Rev. Bras. Saúde Prod. Anim., Salvador, v.19, n.1, p.58-68 jan./mar., 2018 ISSN 1519 9940
http://dx.doi.org/10.1590/S1519-99402018000100006

Cassava bagasse and annatto colorific (*Bixa orellana* L.) in diets for slow-growing broilers from 30 to 90 days of age

Bagaço de mandioca e colorífico de urucum (Bixa orellana L.) em dietas para frangos de crescimento lento de 30 a 90 dias de idade

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SUMMARY

The performance and breast skin color of slow-growing broilers from 30 to 90 days old fed diets with different inclusions of cassava bagasse and annatto colorific were evaluated. 308 slow-growing broilers were used in a completely randomized experimental design, in a factorial scheme with an additional treatment 3 X 2 + 1, with three levels of annatto colorific as a pigmentant agent (1%, 2% and 3%), two levels of cassava bagasse (10% and 20%) and an additional treatment (control diet), totaling seven treatments, four replicates and 11 broilers per experimental unit. Feed intake and feed conversion were affected by treatments, with interaction. The weight gain and final weight were influenced by the treatments and the best results were found for the inclusion of 10% cassava bagasse and 2% annatto colorific. There was no effect of treatment and no interaction on carcass yield. The color parameters L*, a* and b* were not influenced by treatments. The inclusion of 10% cassava bagasse and 1% annatto colorific for slow-growing broilers from 30 to 90 days of age is recommended. However, the use of these ingredients proved to be economically unfeasible.

Keywords: backyard poultry, by-products, nutrition, pigments

RESUMO

Foram avaliados o desempenho e a cor da pele de frangos de corte de crescimento lento no período de 30 a 90 dias, alimentados com dietas com diferentes inclusões de bagaço de mandioca e colorífico de urucum. 308 frangos de corte de crescimento lento foram utilizados em um delineamento experimental inteiramente casualizado, em esquema fatorial com tratamento adicional 3 X 2 + 1, sendo três níveis de colorífico de urucum como agente pigmentante (1%, 2% e 3%), dois níveis de bagaço de mandioca (10% e 20%) e um tratamento adicional (dieta de controle), totalizando sete tratamentos, quatro repetições e 11 frangos de corte por unidade experimental. O consumo de ração e a conversão alimentar foram influenciados pelos tratamentos, com interação. O ganho de peso e o peso final foram influenciados pelos tratamentos (p<0,001) e os melhores resultados foram encontrados para a inclusão de 10% de bagaço de mandioca e 2% de colorífico de urucum. Não houve efeito dos tratamento e nenhuma interação sobre o rendimento da carcaça. Os parâmetros de cor L *, a * e b * não foram influenciados pelos tratamentos. É recomendável a inclusão de bagaço de mandioca a 10% e 1% de colorífico de urucum para frangos de crescimento lento de 30 a 90 dias de idade. No entanto, o uso desses ingredientes provou ser economicamente inviável.

Palavras-chave: aves de capoeira, subprodutos, nutrição, pigmentos

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INTRODUCTION

In recent years, the demand for foods of animal origin with higher quality attributes has intensified. An alternative to this niche market is the raising of slow-growing broilers in the semi-intensive or backyard system. It has been considered that broilers reared in this system have meat with a more pronounced color, firm consistency, sharp taste and lower fat content in the carcass (TAKAHASHI et al., 2006).

The cost of production is mainly influenced by feeding, which is usually based on corn and soybean meal. The availability of these grains varies according to the region and the time of year, directly affecting the poultry industry. Therefore, an alternative to reduce the cost of production is the use of agro-industrial by-products in animal feeding (PELIZER et al., 2007).

Cassava residues (*Manihot esculenta* Crantz) can be added to non-ruminant feeding to reduce corn inclusion and, consequently, the cost of the diets (FREITAS et al., 2008; COSTA et al., 2009). The main problem is the high fiber content, which generally impairs the use of these feeds.

The need to use cheaper alternative energy sources has led to the search for feeds such as sorghum, cassava, millet, rice bran or wheat. These ingredients are poor in xanthophyll carotenoids, directly influencing the carcass pigmentation of birds and egg yolk. In these cases, the addition of some coloring agent is necessary, which can be obtained from natural or artificial source (COSTA et al., 2006; ASSUENA et al., 2008; GARCIA et al., 2009).

Among the natural sources, annatto (*Bixa orellana* L.), of the Bixaceae family, have been outstanding for both human and animal feeding. The main pigment of the annatto is bixin, which can be extracted from the seed pulp and it is characterized as a thin resinous layer of red-orange color (SILVA et al., 2006).

