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PASSION FRUIT SEED CAKE IN THE FEEDING OF MEAT QUAILS: EFFECTS ON PERFORMANCE, CARCASS CHARACTERISTICS, LIPID STABILITY OF THE MEAT, BEDDING QUALITY AND ECONOMIC VIABILITY.

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Abstract

The objective of this study was to determine the chemical composition and energetic value of passion fruit seed cake (PFSC) and to evaluate its inclusion in the ration of quails. In the metabolism assay, 108 quails of 21 days of age were used, being distributed in a completely randomized design with 3 treatments (one reference ration and two test rations with substitution of 20% and 40% of the reference ration by PFSC) and 6 replications of 6 birds each. It was observed that the apparent metabolizable energy corrected by the nitrogen balance (AMEn) determined in the ration with 20% PFSC (3,876.17 kcal/kg DM) was higher than in the 40% (3,469.00 kcal/kg DM). In the evaluation of the inclusion, 432 quails from 7 to 42 days of age were used, being distributed in a completely randomized design with 6 levels of inclusion of PFSC (0, 5, 10, 15, 20 and 25%), and 6 replications of 12 birds. It was observed that the inclusion of PFSC starting from 10% promoted worse FI and FC values, and increasing linear effect of these variables starting from 5% of inclusion. The PFSC did not affect the carcass characteristics and lipid oxidation of the meat. Regarding the bedding quality, there was a linear increase in the pH values and worse economic indexes starting from the inclusion of 10% of PFSC. In conclusion, PFSC can be used up to the level of 5% in diets for meat quails from 7 to 42 days of age.

Keywords: agroindustry by-products, birds, *Coturnix coturnix coturnix*, performance

Introduction

Quail farming has been inserting into industrial poultry production as a profitable activity and with good prospects for development, through the introduction and breeding of European quails (*Coturnix coturnix coturnix*), driven by the significant growth in consumer market demand for quail meat (PASTORE, et al., 2012; SILVA et al., 2018).

Among the factors that most influence the cost of quail production, the feeding represents more than 70% of the total cost. Thus, the use of by-products from the agroindustry in animal feeding can be an alternative to reduce the dependence on the main ingredients used and reduce costs.

The yellow passion fruit (*Passiflora edulis f. Flavicarpa*) stands out as one of the most popular tropical fruits and most important for the fruit processing agrobusiness. From the processing of passion fruit to obtain juice and pulp, approximately 60% of the fruit is disposed in the form of peels and seeds. The seeds represent about 12% of the total weight of the fruit and are sources of proteins, minerals, phenolic compounds with possible

antioxidant and antibiotic action, as well as a content of oil between 28 to 30% (MALACRIDA; JORGE, 2012; LÓPEZ-VARGAS et al., 2013).

The passion fruit seed cake is a product obtained from the oil extraction process of these seeds, and its protein content (14.4%) and concentration of phenolic compounds is higher than what is found in seeds, as well as a lipid content of around 5.17 to 5.61% (WILHELM et al., 2014; PERAR et al., 2017), presenting the potential to be used in poultry feeding, which makes it necessary to evaluate its use in the feeding of meat quails in order to find the optimal level of inclusion and its feasibility, since the research results available in the literature are scarce. This can be an alternative to add value to the oil extraction industry and avoid inappropriate disposal in the environment.

Thus, the objective of this study was to determine the energy value of the passion fruit seed cake and to evaluate the effect of its inclusion in diets for meat quails on the digestibility of the nutrients of the rations, performance, carcass characteristics, bedding quality, lipid stability of the meat and economic viability.

Material and Methods

The passion fruit seeds were purchased from a fruit pulp producing industry in the wet form and were subjected to washing in running water and manual action of friction movements on nylon mesh to assist in the removal of the aryl and mucilage. Then, they were exposed to the sun on plastic canvas for three days, being revolved three times a day. After drying, the seeds were stored in closed plastic bags at room temperature.

The tested passion fruit seed cake was obtained using the method of mechanical pressing of dry seeds, for oil removal, using a Scott Tech mechanical press, model ERT 40-V1, with power of 0.75 KW.

Proximate composition of test ingredients

In order to determine the chemical composition and metabolizable energy of the passion fruit seed cake, samples were sent to the Animal Nutrition Laboratory (LANA / DZ / CCA / UFC) for the determination of the contents of DM, N, EE, MM according to Silva and Queiroz (2002), neutral detergent fiber (NDF) and acid detergent fiber (FDA) according to the methodology of Van Soest *et al*. (1991) and gross energy through a calorimetric pump model IKA C 200. The determination of concentrations of the minerals calcium, phosphorus, potassium, sodium, magnesium, zinc, copper and iron in the samples of the passion fruit seed cake, was carried out in the Soils Laboratory of EMBRAPA Tropical Agroindustry in Fortaleza-CE, with samples prepared by digestion in a mixture of nitric acid (HNO_3) at 65% and perchloric acid ($HClO_4$) at 72%, in the proportion of 3:1, according to methodology described by Silva *et al*. (2009) and the concentration determined by optical emission

spectrophotometry with inductively coupled plasma (ICP-OES), using Perkin Elmer simultaneous spectrometer (Optima 4300DV).

