieta com inclusão de 18% de farelo de mandioca + 4% de farinha de folhas de moringa + 4% de polpa de bocaiuva; 3 - dieta com inclusão de 24% de farelo de mandioca + 6% de farinha de folhas de moringa + 6% de polpa de bocaiuva; 4 - dieta com inclusão de 30% de farelo de mandioca + 8% de farelo de moringa + 8% de polpa de bocaiuva. A inclusão de níveis mais altos de ingredientes alternativos intensificou a cor da gema; melhorou a porcentagem de albúmen, índice de gema, gravidade específica e reduziu a porcentagem de gema. A associação de 30% de farelo de mandioca + 8% de farinha de folhas de moringa + 8% de polpa de bocaiuva não diminui a qualidade dos ovos, resulta na produção de ovos com gema de cor com tom amarelo alaranjado e pode ser usado em dietas de galinhas poedeiras com 34 e 54 semanas de idade criadas em sistemas semi-intensivos.

Palavras-chave: Cor de gema; Dietas não-convencionais; Gravidade específica; Ingredientes alternativos.

Resumen

El estudio se realizó con el objetivo de evaluar la inclusión de harina de yuca, harina de hoja de moringa y pulpa de bocaiuva en las dietas de gallinas ponedoras sobre la calidad del huevo. Novecientos huevos de gallinas ponedoras Dekalb® White entre 34 y 54 semanas de edad criadas en un sistema semi-intensivo se utilizaron en el experimento. Las gallinas ponedoras fueron sometidas a las siguientes dietas: 1 - dieta basada en harina de maíz y soya; 2 - dieta que incluye 18% de harina de yuca + 4% de harina de hoja de moringa + 4% de pulpa de bocaiuva; 3 - dieta que incluye 24% de harina de yuca + 6% de harina de hoja de moringa + 6% de pulpa de bocaiuva; 4 - dieta que incluye 30% de salvado de yuca + 8% de harina de moringa + 8% de pulpa de bocaiuva. La inclusión de niveles más altos de ingredientes alternativos mejoró el color de la yema; mejoró el porcentaje de albúmina, índice de yema, gravedad específica y redujo el porcentaje de yema. La combinación de 30% de harina de yuca + 8% de harina de hoja de moringa + 8% de pulpa de bocaiuva no disminuye la calidad del huevo, da como resultado la producción de huevos con yema de color amarillo-naranja y puede usarse en dietas para gallinas ponedoras a las 34 y 54 semanas de edad criadas en sistemas semi-intensivos.

Palabras clave: Color de yema; Dietas no-convencionales; Gravidad específica; Ingredientes alternativos.

1. Introduction

Energy and protein sources traditionally used in egg laying hens' diets are maize and soya bran. However, these ingredients are scarce, expensive and commonly used in human diets, especially for small farmers living in the Brazilian Pantanal region and other localities where the production of these grains has little significance.

In order to contextualize the egg production in the region of the Brazilian Pantanal west border, it is important to report that the breeding system is extensive, with low technological resources applied and animals without a defined breed. The activity is a subsistence practice, which is important to ensure food to approximately 1,500 families who live in an area of 36.730,33 ha (Curado, Santos & Silva 2003; Friderichs et al., 2008) considering poultry breeding occurs in 83.8% of the properties, with an average of 28 animals per property (Tomich et al., 2006).

Encouraging small farmers to produce eggs can be an alternative to ensure food security but also to add income to these families by providing quality eggs to the local market. Because of that, it is necessary to study local available feeding

alternatives rich in proteins and energy, amongst which are cassava, moringa leaf and bocaiuva, in order to replace maize and soya bran.

Cassava (*Manihot esculenta* Crantz) is vegetal specie that grows in barren soils. It is resistant to prolonged periods of droughts and pests. On average, 25 to 60 ton/ha can be produced (Chauynatong, Evangovan & Iji 2009). Integral scrapings from cassava root presents energy levels around 3,138 Kcal of EM/Kg (Rostagno et al., 2011) and can replace maize in poultry diets. However, the presence of cyanogenic glycosides, low levels of protein and essential amino acids (lysine, methionine and cysteine), plus the absence of pigment agents, limit its use (Cruz et al., 2006).