The coloring ability of the annatto seed was confirmed in different experiments with poultry (COSTA et al., 2006; BRAZ et al., 2007; OLIVEIRA et al., 2007; HARDER et al., 2008; GARCIA et al., 2009; ROJAS et al., 2015).

Due to the market demands, this study sought to evaluate the annatto colorific (*Bixa orellana* L.) effect on performance and skin color of slow-growing broilers from 30 to 90 days fed cassava bagasse.

MATERIAL AND METHODS

The experiment was performed at the Poultry Unit of the Federal University of Tocantins located in Araguaina. The procedures were approved by the Ethics Committee for Animal Use of the Federal University of Tocantins (CEUA-UFT), process n. 76/2013.

The experimental area was sown with African Star Grass and divided into paddocks using stock fence. In each paddock of 100 m², considering the recommendation of 5 m²/bird (ALBINO et al., 2005), small wood shelters covered with Babassu straws with 2m² area, tubular feeder and pendulum drinker were placed.

Five hundred one-day-old male broilers of slow growth (Redbro Cou Nu) were purchased at the local market, vaccinated against Marek and raised up to 30 days old in a conventional shed. The birds were fed a single starting diet based on corn and soybean meal with mineral and vitamin supplementation

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according to the recommendations of Rostagno et al. (2011).

From day 30, all birds were weighed and 308 were selected with an average weight of 615 ± 3.6 grams. Subsequently, they were homogeneously distributed in the experimental paddocks. The experimental design was completely randomized in factorial arrangement, with an additional treatment 3 x 2 + 1, with three levels of annatto as coloring agent (1%, 2% and 3%), two levels of cassava bagasse (10% and 20%) and a control diet, based on corn and soybean meal. Therefore, seven treatments with four replicates allocated in 28 paddocks and 11 broilers per experimental unit were used.

The cassava bagasse (CB) used is a by-product obtained from tapioca industry, by pressing the tuber to extract the starch through the wet method. It consists of the fibrous material from the root with part of the starch that was not extracted during the processing. Subsequently, this material passes through pressings and exposure to the sun for drying. These processes aim to obtain good storage conditions for using the cassava bagasse in the experimental diets. Cassava bagasse was composed of 88.72% dry matter (DM), 1.5% crude protein (CP), 11.10% crude fiber (CF) and 2,378 Kcal/kg of metabolizable energy (ME).(SOUSA et al., 2012).

The annatto colorific (ANC) was purchased at the local market. It consists of the mixture of annatto seed meal and oil extract homogenized in handmade pestle.

The experimental diets were formulated to meet the nutritional requirements of broilers according to Rostagno et al. (2011) and Dourado et al. (2009) and are expressed in Table 1. The difficulty in leaving the isonutritivas rations is due to the use of the alternative foods, nevertheless they were formulated the most similar possible. Lysine requirement was calculated by the equation for male broilers of regular performance, proposed by Rostagno et al. (2005), which used the weight gain and weight at 60 days of age, obtained by the growth parameters of the Gompertz equation for slow-growing SASSO® broilers, proposed by Dourado et al. (2009). For mineral requirements, the equations for male broilers of regular performance proposed by Rostagno et al. (2011) were used.

The weight gain (WG), feed intake (FI) and feed conversion ratio (FC) were calculated to evaluate the performance during the experimental period from 30 to 90 days. The WG was obtained by the difference between initial and final weight of the birds during the experimental period, while the FI was calculated considering the feed supply and leftovers at the end of the experimental period. The FC was obtained through the ratio of the total feed intake and weight gain (FI/WG), corrected for bird mortality (2%) during the experiment proposed by Sakomura & Rostagno (2007).

At the end of the experimental period, two birds from each experimental unit, totaling 56 broilers weighing close to the average (± 10%), were identified and submitted to a 12-hour fasting for carcass yield evaluation.

Subsequently, the birds were weighed, bled, scalded, plucked and eviscerated. After washing, the carcasses were weighed again to determine the hot carcass weight (plucked and eviscerated). The carcass yield was calculated considering the relation between hot carcass weight and live weight after fasting.