In the metabolism assay with meat quails, 216 European quails of 21 days of age were used for a period of eight days, with four days for adaptation to the experimental conditions and four days for the collection of excreta, by the traditional method of total excreta collection. The birds were handled according to technical recommendations for the period from 1 to 20 days of age. At 21 days they were weighed and selected based on the initial average weight (0.130 kg ± 0.005), according to Sakomura and Rostagno (2007), to carry out the metabolism assay.

The birds were housed in batteries of metallic cages, distributed in a completely randomized design with 3 treatments and 6 replications of 12 birds per experimental unit. The treatments consisted of a reference diet based on corn and soybean meal (Table 1), considering the nutritional levels recommended by Silva and Costa (2009) and two test diets, which had 20 and 40% of the reference diet (RD) substituted by the passion fruit seed cake (PFSC).

Table 1 - Proximate composition and calculated nutritional levels of the reference diet

Ingredients	%
Corn	53.88
Soybean meal	40.92
Soybean oil	2.17
Calcitic limestone	1.22
Dicalcium phosphate	0.88
Common salt	0.36
Mineral and vitamin supplement[1]	0.20
DL – methionine	0.24
Choline chloride	0.05
L- lysine	0.04
Anticoccidial	0.05
Nutritional and energetic calculated composition	
Metabolizable energy (kcal/kg)	2,950
Crude protein (%)	23.00
Potassium (%)	0.23
Calcium (%)	0.75
Available phosphorus (%)	0.29
Sodium (%)	0.16
Chlorine (%)	0.26
Digestible lysine (%)	1.17
Digestible methionine (%)	0.54
Digestible methionine + cystine (%)	0.85
Digestible threonine (%)	0.78
Digestible tryptophan (%)	0.26
Digestible valine	0.96

[1]Composition per kg of product: Iron – 50.00 g; Copper – 12.00 g; Manganese – 60.00 g; Zinc – 50.00 g; Iodine – 1,000.00 mg; Selenium – 400.00 mg; Vit. A – 20,000,000.00 IU; Vit. D3 – 5,000,000.00 IU; Vit. E – 100,000.00 IU; Vit. K3 – 6,000.00 mg; Vit. B1 – 7,000.00 mg; Vit. B2 – 15.00 g; Niacin – 80.00 g; Pantothenic acid – 30.00 g; Vit. B6 – 8,000.00 mg; Folic acid – 4,000.00 mg; Biotin – 200.00 mg; Vit. B12 – 36,000.00 mg.

Throughout the whole experimental period, water and feed were provided at will, with feeders being filled up twice a day in order to avoid waste. A program with 24 hours of daily light (natural + artificial) was adopted, using fluorescent lamps of 40 watts, in order to stimulate feed consumption.

At the beginning and at the end of the collection period, the rations were weighed to quantify the consumption. For the collection of excreta, individualized aluminum trays were used under the cages by experimental portion, lined with plastic aiming to prevent loss and oxidation of the excreta samples.

The excreta destined for collection were identified with the addition of 1% of ferric oxide in the diets, as a marker to signal the beginning and the end of the collections. Two daily collections of excreta were carried out, in the early morning and late afternoon. Subsequently, they were packed in plastic bags, identified by replication, weighed and frozen in a freezer at 20 ºC until the end of the experimental period.

For the analysis of the excreta samples, the material was thawed at room temperature and homogenized individually for the removal of a sample. The pre-drying was carried out in a forced ventilation oven at 55 °C, for 72 hours. After drying, the samples were ground in a knife-type mill, with a 16 mesh with 1mm sieve for further analysis.

The excreta and experimental rations samples were sent to the Animal Nutrition Laboratory (LANA / DZ / CCA / UFC) for the determination of dry matter and nitrogen, based on the methodology described by Silva and Queiroz (2002). The gross energy was determined in a calorimetric pump model IKA C 200. For the calculations of AMEn and DMMC, NMC and GEMC, laboratory data were used applying them to the equations proposed by Matterson et al. (1965).

Experimental animals and management

As for the performance assay, 432 European quails were used, from 7 to 42 days of age, housed in a conventional masonry shed with dimensions of 9.5 m of width and 9 m of length, distributed in 36 boxes with dimensions of 0.60 x 0.60 m, containing tubular-type feeder and pressure cup-type drinker.

In the first week of age, from 1 to 7 days, the quails were housed in a protection circle, containing tray-type feeders, pressure cup-type drinkers and hoods used as a heat source, to keep the birds warm. All birds received feed and water at will. At seven days of age, they were selected by the mean body weight of the consignment, 37.5 g ± 0.42 g, and distributed in the plots according to Sakomura and Rostagno (2007) recommendations. A completely randomized design was used with 6 treatments, consisting of a reference diet and five others with increasing levels of inclusion of the passion fruit seed cake (5%, 10%, 15%, 20% and 25%), with 6 replications of

12 birds per experimental unit. The experimental diets (Table 2) were formulated to be iso-nutritive and iso-caloric, according to the requirements proposed by Silva and Costa (2009).

