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Pequi peel flour in diets for Japanese quail

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ABSTRACT. This study was carried out to evaluate the effects of pequi peel flour (PPF) in the diet of laying Japanese quails on their productive performance and on the quality and cost of the eggs produced. A total of 160 quail (*Coturnix coturnix japonica*) were distributed in a completely randomized design with four treatments and five replicates with eight birds each. Treatments consisted of different levels of PPF (0, 1, 2 and 3%) in a commercial diet based on sorghum. Evaluated parameters were productive performance (daily feed intake, laying rate, egg weight, egg mass and feed conversion rate), egg quality (yolk, albumen and eggshell weight and measures, yolk colour, ash and calcium content of eggshell, specific weight, Haugh unit, and nutrient content of the egg) and average cost of the production. PPF did not affect ($p > 0.05$) productive performance and nutritional composition, quality or average cost of the eggs; however, yolk colour was linearly increased ($p < 0.05$) with the PPF levels in the diets. It was concluded that PPF might be included in the commercial diets of Japanese quails up to 3% due to the improvement in yolk colour.

Keywords: alternative feed for quails, *Caryocar brasiliense* Camb., pequi by-product.

Farinha de casca de pequi em dietas para codornas japonesas

RESUMO. Este estudo foi realizado para avaliar os efeitos da farinha de casca de pequi (FCP) em dietas para codornas japonesas sobre o desempenho produtivo, a qualidade dos ovos e o custo dos ovos produzidos. Foram distribuídas 160 codornas (*Coturnix coturnix japônica*) em um delineamento inteiramente casualizado com quatro tratamentos e cinco repetições com oito aves cada. Os tratamentos consistiram de níveis de FCP (0, 1, 2 e 3%) em ração comercial à base de sorgo. Os parâmetros avaliados foram o desempenho produtivo (consumo de ração diário, taxa de postura, peso do ovo, massa de ovo e conversão alimentar), a qualidade do ovo (peso e medidas de gema, albúmen e casca dos ovos, cor da gema e teores de minerais e de cálcio da casca do ovo, peso específico, unidade Haugh e teor de nutrientes dos ovos) e o custo médio da produção. A FCP não afetou ($p > 0,05$) o desempenho produtivo, a composição nutricional, a qualidade e o custo médio dos ovos, entretanto, a cor da gema aumentou linearmente ($p < 0,05$) devido ao aumento dos níveis de FCP nas dietas. Concluiu-se que a FCP pode ser incluída nas dietas comerciais para codornas Japonesas até 3% por melhorar a cor da gema.

Palavras chave: alimento alternativo para codornas, *Caryocar brasiliense* Camb., subproduto do pequi.

Introduction

Interest not only nationally but also internationally in Brazilian Cerrado fruits has grown lately. Exploration of the Cerrado biome has occurred in an extractive form, and it is important that the use of its fruits be done in a more rational way (Soares Júnior et al., 2010).

Pequizeiro (*Caryocar brasiliense* Camb.) is a typical tree in Cerrado with a high commercial value (Werneck, 2011). Normally its peel is discarded during fruit processing (Siqueira, Soares Júnior, Fernandes, Caliari, & Damiani, 2013). Its fruit has antioxidant activity due the presence of vitamins A and E (Sena Jr. et al., 2010). There are some phenolic compounds in pequi that reduce the action of reactive oxygen species. According to Plácido et al. (2015), pequi peel has 204.37 mg g^{-1} expressed as galic acid equivalent (more than its pulp or internal mesocarp) and antioxidant activity of 4.89 EC_{50}.

The fruit peel, instead of being discarded, might be used in pequi peel flour production (PPF), which is rich in fibre, total carbohydrates and minerals such as Mg, Ca, Mn and Cu, but is poor in fats, Zn and Fe (Soares Júnior et al., 2009).

Yellow corn is the main energy source in rations for birds, but sometimes sorghum's cost is only about 70-80% of corn's cost. Sorghum may replace up to 100% of the corn with no negative effects on bird productive performance. However, the inclusion of a yolk pigment is recommended in sorghum-based rations (Moura, Fonseca, Rabello, Takata, & Oliveira, 2010).

Yolk colour is an important factor in consumers' acceptance of a product, and many companies use synthetically produced carotenoids to meet the high demands of the global market (Yaakob, Ali, Zainal, Mohamad, & Takriff, 2014). However, there are some alternatives for increasing the yolk colour, such as natural and synthetic pigment agents. Nevertheless, it is important to consider the economic and market aspects at the moment of choosing the source and level of pigment inclusion.