Moringa (*Moringa oleifera* Lam) is a plant natively from India, commonly cultivated in tropical regions and resistant to droughts (Tesfaye et al., 2014). Its leaf is a rich source of protein (20% to 29% PB/kg of MS), amino acids, vitamins, minerals and xanthophyll. It presents low levels of antinutritional factors (Olugbemi, Mutayoba & Lekule, 2010).

Bocaiuva (*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.) is a palm tree that grows in tropical regions of the Americas, on sandy soils and is resistant to droughts. Its *in natura* pulp and almond are used for human and animal nutrition as well as for oil production (Ciconini et al., 2013). Derived products from oil extraction don't have antinutritional or toxic compounds. Bocaiuva is a rich source of energy (lipids), fibers and presents high levels of β -Carotene acting a natural pigment (Ramos et al., 2009).

Previous researches had demonstrated the possibility of partial substitution of maize and soya bran in laying hens' diets for cassava and moringa leaf meal without negative effects on the development and quality of eggs (Oladunjoye, Ojebiyi & Amao 2010; Raphaël et al., 2015).

Thus, this study had the purpose to evaluate the quality of eggs produced by White laying hens in a semi-intensive system on diets with different levels of a mixture containing cassava, moringa and bocaiuva as a replacement for soybean meal and maize.

2. Methodology

The experimental was a field research, of qualitative nature (Pereira et al., 2018), carried out in an experimental poultry house. All the procedures adopted in the present study were approved by Institutional Ethics Committee (case n° 674/2015) for Animal Use.

Dekalb® White hens (n=160) were housed with density of 0.6 m² per animal. The breeding area was divided in four boxes (40 hens per box) and each was provided with two tubular feeders, two hanging drinkers and ten nests measuring 30x35x35cm (width x length x height) displayed in two platforms (four hens per nest), according to Junior et al. (2010). The temperature and relative humidity were monitored daily at 7 a.m. and 5 p.m. Each group had free access to the outside area consisting of 21m². The adopted lightning program consisted of 16.5 hours of light per day (natural and artificial).

A different diet plan was formulated for each experimental group, containing the following combination of alternative ingredients: 1- maize and soybean meal base control diet (M+SB); 2- diet with the inclusion of 18% of cassava root meal, 4% of moringa leaf meal and 4% of bocaiuva pulp (18CR+4ML+4BP); 3- diet with the inclusion of 24% of cassava root meal, 6% of moringa leaf meal and 6% of bocaiuva pulp (24CR+6ML+6BP); 4- diet with the inclusion of 30% of cassava root meal, 8% of moringa leaf meal and 8% of bocaiuva pulp (30CR+8ML+8BP). The diet plans (Table 1) were formulated to supply the nutritional requirements to light weight laying hens, according to Rostagno et al. (2011), ages between 34 and 54 weeks. Water and food were offered *ad libitum* in through feeders and nipple drinkers.

Table 1. Composition of experimental diets (kg/100 kg as fed basis).

Ingredients	Experimental diets*			
	Diet 1	Diet 2	Diet 3	Diet 4
Maize	61,47	32,13	20,73	9,25
Soybean meal 45%	24,52	26,10	25,77	26,88
Pulp of Bocaiuva	0,00	4,00	6,00	8,00
Cassava root meal	0,00	18,00	25,00	30,00
Moringa leaf meal	0,00	4,00	6,00	8,00
Soybean oil	2,41	3,75	4,16	4,57
Limestone	9,29	9,13	9,03	8,95
Dicalcium phosphate	1,31	1,59	1,62	1,72
Salt	0,40	0,51	0,51	0,51
DL-Methionine	0,20	0,30	0,35	0,35
L-Lysine- HCl	0,00	0,09	0,17	0,24
Mineral supplement**	0,05	0,05	0,05	0,05
Vitamin supplement**	0,10	0,10	0,10	0,10
Kaolin	0,25	0,25	0,31	1,38
Total	100,0	100,0	100,0	100,0
Calculated chemical composition				
Metabolizable energy (MJ/kg)	11.92	11.92	11.92	11.92
Crude protein	16.02	16.02	16.02	16.02
Linoleic acid	3.44	2.66	2.74	2.79
Calcium	3.90	3.90	3.90	3.90
Phosphorus available	0.28	0.28	0.28	0.28
Sodium	0.21	0.21	0.21	0.21
Methi + cist. Digestible	0.68	0.68	0.68	0.68
Lysine digestible	0.75	0.74	0.73	0.73