The chemical composition values of the feed indicated by Rostagno et al. (2017) were considered, except for the passion fruit seed cake, which was considered the apparent metabolizable energy value corrected by the nitrogen balance with levels of 20% of substitution with the passion fruit seed cake obtained in the previous experiment and values of chemical-bromatological and mineral composition (Table 2), based on the methodology described by Silva et al. (2009). The concentrations of minerals, calcium, potassium, sodium, magnesium, zinc, copper and iron, were determined by optical emission spectrophotometry with inductively coupled plasma (ICP-OES), using Perkin Elmer simultaneous spectrometer (Optima 4300DV).

Table 2 - Composition and nutritional levels of the experimental diets for meat quails

Ingredients	Price (U$)	Levels of inclusion of passion fruit seed cake					
		0%	5%	10%	15%	20%	25%
Corn	0.31	53.87	50.23	46.59	42.94	39.30	35.65
Soybean meal	0.52	40.92	39.77	38.61	37.47	36.32	35.16
Passion fruit seed cake	0.14	0.00	5.00	10.00	15.00	20.00	25.00
Soybean oil	0.74	2.17	1.95	1.73	1.51	1.28	1.07
Calcitic limestone	0.05	1.22	1.22	1.23	1.23	1.24	1.24
Dicalcium phosphate	0.98	0.88	0.87	0.86	0.85	0.84	0.84
Salt	0.16	0.36	0.36	0.36	0.36	0.36	0.37
DL – methionine	4.94	0.24	0.24	0.25	0.25	0.25	0.25
L – lysine	2.97	0.04	0.06	0.07	0.09	0.11	0.12
Mineral supplement[1]	1.81	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin supplement[2]	4.06	0.15	0.15	0.15	0.15	0.15	0.15
Anticoccidial	5.84	0.05	0.05	0.05	0.05	0.05	0.05
Choline chloride	5.31	0.05	0.05	0.05	0.05	0.05	0.05
Total		100.00	100.00	100.00	100.00	100.00	100.00
Cost (U$/kg)		0.34	0.34	0.33	0.32	0.32	0.31
Calculated Nutritional and Energetic Composition							
Metabolizable energy (kcal/kg)		2,950	2,950	2,950	2,950	2,950	2,950
Crude protein (%)		23.00	23.00	23.00	23.00	23.00	23.00
Calcium (%)		0.75	0.75	0.75	0.75	0.75	0.75
Available phosphorus (%)		0.29	0.29	0.29	0.29	0.29	0.29
Sodium (%)		0.16	0.16	0.16	0.16	0.16	0.16
Chlorine (%)		0.26	0.26	0.26	0.26	0.25	0.25
Digestible lysine (%)		1.17	1.14	1.12	1.10	1.07	1.05
Digestible methionine (%)		0.54	0.53	0.52	0.51	0.50	0.50
Digestible methionine + cystine (%)		0.85	0.83	0.81	0.79	0.77	0.75
Potassium (%)		0.23	0.21	0.20	0.19	0.18	0.16
Digestible threonine (%)		0.78	0.75	0.72	0.69	0.66	0.64
Digestible tryptophan (%)		0.26	0.25	0.24	0.23	0.23	0.22
Digestible valine (%)		0.96	0.93	0.89	0.86	0.82	0.79

[1]Composition per Kg of product: Vit. A – 9,000,000.00 IU; Vit. D3 – 2,500,000.00 IU; Vit. E – 20,000.00 mg; Vit. K3 – 2,500.00 mg; Vit. B1 – 2,000.00 mg; Vit. B2 – 6,000.00 mg; Vit. B12 – 15.00 mg; Niacin – 35,000.00 mg; Pantothenic acid – 12,000.00 mg; Vit. B6 – 8,000.00 mg; Folic acid – 1,500.00 mg; Selenium – 250.00 mg; Biotin – 100.00 mg; [2]Composition per Kg of product: Iron – 100,000.00 mg; Copper – 20.00 g; Manganese – 130,000.00 mg; Zinc – 130,000.10 mg; Iodine – 2,000.00 mg.

A program of 24 hours of daily light (natural + artificial) was adopted throughout the whole experimental period. Fluorescent lamps of 40 watts were used, distributed at a height of 2.4 m from the floor, so that all birds received light evenly. The temperature and air relative humidity inside the shed were measured daily throughout the experimental period by three thermo hygrometers distributed in the main spots of the shed, with readings being performed twice a day (8 am and 4 pm). The averages of minimum and maximum room temperature, and the air relative humidity recorded inside the shed during the experimental period in the performance assay were 28.0 ºC, 32 ºC and 63%, respectively. The nutrient digestibility and the metabolizable energy of the rations were evaluated, as well as the productive performance, carcass characteristics, lipid stability of the meat, quality of the bedding and the economic viability.

Metabolism of the feed nutrients

In order to evaluate the effect of the inclusion of the passion fruit seed cake on the metabolism of the feed nutrients, the method of total excreta collection was carried out, from 21 to 28 days of age, with three days of adaptation and four days of collection. At 21 days of age, six birds from each experimental plot were housed in batteries of metal cages, following the same experimental design, with aluminum trays lined with plastic, individualized by experimental plot. At the beginning and at the end of the excreta collection period, the birds received a diet containing 1% ferric oxide, to signal the beginning and end of the collections.