Data about the PPF inclusion in animal rations are scarce, and the few studies referred to the digestibility of PPF in goats (Geraseev et al., 2011) and in Nile tilapia (Pessoa et al., 2013). The cost of feeding represents the largest expense in an animal activity, and the pequi peel is intended for organic waste. However, it may be used for PPF production and added to animal rations, mainly for small egg producers, to reduce production costs and increase benefits. Hence this experiment was carried out to evaluate the effects of the inclusion of PPF in the diet of Japanese quails on productive performance, egg quality and production costs.

Materials and methods

Pequi peel flour production

Pequi peels were obtained from local pequi pulp sellers and were selected with consideration given to peels with an absence of injuries. They were immersed in a 200 ppm sodium hypochlorite solution for 30 minutes at room temperature. Then they were rinsed with running water five times. After that they were arranged in a sieve to drain excess water. Thereafter, the epicarp was removed by knife, and the external mesocarp was cut into pieces and placed in an air-forced oven at 65°C for 72 hours until completely dried. They were then ground. The PPF yield was 31.92%.

Experimental assay

A total of one hundred sixty Japanese quails (*Coturnix coturnix japonica*), 40 days old, were used for 84 days that were divided into three 28-days cycles. The quail were assigned in a completely randomized design to one of four treatments with five replicates of eight birds per replicate. Treatments consisted of the inclusion of PPF in a sorghum-based commercial ration at 0, 1, 2 and 3% levels, replacing the same percentage of the basal diet. The chemical composition, presented in Table 1, of the commercial rations containing different levels of PPF was assessed on a dry matter basis using Silva and Queiroz (2002) methodology. Gross energy was determined in an oxygen bomb calorimeter, also according to Silva and Queiroz (2002).

Water as well as mashed rations were provided *ad libitum* twice a day, when the eggs were counted and collected. A light programme was initiated when the quails reached 40 days of age. It initially provided 14 hours of light per day, with weekly increases of 30 minutes per day until reaching 17 hours of light per day, which was maintained until the end of the experiment.

Productive performance parameters evaluated were daily feed consumption, egg weight, laying rate, egg mass and the feed conversion ratio (kg kg^{-1} and kg $dozen^{-1}$ eggs). The daily counting and collection of eggs were performed at 8 and at 17 o'clock. During the last four days of the experimental period, 28 eggs per replicate were used for egg quality traits. Measurement of yolk colour was performed using 25 eggs as reported by Al-Saffar, Attia, Mahmoud, Zewell and Bovera (2013). Yolk colour was evaluated using a DSM® colorimetric fan that presents a value scale from 1 to 15.

Eggshell ash and calcium using three eggs per replicate were measured using the methodology of Silva and Queiroz (2002). The remaining eggs of each replicate were used for specific gravity analysis. Yolk and albumen height and diameter were measured with a manual tripped micrometre in order to calculate yolk and albumen indexes by dividing the height by the diameter of each component.

Table 1. Nutrient profile of commercial rations supplemented with different levels of pequi peel flour (PPF) on dry matter basis.

Parameters	PPF levels in commercial rations (%)			
	0.0	1.0	2.0	3.0
Dry matter (%)	91.70	91.90	91.70	91.90
Crude protein (%)	22.49	22.78	22.15	21.47
Ether extract (%)	2.22	2.25	2.27	2.37
Calcium (%)	4.45	4.51	4.53	4.34
Phosphorus (%)	0.63	0.65	0.73	0.70
Gross energy (kcal kg^{-1})	3724	3652	3679	3698

The eggshells were washed and air-dried to obtain the eggshell weight. Thereafter eggshell thicknesses were measured with a digital micrometre with a precision of 0.01 mm. Albumen weight was obtained by subtracting the yolk and eggshell weights from the egg weight. The Haugh unit was determined using the formula HU = 100 x log (H - 1.7 x $ew^{0.37}$ + 7.6), where *H* was the albumen height (mm) and *ew* was the egg weight (g). The specific gravity of the eggs was obtained by egg immersion in containers containing different saline solutions whose densities ranged from 1.050 to 1.100 with increments of 0.005.

The PPF and eggs were analysed for crude protein (CP), ether extract (EE) and moisture, and the PPF was also analysed for ash, crude fibre (CF), and gross energy (GE) according to the methods of Silva and Queiroz (2002). Determination of total carotenoids was according to Jacques, Pertuzatti, Barcia, Zambiazi and Chim (2010) using the formula C = absorbance x 50 mL x 10^6 / 2500 x 100 x g of each sample. Total carbohydrate content was estimated by difference, subtracting from 100 the sum of proteins, fat, ashes, moisture and crude fibre content.