*Diet 1- maize and soybean meal base control diet (M+SB); Diet 2- diet with the inclusion of 18% of cassava root meal, 4% of moringa leaf meal and 4% of bocaiuva pulp (18CR+4ML+4BP); Diet 3- diet with the inclusion of 24% of cassava root meal, 6% of moringa leaf meal and 6% of bocaiuva pulp (24CR+6ML+6BP); Diet 4- diet with the inclusion of 30% of cassava root meal, 8% of moringa leaf meal and 8% of bocaiuva pulp (30CR+8ML+8BP). **Composition per kg of food: Vitamin A 8.000 UI; Vitamin D3 2.300 UI; Vitamin E 15,00 UI; Vitamin K3 1.000 µg; Vitamin B1 200 µg; Vitamin B2 3.000 µg; Vitamin B6 1.700 µg; Vitamin B12 10,00 µg; Folic acid 500 µg; Pantothenic acid 6,44 mg; Niacin 20 mg; Selenium (Se) 250 µg; Manganese (Mn) 60 mg; Copper (Cu) 9 mg; Zinc (Zn) 60 mg; Iron (Fe) 30 mg; Iodine (I) 1,00 mg. Source: Authors.

Nine hundred (n=900) eggs were selected from 160 laying hens within 34 to 54 weeks of age. The zootechnical performance of laying hens in that period was adequate (Table 2). The eggs sampling occurred in three consecutive days during five production cycles. During quality evaluations, the eggs were distributed in a completely randomized experimental design. Four treatments were carried out with five repetitions of three eggs each.

In the last three days of each evaluation period, all eggs from each experimental group were harvested, identified and the average egg weight (EW) was obtained by a 0.01g precision digital scale. The egg mass (EM) was calculated by multiplying EW by egg production rate. The feed conversion ratio (FCR) was obtained through the ration between consumption per bird per day and the EM.

From the eggs selected for quality evaluation, the height (HE) and diameter (DE) of the egg were measured using a caliper in order to obtain the shape index (SI), which is calculated by $(HE/DE) \times 100$. Egg density (ED) was determined by flotation in salt solution.

Using a caliper, the height of the albumin (HA), diameter (DY) and height (HY) of the yolk were measured. Through a logarithmic relation between WE and height of the albumin (HA), the Haugh Unity (HU) was determined by the following formula: $HU=100\text{Log}(HA+7,57-1.7WE^{0.37})$.

The yolk index (YI) was obtained by $(HY/DY) \times 100$. The yolk percentage (YP) was determined through the relation between the weight of the yolk (WY) and WE multiplied by 100. In order to calculate albumin percentage (AP), the following equation was established: $PA=100-(\%SP+\%YP)$, in which %S=shell percentage.

Table 2. Average value of performance characteristics of 34-54 week old hens fed with diet containing different level of cassava root meal, moringa leaf meal and bocaiuva pulp.

Parameter	Diets ¹			
	1	2	3	4
Initial Body Weight (kg)	1.57	1.63	1.62	1.66
Egg weight (g)	63.29	62.14	63.31	62.45
Feed intake (g/hen/day)	108.26	107.49	118.71	115.88
Egg production (%)	92.77	94.50	94.30	90.39
Egg mass(g/hen/day)	58.72	58.73	59.70	56.45
Feed intake by dozen of egg (kg/dz)	1.40	1.36	1.51	1.54
Food conversion ratio (kg/kg)	1.71	1.73	1.88	1.86

¹ Diet 1- maize and soybean meal base control diet (M+SB); Diet 2- diet with the inclusion of 18% of cassava root meal, 4% of moringa leaf meal and 4% of bocaiuva pulp (18CR+4ML+4BP); Diet 3- diet with the inclusion of 24% of cassava root meal, 6% of moringa leaf meal and 6% of bocaiuva pulp (24CR+6ML+6BP); Diet 4- diet with the inclusion of 30% of cassava root meal, 8% of moringa leaf meal and 8% of bocaiuva pulp (30CR+8ML+8BP). Source: Authors.

The yolk color was obtained through visual comparison with the DSN[®] colorimetric range, with a score varying from 1 to 15; 1 for a lighter color and 15 for an orange color.