Excreta collections were performed twice a day, in the early morning at 8 am and in the late afternoon at 4 pm. At the end of each collection, the excreta were packed in plastic bags, duly identified by replication and frozen until the end of the experimental period to determine the excreta produced. The excreta were then thawed at room temperature, weighed and homogenized to proceed to pre-drying, in a forced ventilation oven at 55 °C, for 72 hours. Then, the samples were ground in a knife mill, with a 16 mash of 1mm sieves, and sent with samples of the experimental rations, to the LANA of the DZ / CCA / UFC for the determination of dry matter, ash, and nitrogen, following the methodology described by Silva and Queiroz (2002). The gross energy was determined in an adiabatic calorimetric pump model IKA C 200.

Performance evaluation

For performance evaluation, birds and rations were weighed at the beginning of the experiment (7 days of age) and at the end of the experimental period (42 days of age), to obtain feed intake (g/bird), weight gain (g/bird)

and feed conversion. Feed intake was obtained by the difference in the amount of feed provided at the beginning of the experiment and the amount of leftover at the end of the experimental period for each plot. Weight gain was calculated by the mean weight difference of the plot at 7 and 42 days of age. Feed conversion was obtained by the ratio of feed intake divided by the weight gain of each plot. In the end, the variables were corrected for mortality.

Carcass evaluation

For carcass evaluation, at 42 days of age and after a 6-hour prior fast, a male and a female from each experimental unit were selected according to the average weight of the plot, desensitized and slaughtered by bleeding, scalded, plucked and eviscerated. Then, the head, neck and feet were removed and the hot carcass weighed to determine the carcass yield using the weight of the fasting bird. Subsequently, cuts were made, parts were separated and it was carried out weighing of the entire breast, drumstick + thigh, abdominal fat, liver and gizzard to calculate the cuts yield.

The yield of breast, drumstick + thigh and abdominal fat were calculated in relation to the weight of the hot carcass. The relative weight of the liver and gizzard was obtained in relation to the weight of the organs by the weight of the fasting bird.

After weighing, the drumsticks + thighs and back of the two birds were ground, divided into two subsamples, identified, frozen in liquid nitrogen at -80 °C and kept refrigerated (-18 °C), until the moment of lipid oxidation analysis, one with one day of storage and the other with 60 days of storage.

Lipid stability evaluation

The evaluation of lipid stability occurred after the period of storage of the samples, determining the concentration of substances reactive to thiobarbituric acid (TBARS). The calibration curve and sample preparation for determining the lipid oxidation of the meat (TBARS) were performed using the aqueous acid extraction method, based on the technique described by Kang et al., (2001). In a 15 mL tube, approximately 2 g of sample were weighed and homogenized with 6.75 ml of perchloric acid (3.86%) and 18.75 µL of BHT (4.5%). Then, 18 mL of perchloric acid (3.86%) were added and the contents homogenized in a Terrutec shredder (Tecnal, Piracicaba, SP) for 15 seconds at high speed. The homogenate was filtered and 0.75mL of this solution was transferred to test tubes with 0.75mL of 2-thiobarbituric acid (20 mM). The tubes were heated in a boiling water bath for 30 minutes. After cooling to room temperature, the spectrophotometer was read at 531nm. The blank used was prepared with 0.75mL of perchloric acid and 0.75mL of the TBA solution. The number of TBARS in the sample was expressed as µg of malonaldehyde per g of the sample.

Quality of the bedding evaluation

At the end of the experimental period, the quality of the bedding was also assessed, with the determination of pH, humidity, temperature and ammonia concentration in the litter. The temperature of the bedding was monitored with a surface thermometer in three different spots of each experimental unit, avoiding areas below the feeders and drinkers, and being carried out at 4 pm on the last day of the experiment. To evaluate the pH and humidity of the bedding, a litter sample from each experimental unit was prepared, obtained from the collection of three subsamples taken from three different spots within each plot on the last day of the experiment, also avoiding the areas near and under feeders and drinkers. Subsequently, the samples were homogenized and hermetically packed. To determine the pH, 30g of macerated sample in a beaker was used, followed by the addition of 250ml of deionized water, proceeding to stir this sample for five minutes. Then, the sample was left to rest for 30 minutes before reading on the pH meter. To determine the moisture content, the methodology proposed by Silva and Queiroz (2002) was used. The concentration of volatilized ammonia was determined according to the adaptation of the methodology proposed by Oliveira et al. (2004). In a plastic container with a lid, 100 g of poultry litter was placed and a universal collection cup was placed on this sample, with capacity of 50 ml, containing 10 ml of boric acid (2%) to capture the volatilized ammonia inside the container. After adding the sample and the universal collection cup, the plastic container was capped and sealed with adhesive tape. The litter samples were kept in the container for 24 hours. Subsequently, the boric acid was titrated with 0.05N sulfuric acid and the amount of volatilized ammonia was determined using the equation: $A = V\ x\ N\ x\ (17\ /\ P)$, with A being the amount of volatilized ammonia (mg/g); V, the volume of sulfuric acid used in the titration (ml); N, the normality of sulfuric acid; 17 the molecular weight of ammonia and P, the weight of the litter sample (g).