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Table 1. Percentage composition and calculated nutritional values of experimental diets

Ingredients	Control diet	Treatments					
		10 % Cassava bagasse			20% Cassava bagasse		
		Annatto colorific inclusion					
		1%	2%	3%	1%	2%	3%
Corn	79.06	64.73	62.72	60.71	50.06	48.06	46.05
Soybean meal 45%	18.35	19.46	19.78	20.10	21.79	22.11	22.42
Cassava bagasse	0.00	10.00	10.00	10.00	20.00	20.00	20.00
Soybean oil	0.00	2.49	3.19	3.88	4.84	5.53	6.22
Annatto colorific	0.00	1.00	2.00	3.00	1.00	2.00	3.00
Limestone	1.00	0.62	0.62	0.62	0.60	0.60	0.60
Dicalcium phosphate	0.81	0.84	0.85	0.85	0.86	0.87	0.87
Salt	0.36	0.37	0.37	0.37	0.38	0.38	0.38
L- Lysine HCL, 79%	0.20	0.20	0.20	0.19	0.17	0.16	0.15
DL –Methionine, 99%	0.12	0.15	0.16	0.16	0.17	0.17	0.18
L-Threonine, 98%	0.00	0.03	0.03	0.03	0.03	0.03	0.03
Supplement[1]	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
		Calculated nutritional composition					
ME (kcal/kg)	3100	3100	3100	3100	3100	3100	3100
Crude protein (%)	14.77	14.34	14.32	14.31	14.37	14.35	14.33
Calcium (%)	0.64	0.51	0.51	0.51	0.51	0.51	0.51
Available P (%)	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Total Lysine (%)	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Total Met.+ Cys.(%)	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Total Methionine (%)	0.35	0.37	0.37	0.37	0.38	0.38	0.38
Total Threonine (%)	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Total Tryptophan (%)	0.16	0.16	0.16	0.16	0.17	0.17	0.17
Sodium (%)	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Potassium (%)	0.57	0.54	0.54	0.54	0.54	0.54	0.54
Crude fiber (%)	2.56	3.49	3.48	3.47	4.50	4.49	4.47

[1] Mineral and vitamin supplement; composition/ton: Manganese 18,175 mg, Zinc 17,500 mg, Iron 11,250 mg, Copper 2,000 mg, Iodine 187.50 mg, Selenium 75 mg, Vitamin K3 360 mg, Vitamin B1 436.50 mg, Vitamin B2 4,300 mg, Vitamin B6 624 mg, Vitamin B12 2,400 mg, Folic acid 200 mg, Pantothenic acid 3.120 mg, Niacin 8,400 mg, Biotin 10,000 mg, Choline 78,102.01 mg, Antioxidant additive 25,000 mg.

Relative to color parameters, one bird from each experimental unit weighing close to the average (± 10%) was selected and breast skin areas were collected to evaluate the pigmentation.

Color quantification was performed using the Minolta CR-200b colorimeter previously calibrated using a white standard (BIBLE & SINGHA, 1997).

Three color parameters were evaluated: L*, a* and b*. The value of a* characterizes coloration from the red (+a*) to green (-a*), while the value of b* indicates coloring in the range from yellow (+b*) to blue (-b*). The value of L indicates the luminosity, varying from white (L = 100) to black (L = 0) (HARDER et al., 2010).

The reading was performed in four distinct points of the breast skin. The average values were used to check if treatments modified the skin coloration.

The data were submitted to Normality (Shapiro-wilk) and Homoscedasticity tests (Cochran and Bartlett). Once these assumptions were satisfied, the variables were submitted to analysis of variance according to the statistical model proposed by Yassin et al. (2002).

Rev. Bras. Saúde Prod. Anim., Salvador, v.19, n.1, p.58-68 jan./mar., 2018 **ISSN 1519 9940**
http://dx.doi.org/10.1590/S1519-99402018000100006

$$Y_{ijk} = \mu + CB_i + ANC_j + CB*ANC_{ij} + \varepsilon_{ijk} \quad \text{and} \quad y_h = \mu + \tau_a + \varepsilon_h$$

In which: Y_{ijk} = is the variable related to cassava bagasse and annatto levels, μ = is the general average, CB_i = = is the effect of cassava bagasse levels, ANC_j = is the effect of annatto colorific levels, $CB*ANC_{ij}$ = is the interaction effect of cassava bagasse and annatto colorific levels, ε_{ijk} = is the experimental error associated with Y_{ijk}.

y_h = is the variable associated with the additional treatment; τ_a = is the effect of the additional treatment; εh = is the experimental error associated with the additional treatment.

Subsequently, the averages were compared individually with the control by the Dunnett's test and the Student's t-test was used for comparisons within the treatments, both at 5% probability according to the recommendations of Sampaio (2002).

To compare the economic efficiency of the experimental diets, the feeding cost per kg of broiler produced was determined as follows:

$$FCi = (FIi \times CDi) / WGi;$$

with i = 1, 2, 3, 4, 5, 6, 7.