The cost of the eggs for the inclusion of the PPF in the commercial rations for Japanese quail hens was performed by multiplying the feed conversion ratio (kg kg^{-1} or kg $dozen^{-1}$) by the price per kilo of the commercial rations (US$ 0.45).

Data were submitted to an analysis of variance, and when the F test was significant, a polynomial regression was applied. Both were at 5% probability using Sisvar 5.3 (Ferreira, 2010).

Results and discussion

The chemical composition of the PPF is presented in Table 2. Low moisture content in meals favours their conservation, durability and quality, reducing microbial growth and enzyme reactions (Aamir, Ovissipour, Sablani, & Rasco, 2013; Bonazzi & Dumoulin, 2011). The moisture content was within the legal limits in Brazil for meal used in animal feeding (Brasil, 1988), that is, up to 12%. The obtained value was similar to that found by Geraseev et al. (2011), 9.56%, and is different from the 10.32% determined by Pessoa et al. (2013).

CP content, 3.81%, was similar to that found by Oliveira, Guerra, Barros and Alves (2008) and by Geraseev et al. (2011), 3.83 and 4.92%, respectively. However, it was lower than the value reported by Pessoa et al. (2013) (4.78%) and higher than that reported by Siqueira et al. (2013) (2.65%).

Table 2. Chemical composition of pequi peel flour (PPF) on dry matter basis.

Parameter	Content
Moisture (%)	6.06
Crude protein (%)	3.81
Ether extract (%)	0.48
Total carbohydrates (%)	73.31
Crude fibre (%)	14.34
Ashes (%)	2.00
Gross energy (kcal kg^{-1})	3818
β-carotene (mg 100 g^{-1})	9.95

EE was 0.48%, lower than the values obtained by Oliveira et al. (2008) and Siqueira et al. (2013) of 1.31 and 1.32%, respectively. Epicarp was removed before the PPF production, and there are structures for mechanical defence of lipid origin in the cell wall, such as waxes and resins (Soares & Machado, 2007), which might increase the EE content if PPF is produced using also the epicarp.

Total carbohydrate content was lower than that determined by Oliveira et al. (2008), 91.03%, and the GE value was close to that described for rice bran (3740 kcal kg^{-1}) and wheat bran (3914 kcal kg^{-1}) (Rostagno et al., 2011).

Although PPF has a high CF content, its value was similar to that found by Pessoa et al. (2013), of 21.81%, but was very much lower than the 59.67% described by Siqueira et al. (2013), whose high value was due to the presence of epicarp in the PPF.

Ash content (2%) was close to that of Siqueira et al. (2013) of 2.09%. PPF might not be considered a mineral source for animals, since its mineral content is lower than that observed in other meals, such as wheat bran (4.70%) or rice bran (8.98%) (Rostagno et al., 2011).

PPF contained 9.95 mg 100 g^{-1} β-carotene. Its importance is more than just for its role as a pigment. Carotenoids are precursors of retinol (vitamin A); however, their main function seems to be as potent scavengers of other reactive oxygen species, reducing oxidative stress (Fiedor & Burda, 2014). According to Lima, Oliveira e Silva, Trindade, Torres and Mancini-Filho (2007), pequi is rich in fatty acids, β-carotene and vitamin A.

The differences in these results compared to those found in the literature may be related to the harvest season, locality and the fruit storage form as well as to the preparation techniques and methodology for PPF analysis.

There was no influence ($p > 0.05$) of the treatments on the productive performance of the Japanese quail hens, indicating that the PPF had no adverse effects on laying performance and may be used for feeding Japanese quail (Table 3).

Table 3. Productive performance of Japanese quails that were fed diets supplemented with pequi peel flour (PPF).

Parameters	PPF levels in commercial rations (%)				SEM	p value
	0.0	1.0	2.0	3.0		
Daily feed intake (g d^{-1})	32.12	32.66	31.52	30.64	0.84	0.4008
Laying rate (%)	92.41	96.21	90.17	92.70	3.01	0.3029
Egg mass (g $bird^{-1}$ d^{-1})	11.62	12.41	11.72	11.77	0.40	0.5244
Feed conversion (kg kg^{-1})	3.23	3.19	3.14	2.98	0.10	0.4144
Feed conversion (kg $dozen^{-1}$)	0.501	0.492	0.500	0.464	0.01	0.3348

Egg nutritional composition was not affected ($p > 0.05$) by PPF supplementation in the commercial diet of Japanese quail (Table 4), showing that this feedstuff may be fed to laying hens without effect on the nutritive value of the eggs.