Economic analysis

To determine the economic viability of the inclusion of passion fruit seed cake in the rations, the cost of the ration was determined based on the prices of the ingredients in the city of Fortaleza - CE in the experimental period. The cost of the feed per kilogram of body weight gain was calculated according to the equation proposed by Bellaver *et al*. (1985), considering Yi = (Qi × Pi) / Gi, where Yi = amount spent on feed per kilogram of body weight in the i^{th} treatment; Pi = price of kilogram of the feed used in the i^{th} treatment; Qi = amount of feed consumed in the i^{th} treatment and Gi = weight gain in the i^{th} treatment. The economic efficiency index (EEI) and the cost index (CI) proposed by Fialho et al. (1992) were calculated as: EEI = (MCei / CTei) × 100 and CI = (CTei / MCei) × 100, where MCei = lowest feed cost per kilogram of gain, observed among treatments and CTei = cost of treatment *i* considered.

Statistical analysis

The statistical analysis of the data was performed using the Statistical Analysis System (SAS). The data of apparent metabolizable energy corrected of the passion fruit seed cake were subjected to analysis of variance and F test (5%). The data of digestibility of feed nutrients, performance, carcass parameters, bedding quality and economic viability were subjected to analysis of variance and the means were compared by the Dunnett test (5%). The lipid stability data were subjected to analysis of variance, following a completely randomized model in a 6x2 factorial scheme (six levels of inclusion of the tested feed and two storage times) and the means were compared by the SNK test (5%). All variables were submitted to regression analysis to determine the best level of inclusion of the passion fruit seed cake, considering only the data referring to the treatments that included the tested feed, excluding the control treatment.

Results

Chemical and energetic composition of passion fruit seed cake

The results of chemical, energetic and mineral composition of the passion fruit seed cake (PFSC), expressed on as-fed basis (Table 3).

Table 3 - Chemical, energetic and mineral composition of passion fruit seed cake, expressed on as-fed basis

Parameters	Passion fruit seed cake
Dry matter (%)	93.20
Crude energy (kcal/kg)	5,233.00
Crude protein (%)	13.56
Ether extract (%)	5.04
Neutral detergent fiber (%)	62.86
Acid detergent fiber (%)	53.36
Mineral matter	1.32
Calcium (%)	0.06
Phosphorus (%)	0.33
Potassium (g/kg)	0.33
Sodium (g/kg)	0.03

[1]Analyses performed in the Animal Nutrition Laboratory of DZ/UFC and Soils Laboratory of Embrapa.

Metabolizable energy of the passion fruit seed cake

In the determination of the metabolizable energy, it was observed that there was a difference between the values of apparent metabolizable energy corrected by the nitrogen balance (AMEn) of the passion fruit seed cake determined with the levels of 20 and 40%, in which a higher value of AMEn was obtained with the level of 20% of substitution (Table 4).

Table 4 - Average values of corrected apparent metabolizable energy (AMEn) of passion fruit seed cake determined using meat quails, expressed on dry matter basis

Levels of inclusion	AMEn (kcal/kg DM)
20%	3,876.17a
40%	3,469.00b
Mean	3,672.58
Coefficient of variation (%)	3.03
Analysis of variance *(p*-value*)*	0.0005

253

254 **Metabolizability coefficients and metabolizable energy values of the diets**

255 According to the results of the metabolism assay carried out during the performance assay (Table 5), it was
256 observed that the diets containing 15, 20 and 25% of inclusion of the passion fruit seed cake showed lower values
257 of metabolizability coefficients of the dry matter (DMMC), gross energy (GEMC), apparent metabolizable energy
258 (AME) and apparent metabolizable energies corrected by the nitrogen balance on dry matter basis (AMEn), in
259 comparison to the control diet, with no significant effect, except for the nitrogen metabolizability coefficient
260 (NMC).

261 In the regression analysis, it was found that there was a linear decreasing effect starting from the level of
262 inclusion of 5% of passion fruit seed cake on all variables, except for the NMC which was not significantly
263 different.

Table 5 – Metabolizability coefficients and metabolizable energy values of the diets for meat quails containing passion fruit seed cake

Level of Inclusion (%)	GEMC (%)	DMMC (%)	NMC (%)	AME (kcal/kgDM)	AMEn (kcal/kgDM)	AMEn (kcal/kgAF)
0	87.57	86.37	70.42	3,644	3,418	3,0800
5	87.24	85.24	70.51	3,6488	3,4085	3,0883
10	85.79	83.80*	70.60	3,5951	3,3673	3,0770
15	83.56*	82.26*	70.69	3,5056*	3,2618*	2,9623*
20	81.37*	79.99*	69.64	3,4696*	3,2333*	2,9566*
25	80.23*	78.82*	69.42	3,4610*	3,2417*	2,9391*
Mean	84.2	82.64	70.21	3,5514	3,319	3,0200
CV[6] (%)	1.79	1.84	3.31	1.79	1.74	1.74
ANOVA[7]				*p*-value		
Level	<0.0001	<0.0001	0.8895	<0.0001	<0.0001	<0.0001
Regression						
Linear	<0.0001[1]	<0.0001[2]	0.2826	<0.0001[3]	<0.0001[4]	<0.0001[5]
Quadratic	0.7833	0.9423	0.6121	0.1576	0.0619	0.2767

[1]GEMC (Y = 89.1766 – 0.3689X, R^2 = 0.7627), [2] DMMC (Y = 87.0168 – 0.3327X, R^2 = 0.7220),[3]AME (Y = 3.6864 – 0.010X, R^2 = 0.5534), [4]AMEn DM (Y = 3.4418 – 0.0092X, R^2 = 0.5298), [5]AMEn AF (Y = 3.1307-0.0083X, R^2 = 0.5301[1]). CV= [6]Coefficient of variation; [7]ANOVA= Analysis of variance. *Significant statistical effect by the Dunnett test (P<0.05).