In which: FCi = feeding cost per kg of broiler produced with the use of the i^{th} cassava bagasse and annatto colorific level (R$/kg), FIi = feed intake for the i^{th} cassava bagasse and annatto colorific level (kg), CDi = cost of the diet using the i^{th} cassava bagasse and annatto colorific level (R$/kg) and WGi = weight gain of broilers fed the i^{th} cassava bagasse and annatto colorific level (kg).

The gross margin relative to the feeding cost per kg of broiler for each cassava bagasse and annatto colorific level in the diet was calculated by the expression: GMi = BSP - FCi; in which GMi = gross margin relative to the feeding cost per kg of broiler obtained from the use of the i^{th} cassava bagasse and annatto colorific level (R$); BSP = live broiler selling price (R$/kg) and FCi = feeding cost per kg of broiler produced with the use of the i^{th} cassava bagasse and annatto colorific level (R$/kg).

RESULTS AND DISCUSSION

The inclusion of cassava bagasse and annatto colorific ($P<0.05$) influenced the feed intake from 30 to 90 days, with significant interaction. Comparing treatments individually, diets with 10% of cassava bagasse and 1 and 2% of annatto colorific were not statistically different compared to the control treatment. However, when the percentage of pigment or cassava bagasse increased, a reduction in feed intake was found (Table 2).

Oliveira et al. (2007) evaluated eight experimental diets resulting from the combination of four levels of colorific (0, 1.5, 3.0 and 4.5%) and two energetic sources (corn and rice bran) for Japanese quails. The authors observed that as the colorific levels increased, there was a reduction in FI of quails fed corn-based diets and a linear increase in FI of quails fed rice bran. However, quails fed colorific and corn had higher feed intake when compared to those fed colorific and rice bran.

The possible cause for these results may be related to the amount of crude fiber in plant-derived foods, which cannot be digested by birds, since its glycosidic bonds (α-1,6 and β1,4 and β1,6) are resistant to hydrolysis in the digestive tract and may even influence the digestion of other nutrients (BRITO et al., 2008).

The weight gain and the final weight of the broilers were also affected ($P<0.05$) by the inclusion of cassava bagasse and annatto colorific. Nevertheless, the

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interaction was not significant (P>0.05). Broilers fed 10% cassava bagasse had greater weight gain and final weight when compared to those fed 20%. Relative to the annatto colorific levels, the inclusion of 2% resulted in the best weight gain and final weight. The diet with 10% of cassava bagasse and 2% of annatto colorific resulted in the highest weight gain and final weight, even compared to broilers fed control diet.

Table 2. Performance of slow-growing broilers from 30 to 90 days fed diets containing cassava bagasse (CB) and annatto colorific (ANC) as a coloring agent

Item	ANC Levels	Cassava bagasse levels			Control	CB	ANC	CB x ANC	CV (%)
		10%	20%	Average		Probabilities			
	1%	7.43^{aA}	7.07^{aB}*	7.25	-	-	-	-	-
Feed intake	2%	7.25^{bA}	6.63^{bB}*	6.94	-	0.0001	<0.0001	0.00274	2.31
(kg/bird)	3%	6.72^{cA}*	6.74^{bA}*	6.73	-				
	Average	7.13	6.81	-	7.37				
	1%	2.19	2.00*	2.09^{b}	-	-	-	-	-
Weight gain	2%	2.25*	2.13	2.19^{a}	-	<0.0001	0.0001	NS	2.89
(kg/ bird)	3%	2.12	1.94*	2.03^{c}	-	-	-	-	-
	Average	2.18^{A}	2.02^{B}	-	2.17	-	-	-	-
	1%	3.39^{bA}	3.52^{bB}*	3.45	-	-	-	-	-
Feed conversion	2%	3.22^{aB}*	3.11^{aA}*	3.16	-	0.0208	<0.0001	0.0029	3.12
(kg/kg)	3%	3.17^{aA}*	3.46^{bB}	3.31	-	-	-	-	-
	Average	3.26	3.36	-	3.39	-	-	-	-
	1%	2.81	2.62*	2.72^{b}	-	-	-	-	-
Final weight	2%	2.87*	2.75	2.81^{a}	-	<0.0001	0.0002	NS	2.30
(kg)	3%	2.74	2.56*	2.65^{c}	-	-	-	-	-
	Average	2.80^{A}	2.64^{B}	-	2.79	-	-	-	-
	1%	76.10	76.27	76.18	-	-	-	-	-
Carcass yield	2%	77.40	76.87	77.13	-	NS	NS	NS	1.80
(%)	3%	76.08	75.89	75.98	-	-	-	-	-
	Average	76.52	76.34	-	76.45	-	-	-	-

CB = cassava bagasse; NS = not significant; CV = coefficient of variation; Control: diet without cassava bagasse and annatto colorific.*Means differ from the control by the Dunnett's test (P<0.05). Means followed by different lowercase letters in the columns differ by the Student's t-test (P<0.05).