The shells were washed and dried in the shade, at air temperature, during 48 hours. After this period, the shell was weighed to obtain “shell percentage” determined by the relation between the weight of the shell, the weight of the whole egg, then multiplied by 100. After that, the thickness of the shell was measured with the help of micrometer. The shell percentage was obtained by the relation between the weight of the shell and the weight of the egg, multiplied by 100.

The results obtained were submitted to an analysis of variance with the help of the Statistical Analysis System University (SAS 2002). The measurements comparison was carried out using the Duncan test, at 5% of probability rate.

3. Results and Discussion

In relation to the external quality of the eggs, it has been observed that the introduction of varying levels of cassava root meal (CR), bocaiuva pulp (BP) and moringa leaf meal (ML) interfered in the average weight of the eggs ($P<0.05$) without affecting ($P>0.05$) the percentage and thickness of the shell (Table 3).

The group of birds that received the diet containing M+SB and the diet made of 24CR+6ML+6BP presented high egg weight in relation to the group that received a diet consisting of 18CR+4ML+4BP. Next, the birds that received the diet made of 30CR+8ML+8BP presented an intermediary egg weight.

Table 3. External egg quality characteristics of 34-54 week old hens fed with diet containing different level of cassava root meal, moringa leaf meal and bocaiuva pulp.

Parameter	Diets ¹				P-Value	CV (%)
	1	2	3	4		
Egg weight (g)	63.29 a	62.14 b	63.31 a	62.45 ab	0.024	1.04
Shell (%)	9.41	9.37	9.48	9.50	0.266	1.10
Shell thickness (mm)	0.485	0.485	0.484	0.485	0.850	0.73
Egg shape index	76.96 a	76.21 ab	75.57 b	75.57 b	0.016	1.00
Specific gravity (g/mL H ₂ O)	1.0880 bc	1.0874 c	1.0882 ab	1.0888a	0.008	0.05

¹ Diet 1- maize and soybean meal base control diet (M+SB); Diet 2- diet with the inclusion of 18% of cassava root meal, 4% of moringa leaf meal and 4% of bocaiuva pulp (18CR+4ML+4BP); Diet 3- diet with the inclusion of 24% of cassava root meal, 6% of moringa leaf meal and 6% of bocaiuva pulp (24CR+6ML+6BP); Diet 4- diet with the inclusion of 30% of cassava root meal, 8% of moringa leaf meal and 8% of bocaiuva pulp (30CR+8ML+8BP). ^{a-c} Means within the same line with the different letter are significantly different for Duncan test (P<0.05). Source: Authors.

The study's results support the ones reported by Tesfaye et al. (2014) by encountering a higher egg weight average and no difference in the percentage and thickness of egg shells when animals received diets with the combination of cassava root meal and moringa leaf meal (50% CR and 5% ML) as a result of working with Dominant CZ laying hens at 22 weeks of age.

According to Nys and Guyot (2011) egg weight depends mainly on intrinsic factors, such as genetic origin, age of the bird and diet nutritional value during the production period. Within the same context, Costa et al. (2004) emphasized that the deficiency of essential amino acids can cause the reduction of egg weight and egg production by the laying hens, due to limitation of protein synthesis.

It should be emphasized that the inclusion of alternative foods in diets of white laying hens, bred in semi-intensive system, kept the average egg weight similar to the breed's standard weight (65.6g) at around 54 weeks of age (Granja Planalto, 2009) and they belong to the class of extra-large eggs according to the Brazilian egg measuring standards (Portaria n. 1, 1990). These results suggest that the experimental diet plans provided adequate levels of energy and nutrients. The high levels of vitamins and minerals in BP (Ramos et al., 2008) and high concentration of amino acids in ML (Moyo et al., 2011) combined in the diet could contribute to higher egg weight and food conversion ratio.

The thickness values and egg shell percentage (Table 3) observed in the present study were superior to the average values of 0.384 mm (Oliveira & Oliveira 2014) and 0.36 mm (Oladunjoye, Ojebiyi & Amao 2010) and the same values were found within the acceptable range for the lineage under study, which goes from 0.41 to 0.50mm (Oliveira et al., 2014). The laying hens of *Dekalb White* type are able to maintain an excellent shell quality as they get older (Granja Planalto, 2009).