Growth performance of meat quails

For the performance variables (Table 6), when comparing the control treatment with those that included the passion fruit seed cake, it was observed that there was no significant difference on weight gain, however, there was a significant difference on feed intake and feed conversion. According to the results, the inclusion of passion fruit seed cake in a level of 10% promoted a significant increase in feed intake, with a corresponding worsening in the feed conversion. In the regression analysis, it was observed that the inclusion of passion fruit cake, starting with 5%, influenced linearly, causing the increase in consumption (Y = 878.80 + 6.43X, R^2 = 0.43) and worsening the feed conversion (Y = 3.91 + 0.03X, R2 = 0.55).

Table 6 - Performance of meat quails fed diets containing passion fruit seed cake from 7 to 42 days of age

Level of inclusion (%)	Feed intake (g/bird)	Weight gain (g/bird)	Feed conversion (g/g)
0	837.40	225.20	3.72
5	892.00	221.83	4.03
10	956.00*	224.17	4.27*
15	981.33*	223.83	4.38*
20	1,032.67*	229.17	4.51*
25	1,014.50*	221.82	4.66*
Mean	955.60	223.69	4.28
CV[1] (%)	5.34	4.53	4.76
Analysis of variance		*p*-value	
Level	<0.0001	0.9832	<0.0001
Regression			
Linear	<0.0001[2]	0.8643	<0.0001[3]
Quadratic	0.0985	0.2003	0.6187

*Statistically different when compared to the control treatment by the Dunnett test (P<0.05). [1]Coefficient of variation [2]Feed intake (Y = 878.80 + 6.43X, R^2= 0.43) and [3]Feed conversion (Y = 3.91 + 0.03X, R^2 = 0.55).

Carcass yield, cuts and percentage of organs of meat quails

In the evaluation of the carcass characteristics (Table 7), it was found that carcass yield, proportion of breast, drumstick + thigh, abdominal fat, gizzard and liver did not differ between birds fed the diets containing passion fruit seed cake and those of the control group. There was also no significant effect in the regression analysis for carcass characteristics.

Table 7 - Carcass yield, cuts and percentage of organs of meat quails fed diets containing passion fruit seed cake from 7 to 42 days of age

Level of Inclusion (%)	Final Weight	Carcass (%)	Breast (%)	Drumstick + thigh (%)	Abdominal Fat (%)	Gizzard (%)	Liver (%)
0	257.20	78.18	41.90	22.38	1.09	1.93	2.04
5	254.00	74.53	42.56	22.49	1.31	2.05	1.88
10	251.50	74.81	42.92	22.74	0.92	1.88	1.89
15	256.17	76.39	40.67	23.15	0.92	2.05	2.12
20	254.00	75.59	43.14	23.58	1.05	1.95	2.02
25	251.50	76.34	40.67	22.92	1.06	1.84	1.92
Mean	254.49	75.91	42.02	22.89	1.06	1.95	1.97
CV[1] (%)	5.11	3.30	5.47	4.55	32.96	7.63	17.53
ANOVA[2]				*p*-value			
Level	0.98	0.2151	0.3159	0.4179	0.4296	0.1056	0.8052
Regression							
Linear	0.8371	0.1582	0.3399	0.2362	0.4257	0.0949	0.6205
Quadratic	0.9676	0.6909	0.8967	0.2828	0.0815	0.5856	0.2377

[1]Coefficient of variation; [2]Analysis of Variance

Lipid stability of the meat of the quails fed the passion fruit seed cake

In the evaluation of the lipid stability of the meat of the quails fed the passion fruit seed cake, through the determination of the value of substances reactive to 2-thiobarbituric acid (TBARS), it was observed that there was no significant interaction between the tested levels of inclusion and meat storage times (Table 8). There was also no significant difference (P>0.05) between the different levels of inclusion of the passion fruit seed cake and the control treatment. However, it was observed that the mean value of TBARS in the meat stored for 60 days was significantly higher than the one determined in the meat stored for 1 day.

Table 8 - Lipid oxidation of meat (breast, drumstick and thigh) of meat quails fed diets containing passion fruit seed cake

Factor	TBARS (mg/kg of malonaldehyde)
Level of Inclusion (%)	
0	2.25
5	2.31
10	2.26
15	2.31
20	2.37
25	2.01
Time (Days)	
0	1.71[b]
60	2.75[a]
Mean	2.23
Coefficient of Variation (%)	18.75
Analysis of variance	*p*-value
Level	0.4039
Storage time	<0.0001
Level x Storage time	0.4410
Regression	
Linear	0.4013
Quadratic	0.5726

Non-significant statistical effect by the SNK test (P>0.05).