Means followed by different capital letters in rows differ by the Student's t-test (P<0.05) One of the disadvantages of these by-products is the high fiber content, which affects the digestibility because birds are not specialized in their digestion (BRITO et al., 2008). Poultry of lineages enhanced genetically limit feed intake, more by physical action of filling the gastrointestinal tract and palatability of food, than by weight maintenance and body composition (GONZALES, 2008).

There was an effect (P<0.05) regarding the inclusion of cassava bagasse and annatto colorific on feed conversion, with interaction. Broilers fed 10% of cassava bagasse and 1% of annatto colorific had similar feed conversion to those fed control diet. As the annatto colorific levels increased to 2 and 3%, it is possible to notice an improvement in feed conversion, even compared to broilers fed control diet.

Oliveira (2012) evaluated the inclusion of cassava bagasse (0, 10, 20 and 30%) during starting, growing and finishing stages of slow-growing broilers and found that the inclusion of up to 10.39% did not affect feed conversion during starting stage. In the growing phase, the increased inclusion worsened feed conversion. On the other hand, the inclusion of cassava bagasse did not affect this variable during the finishing stage, allowing its inclusion of up to 30%.

There was no effect and interaction (P>0.05) of the inclusion of cassava bagasse and annatto colorific on carcass yield.

Carrijo et al. (2010) also did not verify differences in carcass yield of slow-growing broilers when evaluating different levels (0, 15, 30 and 45%) of cassava root meal. Souza et al. (2011), evaluating the inclusion of 0, 20, 40, 60% of cassava root meal for slow-growing broilers during the finishing phase, concluded that there was no effect on the carcass yield at 84 days of age.

The results above differ from those found by Oliveira (2012) when evaluating 0, 10, 20 and 30% of cassava bagasse for slow-growing broilers. According to these authors, the best carcass yield was found for the inclusion of 17.25% CB.

It is important to note that alternative feeds can constantly vary their nutrient contents and composition. This is usually due to the lack of standardization to obtain the products. In addition to these factors, the type, processing time and inadequate food storage conditions may alter their composition and may influence the nutritional quality of the feed. This demonstrates the importance to analyze the nutritional composition aspects of alternative feeds for research (BRUMANO et al., 2006; GOMES et al., 2007; NERY et al., 2007; CALDERANO et al., 2010).

The color parameters L*, a* and b* were not significantly influenced (P<0.05) by the inclusion of cassava bagasse and annatto colorific and there was no interaction between them (Table 3).

Table 3. Average values of color parameters L*, a* and b* of the skin of slow-growing broilers from 30 to 90 days fed diets containing cassava bagasse (CB) and annatto colorific (ANC) as a coloring agent

Item	ANC Levels	Cassava bagasse levels			Control	CB	ANC	CB x ANC	CV (%)
		10%	20%	Average	Probabilities				
L*	1%	70.75	70.21	70.48	-	-	-	-	-
	2%	71.10	69.54	70.32	-	NS	NS	NS	1.75
	3%	70.75	71.24	70.99	-	-	-	-	-
	Average	70.86	70.33	-	69.58	-	-	-	-
a*	1%	2.71	2.79	2.75	-	-	-	-	-
	2%	2.63	2.37	2.5	-	NS	NS	NS	28.1
	3%	3.30	1.66	2.48	-	-	-	-	-
	Average	2.88	2.27	-	3.03	-	-	-	-
b*	1%	31.00	30.81	30.90	-	-	-	-	-
	2%	31.60	30.88	31.24	-	NS	NS	NS	10.9
	3%	30.27	28.98	29.62	-	-	-	-	-
	Average	30.95	30.22	-	29.96	-	-	-	-

CB = cassava bagasse; NS = not significant; CV = coefficient of variation;
Control =diet without cassava bagasse and annatto colorific.
*Means differ from the control by the Dunnett's test (P<0.05).
Means followed by different lowercase letters in the columns differ by the Student's t-test (P<0.05).
Means followed by different capital letters in rows differ by the Student's t-test (P<0.05).

Rodrigues et al. (2008) found color changes in carcass ranging from bright yellow to white according to the higher corn inclusion in substitution for the residue of cassava industrialization. The authors pointed out the need to research on an additive able to maintain the coloration pattern, since this is important matter for consumers when choosing the backyard chicken.

In the present study, although the treatments had no significant effect on color parameters, the broilers at the end of the experiment showed an equivalent skin coloration regardless of treatment, different from the coloration modifications found by Rodrigues et al. (2008).