The thickness of the shell has strong influence in the commercialization of eggs because it allows egg resistance during collection and transport (Abou-Elezz et al., 2011). But shell quality can be influenced by factors such as temperature, bird's age, lineage, seedlings, nutrition (levels of calcium, phosphorus and vitamin D), diseases, enzymatic additives in the diet, stress (lodging density) and breeding system (Fraser, 1994).

The stress caused by high temperatures can reduce food ingestion, limit the availability of calcium for the shell formation of and reduce the activity of carbonic anhydrases enzyme. Moreover, laying hen breeding in a free system can affect the shell quality due to inadequate stock of calcium in the diets offered to the birds (Roberts, 2004).

Although the high temperatures (34.18°C on average) registered during the experimental period were above the thermal comfort range recommended by the lineage manual, which is between 21°C and 27°C, the results of thickness and

percentage of the egg shell can be considered adequate. This is probably the result of adequate levels of calcium and other nutrients and good palatability of the experimental diet plans, ability to maintain feeding rate (108.26 to 118.71 g/bird/day), above the average described for this lineage, even in less favorable climatic conditions (Granja Planalto, 2009).

The alternative diets influenced the egg shape index ($P < 0.05$). The birds fed without alternative ingredients presented higher values than other groups and no differences ($P > 0.05$) were observed between the group of birds that received diets with inclusion of alternative ingredients. The results disagreed with Olugbemi, Mutayoba and Lekule (2010) whom observed differences in the shape index on eggs from laying hens around 65 weeks of age. The authors reported that the shape index increased in birds that received diets with the inclusion of CR and ML when compared to the control group.

According to USA (2000), the eggs are classified by shape index as pointed (< 72), standard (between 72 and 76) and rounded (> 76) (USA, 2000). The average values observed reflect that birds fed on control diet and diet composed by 18CR+4ML+4BP presented rounded format (76.96 and 76.21), respectively, and birds fed on diet containing 24CR+6ML+6BP and 30CR+8ML+8BP presented the standard format. The shape index allows egg standardization, which favors the visual appearance and the reduction of losses due to better accommodation in the packages. Then, it's possible to conclude that the eggs produced by chickens fed with diet 3 and 4 maintained an index shape that comply with market demands for this external quality criterion.

There were differences ($P < 0.05$) on the specific gravity of eggs among experimental groups (Table 3). Birds that received diet 4 presented eggs with higher specific gravity (1.0888 g/mL of water). The small value was observed in group 2. Specific gravity allows for indirect evaluation of the shell quality, without needing to break the egg. This is mostly done in hen farms and enterprises to monitor quality with a quick and practical procedure in egg production (Oliveira & Oliveira, 2014). The values of specific gravity observed in the present research are within the parameters recommended for the lineage (Granja Planalto, 2009) and classifies the shell as of good quality.

It has been noticed that all characteristics of internal egg quality (Table 4) evaluated in this study were influenced ($P < 0.05$) by diet composition, except the Unity of Haugh (UH) which did not present any difference ($P > 0.05$). The yolk percentage was reduced with the increase of alternative ingredients inclusion rates and the percentage of albumen was higher in group 4 than in other groups ($P < 0.05$). The results of yolk and albumen percentages in the present research match with the ones reported by Abou-elezz et al. (2011) in eggs from laying hens of Rhode Island Red lineage, at the age of 36 weeks, fed on diets containing ML (0, 5, 10, and 15%) as a replacement for soybean meal.

The UH did not differ between the groups ($P > 0.05$). Similar results were reported by Tesfaye et al. (2014) no differences were observed in HU when laying hens fed on diets with different levels of CR and ML association. According to USA (2000) classification, eggs with UH values above 72 are considered as of excellent quality, between 60 to 72, the eggs are of good quality, and eggs considered poor quality are those with UH values below to 60. In this way, it is possible conclude that eggs can be considered of excellent quality even with the inclusion of CR, ML and BP in diets, using the tested levels in this study.

The UH can be influenced by temperature and storage time, among other factors (Alleoni & Antunes, 2001; Oliveira & Oliveira, 2014). As the analyses were done with fresh eggs, soon after collection, there was no opportunity for temperature to interfere in the decrease of UH.