290

291 **Quality parameters of the bedding of meat quails**

292 In evaluating the quality of the bedding was observed that none of the variables is influenced by different
293 levels of passion fruit seed cake used in relation to the control treatment (Table 9). However, a linear increase (Y
294 = 7.73 + 0.04X, R^2 = 0.16) was observed in pH values from 5% of the inclusion of the passion fruit seed cake.

295

Table 9 - Quality parameters of the bedding of meat quails fed diets containing passion fruit seed cake

Level of Inclusion (%)	Moisture (%)	pH	Volatilized Ammonia (mg/g)	Temperature (°C)
0	12.17	8.64	0.33	32.16
5	12.32	7.98	0.24	31.79
10	12.03	7.97	0.29	31.98
15	12.66	8.42	0.31	31.92
20	12.69	8.51	0.22	32.09
25	12.49	8.65	0.22	32.43
Mean	12.40	8.35	0.27	32.06
CV[1] (%)	13.26	7.72	33.54	3.23
Analysis of variance			*p*-value	
Level	0.9772	0.2646	0.2145	0.9264
Regression				
Linear	0.6451	0.0308	0.2259	0.2819
Quadratic	0.8712	0.9486	0.1923	0.7314

Non-significant statistical effect by the Dunnett test (P>0.05). [1]Coefficient of variation.

296 **Economic evaluation of the inclusion of passion fruit seed cake**

297 Regarding the economic viability (Table 10), there was a significant difference between treatments in the
298 cost of feed, economic efficiency index (EEI) and in the cost index (CI). The inclusion of the passion fruit seed
299 cake starting from 10% promoted increase in the costs with feeding, worse CI and worse EEI, when compared to
300 the control treatment. However, based on the regression analysis, there was no significant effect of adding the cake
301 in levels above 5%, for the analyzed variables.

302

Table 10 - Economic evaluation of the inclusion of passion fruit seed cake in the feeding of meat quails

Level of Inclusion (%)	Cost with feeding (U$/kg weight gain)	Economic efficiency index (%)	Cost index (%)
0	1.28	100.00	100.00
5	1.35	95.12	105.48
10	1.40*	92.02*	108.93*
15	1.40*	91.79*	108.99*
20	1.41*	91.79*	108.97*
25	1.43*	91.62*	109.53*
Mean	1.38	93.55	107.19
CV[1](%)	4.74	4.71	4.76
ANOVA		*p*-value	

Level	0.0010	0.0003	0.0010
Regression			
Linear	0.2098	0.2847	0.2103
Quadratic	0.4718	0.3981	0.4720

[1]Coefficient of variation; [2]Analysis of variance.

Discussion

Studies conducted to date on the effect of the passion fruit seed cake (PFSC), indicate that the processing of the seed to extract the oil reduces the ether extract and increases the crude protein. The results obtained are slightly different from those found by Perar *et al.* (2017), which were 14.74% of crude protein and 9.89% of ether extract in the passion fruit seed cake used.

In general, the composition of the cake obtained from different oilseeds varies due to the same factors that influenced the composition of the seed, adding to this the type of processing for oil extraction. The differences found in the composition of the passion fruit are linked to the characteristics of the soil type of the region, the different forms of cultivation and fertilization, which is an important factor in the quality of the passion fruit and can result in variations in the composition of the fruit and seeds (MENDONÇA *et al*., 2006).

The decrease in AME values as the level of substitution increased can be associated with the negative effects of increasing the fiber content in the feed, since the passion fruit seed has mostly the presence of insoluble fiber (CHAU; HUANG, 2004). For Arruda and Fernandes *et al*. (2014), the increase in fiber content can reduce the digestibility of nutrients, by increasing the rate of passage of the feed through the gastrointestinal tract, making it difficult for digestible enzymes to access.

The AMEn values determined for passion fruit seed cake for meat quails were higher than those found in passion fruit seeds by Fachinello *et al*. (2016), who estimated AME and AMEn values of 2,976 and 2,939 kcal/kg, respectively. However, these differences are justified by the variation in the composition of the passion fruit seed, mainly in energy and fiber content. However, the value determined with the level of 20% of substitution is close to the value determined by Zanetti *et al*., (2017) for broilers, which was 3,945.41 kcal/kg.

Due to these results, it is possible to recommend the value of 3,876 AMEn/kg of DM of the passion fruit seed cake for formulations of the meat quails diets, since the results for the AME values obtained with the substitution of the reference diet by the tested feed in 20% has been recommended for fibrous feeds, using the total excreta collection of (SAKOMURA; ROSTAGNO, 2007).

The decrease of the values of metabolization coefficients and metabolizable energy of the rations as the inclusion of the passion fruit seed cake occurred can be associated with the negative effects of the increase in

the fiber content in the ration on the digestibility of nutrients. For Chau and Huang (2004), the fibrous fraction of the passion fruit seed is made up mostly of insoluble fiber (98.9%), with the soluble fraction represented by 1.13%. Feeds with high content of insoluble fiber can cause shorter time of exposure of the digesta to the digestion processes, since its presence in high concentrations tends to increase the rate of passage of the digesta, resulting in reduced availability of dietary nutrients (KHAJALI; SLOMINSKR, 2012) and, consequently, in the metabolizable energy.