Silva et al. (2005), when evaluating performance, carcass characteristics and pigmentation of broilers fed diets with 0; 2.5; 5.0; 7.5; 10.0; 12.5; and 15.0% of annatto seed residue, found no effect on the percentage of abdominal fat and pigmentation of the carcass measured on leg skin by the visual method of the color fan. However, Silva et al. (2006) observed that the addition of up to 12% of this by-product to a diet containing 40% sorghum as the main source of energy linearly improved egg yolk pigmentation.

Harder et al. (2010) when evaluating the color of cooked cuts from commercial broilers fed 1, 2 and 3% of annatto seed meal, concluded that the use of annatto intensified the color of the cuts, mainly evidenced by the inclusion of 3% annatto.

Studies that link alternative feeds and the use of annatto as skin and carcass pigment for slow-growing broilers are scarce in the literature for a more detailed comparison. The need for further studies is justified by the fact that alternative feeds in substitution for corn are generally poor in carotenoids, which can alter the coloration of the skin and carcass of the birds.

Considering the prices of inputs used to formulate the experimental diets for slow-growing broilers from 30 to 90 days, the inclusion of cassava bagasse and annatto colorific promoted an increase in the price of diets (Table 4).

Table 4. Feed cost (R$/kg), feed cost per kg of weight gain (R$/kg) and gross margin (R$/kg) for slow-growing broilers from 30 to 90 days

Variables	Control diet	Treatments					
		10 % Cassava bagasse			20% Cassava bagasse		
		Annatto colorific inclusion					
		1%	2%	3%	1%	2%	3%
Feed cost[1] (R$/kg)	0.77	0.91	1.00	1.09	0.98	1.07	1.16
Feed cost per kg of weight gain (R$/kg)	2.62	3.09	3.22	3.45	3.45	3.31	4.017
Gross margin[2] (R$/kg)	5.38	4.91	4.78	4.55	4.55	4.69	3.98

[1] Considering the following prices: Corn = R$ 0.59/kg; Soybean meal = R$ 1.30/kg; Cassava bagasse = R$ 0.63/kg; Annatto colorific = R$ 8.00/kg; Dicalcium phosphate = R$ 2.77/kg; Soybean oil = R$ 2.49/kg; Limestone = R$ 0.43/kg; Salt = 0.80/kg; DL-Methionine = R$ 11.87/kg; L-Lysine HCl = R$ 6.67/kg; L-Threonine = R$ 6.76/kg; Mineral and vitamin supplement = R$ 9.00/kg.

[2] Considering the price of a live chicken at the local market on November 16th 2011 of R$ 8.0/kg.

The lowest feed cost per kg of weight gain was obtained for the diet with 0% of cassava bagasse and 0% of annatto colorific, which resulted in the higher gross margin. Therefore, the use of these ingredients is economically infeasible.
The inclusion of 10% cassava bagasse and 1% annatto colorific is recommended for slow-growing broilers from 30 to 90 days of age. However, the inclusion of these ingredients increases the cost per kg of broiler produced and reduces gross margin, which is economically unfeasible.

REFERÊNCIAS

ALBINO, L.F.T.; NERY, L.R.; JUNIOR, J.G.V.; SILVA, J.H.V. **Criação de frango e galinha caipira**, Viçosa: UFV, 2005.

ASSUENA, V.; FILARDI, R.S.; JUNQUEIRA, O.M.; CASARTELLI, E.M.; LAURENTIZ, A.C.; DUARTE, K.F. Substituição do milho pelo sorgo em rações para poedeiras comerciais formuladas com diferentes critérios de atendimento das exigências em aminoácidos. **Ciência Animal Brasileira**, v.9, n.1, p.93 - 99, 2008.

BIBLE, B.B.; SINGHA, S. Canopy position influences CIELab coordinates of peach color. **Hortscience**, v.28, p.992 - 993, 1997.

BRAZ, N.M.; FUENTES, M.F.F.; FREITAS, E.R.; SUCUPIRA, F.F.; MOREIRA, R. F.; LIMA, R.C. Semente residual do urucum na alimentação de poedeiras comerciais: desempenho e características dos ovos. **Acta Scientarium Animal Science**, v.29, n.2, p.129-33, 2007.

BRITO, M.S.de.; OLIVEIRA, C.F.S.de.; SILVA, T.R.G. da.; LIMA, R.B.de.; MORAIS, S.N.; SILVA, J.H.V.da. Polissacarídeos não amiláceos na nutrição de monogástricos - Revisão. **Acta Veterinaria Brasilica**, v.2, n.4, p.111-117, 2008.