Alternative feeds might contain anti-nutritional factors that interfere with nutrient bioavailability and might also be toxic. According to Siqueira et al. (2013), PPF did not show α-amylase inhibitors, but contains 1.5% trypsin inhibitor and 0.4% phytic acid in addition to tannins (14.51%). Enzyme inhibitors interfere with starch and protein digestion, phytic acid may act as mineral binders, and tannins have the ability to bind to proteins and other macromolecules, precipitating them and affecting mineral and vitamin utilization. Despite their presence, there was no effect on feed intake and nutrient utilisation by the quails. Possibly the intake of these anti-nutritional substances did not reach harmful levels.

PPF supplementation did not influence ($p > 0.05$) egg quality or the eggs' internal components, except for the yolk colour, which was linearly increased ($p < 0.05$) (Table 5), resulting in a linear effect equal to 0.13 points higher colour for each 1% of PPF level ($\hat{Y} = 3.08 + 0.13x$; $r^2 = 0.72$).

Corn is the main energetic ingredient in diets for birds, and its price rises in the off-season, so sorghum is generally used as a corn substitute. However, sorghum is low in pigments (Laganá, Pizzolante, Turco, Moraes, & Saldanha, 2012; Garcia et al., 2013), making necessary an artificial pigment inclusion in rations. Although the pigment content in PPF was not very high, it was sufficient to increase the yolk colour. However, even 3% supplementation level was not enough to reach values usually obtained with corn use. Moura et al. (2010), working with corn replacement by sorghum in quail diets, reported that the yolk colour linearly decreased as sorghum level increased in diets. According to the authors, yolk colour, determined by using the colorimetric fan, was 7.21, 6.52, 5.56, 3.88 and 1.48, respectively for 0, 25, 50, 75 and 100% corn replacement by sorghum.

Although there was no significant effect ($p > 0.05$) of the treatments, it was observed that PPF supplementation might reduce the cost of production of eggs per kilo and dozen by 7.58 and 7.55%, respectively. Table 6 shows the economic potential for the use of PPF in the diet of laying quails.

Table 4. Nutritive value of the eggs of Japanese quails that were fed diets supplemented with pequi peel four (PPF).

Parameters	PPF levels in commercial rations (%)				SEM	p value
	0.0	1.0	2.0	3.0		
Dry matter (%)	28.00	27.98	28.65	27.34	0.23	0.3214
Crude protein (%)	12.29	12.57	12.50	12.53	0.14	0.5373
Ether extract (%)	11.69	11.56	11.79	11.65	0.17	0.8393

Table 5. Egg quality of Japanese quails that were fed diets supplemented with pequi peel flour (PPF).

Parameters	PPF levels in commercial rations (%)				SEM	p value
	0.0	1.0	2.0	3.0		
Egg weight (g)	12.91	12.87	13.26	12.96	0.15	0.2826
Haugh unit	93.41	90.90	89.11	95.53	1.48	0.1672
Specific weight (g cm^{-3})	1.072	1.074	1.070	1.072	0.0007	0.3555
Yolk						
Weight (g)	4.28	4.29	4.26	4.07	0.22	0.8890
Percentage (%)	32.97	33.16	31.82	31.39	1.60	0.8320
Index	0.473	0.458	0.481	0.445	0.01	0.4961
Colour[1]	3.00	3.37	3.40	3.47	0.07	0.0062
Albumen						
Weight (g)	7.78	8.03	8.14	8.20	0.13	0.1904
Percentage (%)	59.55	60.28	60.81	61.45	1.02	0.1562
Index	0.130	0.122	0.116	0.150	0.01	0.1567
Eggshell						
Weight (g)	1.03	1.04	1.00	0.82	0.12	0.5797
Percentage (%)	8.05	8.07	7.66	8.11	0.27	0.6422

SEM = standard error of the mean. [1]Linear effect ($\hat{Y} = 3.08 + 0.13x$; $r^2 = 0.72$).

Table 6. Cost of a kilo and a dozen eggs produced by Japanese laying quails that were fed diets supplemented with pequi peel floor (PPF).

	PPF levels in commercial rations (%)			
Parameters	0.0	1.0	2.0	3.0
Cost of a kilo eggs (US$ kg^{-1})	1.45	1.43	1.41	1.34
Cost of a dozen eggs (US$ $dozen^{-1}$)	0.225	0.221	0.225	0.208

Conclusion

Pequi peel flour may be used in commercial diets for laying quails at up to a 3% level while maintaining bird productivity, improving yolk colour and reducing egg production costs.

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