Among other effects expected with the inclusion of fiber in the diets, it is the dilution of energy concentration and the interaction with the use of other nutrients due to the increase in the speed of the digestive transit. The fibrous fraction of the feed negatively influences the its metabolizable energy (ARRUDA; FERNANDES, 2014). That explain the results found, when the levels of inclusion of the passion fruit seed cake were raised to 15, 20 and 25% and there was a loss caused in the AMEn.

As reported in the results of the metabolism assay, there was a reduction in the metabolizable energy of the diets with the increasing inclusion of the passion fruit seed cake in the diet. Thus, considering that the voluntary feed intake by the birds is regulated, mainly by the amount of energy in the feed destined to the metabolic processes of the organism, the increase in feed intake is a way for the bird to meet its nutritional requirements. As the increase in feed intake did not express a corresponding response in the weight gain of the birds, the worse feed conversion was an expected result.

Although, the increasing inclusion of passion fruit seed cake resulted in the reduction of the AMEn of the rations, there was the possibility that there would be significant effects on the deposition of muscles and fat in the carcass, as occurred a change in the relationship between energy and the amino acids in the diets. However, the results indicated that the reduction of the AMEn of the diets was not enough to cause a significant effect on the carcass characteristics of the meat quails, as the birds fed the diets containing the passion fruit seed cake increased feed intake ensuring the consumption of nutrients.

For Zeraik *et al*., (2010), passion fruit seeds have phenolic compounds with antioxidant activity, whereas Wilhelm *et al*. (2014), state that the concentration of these compounds in the passion fruit seed cake would be higher than in the seeds, and another important point would be the reduction of fatty acids in the cake when compared to the seeds. Therefore, it was expected that the inclusion of the passion fruit seed cake would reduce the lipid peroxidation of the meat. However, up to tested levels of inclusion it was not possible to observe this effect.

In studies with passion fruit seeds, Zanetti *et al*. (2017), also observed the effect on the lipid oxidation of chicken meat (drumstick) and found that there was no effect of interaction between the levels of inclusion of the passion fruit seeds, observing effect only between the storage times, when the level of inclusion of 5% presented lower values of lipid oxidation of the meat when compared to the control treatment at 60 days of storage.

For bedding quality results, the change in pH may be due to microbial degradation in the nitrogen substrate under humidity condition (CARVALHO et al., 2011), however this process results in an increase in ammonia volatilization, which was not observed in this study. Thus, the change in the pH of the bedding, as the inclusion of the passion fruit seed cake increased, may be associated with the high fiber content present in the passion fruit seed cake, represented mainly by insoluble fibers. The high content of insoluble fiber in the diet can cause increase in the rate of passage of the digesta, providing a shorter exposure time to the digestion and absorption processes, causing reduction in the use of nutrients (KHAJALI; SLOMINSKR, 2012) and, consequently, more excretion of undigested nutrients, changing the composition and pH of the poultry litter. According to Traldi *et al*. (2007), pH values above 7.0 usually stimulate bacterial proliferation in the bedding and increased ammonia volatilization. However, the change in pH did not represent a loss of quality, with no effect on the other parameters.

According to the results, it is possible to include up to 5% of passion fruit seed cake, obtaining economic viability similar to the control group.

The worsening of the results for the economic viability variables may be associated with the increase in consumption as the passion fruit seed cake was added to the rations, because, even with the reduction in the cost of the kg of ration as the level of inclusion increased, this effect did not outweigh the increase in cost with higher feed intake to maintain weight gain. Thus, considering that the cake is a by-product of the use of passion fruit seed to launch a product with a high market value, which is the passion fruit oil, the inclusion of cake in levels above 5% may become viable depending on price, which must be lower than the ones used for calculating the economic viability in the present study.

On the basis of the obtained results, it can be concluded that the inclusion of the passion fruit seed cake in diets for meat quails from 7 to 42 days of age, increases feed intake and worsens feed conversion. However, it does not alter the carcass characteristics, the lipid stability of the meat and presents economic viability for its inclusion up to the level of 5%.

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Code availability

Not applicable.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Tiago Freitas Silva], [Otoniel Félix de Souza], [Marcelle Craveiro Abreu de Melo], [Paula Joyce Delmiro de Oliveira Lima] and [Edibergue Oliveira dos Santos]. The first draft of the manuscript was written by [Tiago Freitas Silva] and [Rafael Carlos Nepomuceno], review and editing [Thalles Ribeiro Gomes], supervision [Ednardo Rodrigues Freitas] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest Statement

Author declares there is no conflict of interest of any form on the journal article.

Declarations

Ethics approval

That experiments were conducted in a manner that avoided unnecessary discomfort to the animals by use of proper management and laboratory techniques and the experimental procedures were approved by the Ethics Committee on the Use of Animals - CEUA / UFC under protocol No. 8752160418, according to the ethical principles adopted by the Brazilian Council for the Control of Animal Experimentation.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

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