BRUMANO, G.; GOMES, P.C.; ALBINO, L.F.T.; ROSTAGNO H.S.; GENEROSO, R.A.R.; SCHMIDT, M. Composição química e valores de energia metabolizável de alimentos proteicos determinados com frangos de corte em diferentes idades. **Revista Brasileira de Zootecnia**, v.35, n.6, p.2297-2302, 2006.

CALDERANO, A.A.; GOMES, P.C.; ALBINO, L.F.T.; ROSTAGNO, H. S.; SOUZA, R. M. de.; MELLO, H. H. de C. Composição química e energética de alimentos de origem vegetal determinada em aves de diferentes idades. **Revista Brasileira de Zootecnia**, v.39, n.2, p.320-326, 2010.

CARRIJO, A.S.; FASCINA, V.B.; SOUZA, K.M.R.; RIBEIRO, S.S.; ALLAMAN, I.B.; GARCIA, A.M.L.; HIGA, J.A. Níveis de farelo da raiz integral de mandioca em dietas para fêmeas de frangos caipiras. **Revista Brasileira de Saúde e Produção Animal** [online], v.11, n.1, p.13 1- 139, 2010.

COSTA, F.G.P.; GOMES, C.A.V.; DA SILVA, J.H.V.; CARNEIRO, M.V.D.; GOULART, C.C.; DOURADO, L.R.B. Efeitos da inclusão do extrato oleoso de urucum em rações de poedeiras com substituição total ou parcial do milho pelo sorgo de baixo tanino. **Acta Scientarium. Animal Science**, v.28, n.4, p.409-414, 2006.

COSTA, F.G.P.; GOULART, C.de C.; COSTA, J.S.; SOUZA, C.J.de; DOURADO, L.R.B.; SILVA, J.H.V. Desempenho, qualidade de ovos e análise econômica da produção de poedeiras semipesadas alimentadas com diferentes níveis de raspa de mandioca. **Acta Scientiarum. Animal Sciences**, v.31, n.1, p.13-18, 2009.

DOURADO, L.R.B.; SAKOMURA, N.K.; NASCIMENTO D.C.N.do.; DORIGAM J.C.; MARCATO, S.M.; FERNANDES, J.B.K. Crescimento e desempenho de linhagens de aves pescoço pelado criadas em sistema semi-confinado. **Ciência e Agrotecnologia**, v.33, n.3, p.875-881, 2009.

FREITAS, C.R.G.; LUDKE, M.do C.M.M.; LUDKE, J.V.; RABELLO, C.B.; NASCIMENTO, G.R.do.; BARBOSA, E.N.R. Inclusão da farinha de varredura de mandioca em rações de frangos de corte. **Acta Scientiarum. Animal Sciences**, v.30, n.1, p.155-163, 2008.

GARCIA, E.A.; MOLINO, A.B.; BERTO, D.A.; PELÍCIA, K.; OSERA, R.H.; FAITARONE, A.B.G. Desempenho e qualidade dos ovos de poedeiras comerciais alimentadas com semente de urucum (*Bixa orellana* L.) moída na dieta**. Veterinaria e Zootecnia,** v.16, n.4, p.689-697, 2009.

GOMES, F.A.; FASSANI, E.J.; RODRIGUES, P.B. FILHO, J.C.S. Valores energéticos de alguns alimentos utilizados em rações para codornas japonesas. **Revista Brasileira de Zootecnia**, v.36, n.2, p.396-402, 2007.

GONZALES, E. Ingestão de alimentos: mecanismos regulatórios. In: MACARI, M.; FURLAN, R.L.; GONZALES, L. (Eds.). **Fisiologia Aviária Aplicada a Frangos de Corte**. Jaboticabal: Funep, 2008. p.187-192.

HARDER, M.N.C.; CANNIATTI-BRAZACA, S.G.; SAVINO, V.J.M.; COELHO, A.A.D. Efeito de *Bixa orellana* L. na alteração de características de ovos de galinhas. **Ciência e Agrotecnologia**, v.32, n.4, p.1232 - 1237, 2008.

HARDER, M.N.C.; SPADA, F.P.; SAVINO, V.J.M.; COELHO, A.A.D.; CORRER, E.; MARTINS, E. Coloração de cortes cozidos de frangos alimentados com urucum. **Ciência e Tecnologia de Alimento***,* v.30, n.2, p.507-509, 2010.

NERY, L.R.; ALBINO, L.F.T.; ROSTAGNO, H.S.; CAMPOS, A.M.A.; SILVA, C.R. Valores de energia metabolizável de alimentos determinados com frangos de corte. **Revista Brasileira de Zootecnia**, v.36, n.5, p.1354-1358, 2007.