Yolk index increased ($P < 0.05$) with the inclusion of CR, ML and BP (Table 4). Yolk index was smaller in the base control diet and it was in disagreement with Tesfaye et al. (2014) whom worked with laying hens submitted to a feeding process in which maize and soybean meal were replaced by CR and ML. The authors concluded that the inclusion of these ingredients did not compromise the yolk index. It's possible that the lipids present in the BP may interfere in the yolk index, justifying different results obtained in experiments that used diets only with CR and ML.

Table 4. Internal egg quality characteristics of 34-54 weeks old hens fed a diet containing different level of cassava root meal, moringa leaf meal and pulp bocaiuva.

Parameter	Diets ¹				P-Value	CV (%)
	1	2	3	4		
Yolk (%)	27.38 ab	27.5 a	27.00 b	26.38 c	0.0004	1.26
Albumen (%)	63.24 b	63.27b	63.56 b	64.06 a	0.008	0.56
Haugh unit	99.82 a	98.43a	97.82a	98.07a	0.294	1.75
Yolk index	0.39 b	0.40 a	0.40 a	0.41 a	0.0023	1.86
Yolk color	6.63 d	8.65 c	9.31 b	10.10 a	<.0001	1.78

¹ Diet 1- maize and soybean meal base control diet (M+SB); Diet 2- diet with the inclusion of 18% of cassava root meal, 4% of moringa leaf meal and 4% of bocaiuva pulp (18CR+4ML+4BP); Diet 3- diet with the inclusion of 24% of cassava root meal, 6% of moringa leaf meal and 6% of bocaiuva pulp (24CR+6ML+6BP); Diet 4- diet with the inclusion of 30% of cassava root meal, 8% of moringa leaf meal and 8% of bocaiuva pulp (30CR+8ML+8BP). ^{a-c} Means within the same line with the different letter are significantly different for Duncan test (P<0.05). Source: Authors.

Yolk pigmentation has great influence in eggs commercialization, as more pigmented yolks are the most preferred ones by consumers at the market (Roberts, 2004). Laying hens are not able to synthesize the pigment agents and the properties of the color of egg yolk, so when they become dependent a diet rich in natural yellow/orange pigments, mainly xanthophyll, zeaxanthin, lutein and synthetic pigments (citranaxanthin, capsanthin, cryptoxanthin and cataxanthin), they promote different egg coloring, from yellow-bright to red-dark (Albino et al., 2014). On the other hand, the yolk color depends on the solubilization of pigments in the fat and can differ among lineages due to the deposit capacity of these pigments, which are related to the birds characteristics of metabolism and absorption (Oliveira & Oliveira 2014).

The color of the yolk intensified proportionally with the increase CR, ML and BP (P<0.05) inclusion rates. Similar results were reported by Abou-elezz et al. (2011); Olugbemi et al. (2010); Tesfaye et al. (2014) and Gakuya et al. (2014) who observed intense pigmentation of yolk when they increased the levels of inclusion of moringa leaf meal. The intense pigmentation of yolk (Table 4) observed in eggs of group 4 birds can be explained on the basis of percentage increase of ML and BP, since such ingredients are rich in carotenoids (Ramos et al. 2009). All experimental groups had equal access to grazing areas and, therefore, the interference of the diet should be considered the relevant factor for the higher intensity of yolk color.

Although it was not the objective of this study, it is important to mention that the ingredients used in the diets of the birds did not interfere in the taste and acceptance of the eggs. These factors were verified afterwards, in a study with non-specialized tasters (Juliano et al., 2017).

However, it can be said that alternative ingredients can partially replace corn and soybean meal in laying hens' diets. The association of cassava root meal, moringa leaf meal and bocaiuva pulp can be used in the diets of laying hens free from cages in a semi-intensive system and does not affect the zootechnical performance and quality characteristics of the eggs.

4. Conclusion

This article provides unpublished information on the internal and external quality characteristics of white eggs from hens reared without a cage in a semi-intensive system. These results help to generate technical information to assist producers in choosing a diet with replacement, even if partial, of corn and soybean meal with alternative ingredients.

The inclusion of alternative ingredients in maximum levels of 30% of CR, 8% of ML and 8% of BP does not affect negatively the quality of eggs of white laying hens between 34 and 54 weeks of age, bred in semi-intensive systems. The addition of CR, ML and BP results in a more intense color of yolk.

Future research involving higher levels of inclusion, with different proportions of mixture of alternative ingredients is important, taking into account the replacement of corn and soy meal in the diet and availability of food purchases.

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