OLIVEIRA, N.T.E.; FONSECA, J.B.; SOARES, R.T.R.N.; FERREIRA, K.S.; THIÉBAUT, J.T.L. Pigmentação de gemas de ovos de codornas japonesas alimentadas com rações contendo colorífico. **Ciência e Agrotecnologia**, v.31, n.5, p.1525-1531, 2007.

OLIVEIRA, I.M.M.de. **Caracterização nutricional do bagaço de mandioca e sua utilização na alimentação de frangos de crescimento lento**. 2012. 73p. Dissertação (Mestrado em Ciência Animal Tropical) – Universidade Federal do Tocantins, Araguaína.

PELIZER, L.H.; PONTIER, M.H.; MORAIS, T.de O. Utilização de resíduos agro-industriais em processos biotecnológicos como perspectiva de redução do impacto ambiental. **Jornal Technology Managemente & Innovation**, v.1, n.1, p.118-124, 2007.

RODRIGUES, K.F.; BEZERRA, A.V.; SILVA, G.F.; SOUSA, J.P.L. de.; NETA, E.S.; VAZ, R.G. Utilização do resíduo da fabricação da fécula de mandioca na alimentação de frangos do tipo caipira – label rouge. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 45., 2008, Lavras, MG. **Anais...** Lavras, MG, 2008.

ROJAS, V.V.; CALLACNA, C.M.; ARNAIZ, P.V. Uso de un aditivo a base de cantaxantina y extracto de achiote em dietas de gallinas de postura y su efecto sobre la coloración de la yema y la vida de anaquel del huevo. **Scientia Agropecuaria**, v.6, n.3, p.191–199, 2015.

ROSTAGNO, H.S.; ALBINO, L.F.T.; DONZELE, J.L.; GOMES, P.C.; OLIVEIRA, R.F.; LOPES, D.C.; FERREIRA, A.S.; BARRETO, S.L.T.; EUCLIDES, R.F. **Tabelas brasileiras para aves e suínos:** composição de alimentos e exigências nutricionais. Viçosa, MG. UFV,.2011. 252p.

SAMPAIO, I.B.M. **Estatística aplicada à experimentação animal**. 2. ed. Belo Horizonte: FEPMVZ, 2002. 265p.

SAKOMURA, N.K.; ROSTAGNO, H.S. **Métodos de pesquisa em nutrição de monogástricos**. Jaboticabal: Funep. 283 p. 2007.

SILVA, J.H.V.; SILVA, E.L.; JORDÃO FILHO, J.; RIBEIRO, M.L.G. Efeitos da inclusão do resíduo da semente de urucum (*Bixa Orellana* L.) na dieta para frangos de corte: desempenho e características de carcaça. **Revista Brasileira de Zootecnia**, v.34, n.5, p.1606 - 1613, 2005.

SILVA, J.H.V.; SILVA, E.L.; FILHO, J.J.; RIBEIRO, M.L.G.; COSTA, F.G.P. Resíduo da semente de urucum (*Bixa orellana L.)* como corante da gema, pele, bico e ovário de poedeiras avaliado por dois métodos analíticos. **Ciência e Agrotecnologia***,* v.30, n.5, p.988-994, 2006.

SOUSA, J.P.; RODRIGUES, K.F.; ALBINO, L.F.T.; SANTOS NETA, E.R.; VAZ, R.G.M.V.; PARENTE, I.P.; SILVA, G.F.; AMORIM, A.F. Bagaço de mandioca em dietas de frangos de corte. **Revista Brasileira de Saúde e Produção Animal** [online], v.13, n.4, p.1044-1053, 2012.

SOUZA, K.M.R.; CARRIJO, A.S.; KIEFER, C.; FASCINA, V.B.; FALCO, A.L.; MANVAILER, G.V.; GARCIA, A.M.L. Farelo da raiz integral de mandioca em dietas de frangos de corte tipo caipira. **Archivos de zootecnia***,* v.60, n.231, p.490, 2011.

TAKAHASHI, A.A.; MENDES, E.S.P.B.; SALDANHA, C.C.; PIZZOLANTE, K.; PELÍCIA, R.G.; GARCIA, I.C.L.A.; PAZ, R.R. Efeito do sistema de criação sobre o desempenho e rendimento de carcaça de frangos de corte tipo colonial. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia,** v. 58, p. 624-632, 2006.

YASSIN, N.; MORAIS, A.R.de.; MUNIZ, J.A. Análise de variância em um experimento fatorial de dois fatores com tratamentos adicionais. **Ciência e Agrotecnologia,** v.26, p.1541-1547, 2002.

Receipt date: 12/09/2017
Approval date: 27/02/2018