Revista Ciência Agronômica, v. 52, n. 4, e20207591, 2021
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Passion Fruit Peel in Growing Rabbits Feed[1]

Casca do maracujá na alimentação de coelhos em crescimento

Thalles Ribeiro Gomes[2]*, Ednardo Rodrigues Freitas[2], Pedro Henrique Watanabe[2], Ana Carolina Sampaio Ferreira[2], Leila Maria de Sousa Tavares[2]

ABSTRACT - The use of alternative foods for rabbits aims to reduce production costs, due to their ability to extracting nutrients from non-conventional feeds. Thus, passion fruit peel (PFP) appears as a potential use in feeding rabbits. This study aimed to determine the chemical and energetic composition of PFP and evaluate the effects of inclusion for growing rabbits. For the digestibility trial, 24 rabbits were distributed between two treatments (reference ration and test ration, composed of 70% reference ration and 30% PFP) with 12 replications of one animal per plot. For the performance trial, 120 rabbits were distributed within a randomized block design, in a 5x2 factorial arrangement, with 5 levels of inclusion of PFP (0, 8, 16, 24, 32%) and 2 sexes (male and female) corresponding to a total of 10 treatments with 12 replications each. PFP had 10.99% CP, 6.25% EE, 47.40% ADF, 54.66% NDF and 4,156.50 kcal DE/kg, on a dry matter. The inclusion of PFP did not influence the final weight and weight gain of rabbits, however it was observed that rabbits fed at the level of 32% inclusion of PFP consumed less amount of feed, with no negative effect on performance. Decreased cholesterol and triglyceride levels were observed in relation to control and an increase of creatinine in rabbit's blood. As there was an improvement in the economic parameters without affecting the performance and carcass characteristics, it's recommended to include this ingredient up to level of 32% in the feed for growing rabbits.

Key words: Agroindustry byproduct. Cholesterol. *Oryctolagus cuniculus. Passiflora edulis.* Performance.

RESUMO - A utilização de alimentos alternativos para coelhos visa reduzir os custos de produção, devido sua habilidade em aproveitar os nutrientes de alimentos não-convencionais. Desse modo, a casca do maracujá (CM) surge como potencial de utilização na alimentação de coelhos. Objetivou-se determinar a composição química e energética da CM e avaliar os efeitos da inclusão para coelhos em crescimento. No ensaio de digestibilidade foram utilizados 24 coelhos distribuídos entre dois tratamentos (ração referência e ração teste, composta por 70% de ração referência e 30% de CM) com 12 repetições de um animal por parcela. No ensaio de desempenho foram utilizados 120 coelhos, distribuídos em delineamento de blocos ao acaso, em arranjo fatorial 5x2, sendo 5 níveis de inclusão de CM (0, 8, 16, 24, 32%) e 2 sexos (machos e fêmeas) correspondendo ao total de 10 tratamentos com 12 repetições cada. A CM apresentou 10,99% PB, 6,25% EE, 47,40% FDA, 54,66% FDN e 4.156,50 kcal de ED/kg de matéria seca. A inclusão da CM não influenciou o peso final e o ganho de peso dos coelhos, no entanto observou-se que os coelhos alimentados ao nível de 32% de inclusão consumiram menor quantidade de ração, sem efeito negativo sobre o desempenho. Observou-se diminuição dos níveis de colesterol e triglicerídeos em relação ao controle e um aumento da creatinina no sangue dos coelhos. Como houve melhora nos parâmetros econômicos sem prejudicar o desempenho e características de carcaça, recomenda-se a inclusão deste ingrediente até o nível de 32% em rações para coelhos em crescimento.

Palavras-chave: Colesterol. Desempenho. *Oryctolagus cuniculus. Passiflora edulis.* Resíduo da agroindústria.

DOI: 10.5935/1806-6690.20210051
Editor-in-Chief: Profa. Andrea Pereira Pinto - deiapp@hotmail.com
*Author for correspondence
Received for publication 31/08/2020; approved on 09/03/2021
[1]This article is part of the Research Project of the first author submitted to the National Post-Doctoral Program (PNPD/CAPES) of the Postgraduate Program in Animal Science at the Federal University of Ceará
[2]Departamento de Zootecnia, Centro de Ciências Agrárias/CCA, Universidade Federal do Ceará/UFC, Fortaleza-CE, Brasil, thalleszoo@yahoo.com.br (ORCID ID 0000-0002-7890-7783), ednardo@ufc.br (ORCID ID 0000-0001-7226-9517), pedrowatanabe@ufc.br (ORCID ID 0000-0002-1010-2305), carolinaanasampaio@yahoo.com.br (ORCID ID 0000-0001-5075-4845), tavaresleila287@gmail.com (ORCID ID 0000-0003-1867-3580)

INTRODUCTION

Yellow passion fruit (*Passiflora edulis f. flavicarpa.*), is considered one of the most important fruits for the processing agroindustry in Brazil, and it is the variety of greatest commercial interest, for presenting high productivity, fruit quality, high pulp yield and resistance or tolerance to diseases and pests (DIAS *et al*., 2017; MELETTI, 2011).

It is mainly commercialized in the form of juice or pulp, with peel and seeds being the main residues, represent about 70% of the total weight of the fruit (COELHO; CENCI; RESENDE, 2011). Currently, about 90% of passion fruit peel and seeds from the juice and pulp industries are wasted.

The passion fruit peel is composed of the flavedo (epicarp), which corresponds to the outer layer, presenting colors that vary from green to yellow, and it is rich in insoluble fibers (cellulose, hemicellulose and lignin), and the albedo (mesocarp), which corresponds to the white inner layer, and it is rich in soluble fiber, especially pectin, with small amounts of hemicelluloses, gums and mucilage (SILVA *et al*., 2016). The components of the passion fruit peel were studied by Cruz *et al*. (2011), who reported 59.00% of neutral detergent fiber, 49.20% of acid detergent fiber and a considerable amount of protein (13.40%), ether extract (2.50%), and minerals (9.90%) such as potassium, iron, sodium, phosphorus and calcium on the dry matter basis.

The nutritional quality of this residue and its low acquisition costs, makes it interesting to be used in the feeding of rabbits, as the use of agro-industrial residues of fruit for them aims to reduce production costs, due to their ability of these animals to convert them into meat of high biological value for human consumption (MELO, 2011). However, there is little information about the use of passion fruit peel in rabbit feeding, which justifies the evaluation of the real potential of this ingredient, in order to verify the appropriate level and the feasibility of its use.

Thus, the aim of the present study was to determine the nutritional and energetic value of the passion fruit peel (PFP) and to evaluate the impact of including this ingredient in the feeding of growing rabbits on performance, carcass traits and economic evaluation.

MATERIAL AND METHODS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

The experimental procedures followed the protocols approved by the Ethics Committee on the Use of Animals (CEUA 19/2017) of the Federal University of Ceará (UFC).

The passion fruit residue (peels) was purchased from a fruit pulp processing industry in the moist form and was exposed to the sun on plastic canvases for four days, being revolved three times a day. After drying, the peels were stored in closed plastic bags, at room temperature, for later use in digestibility and performance trials, when they were then crushed in a hammer mill equipped with a 3-mm mesh sieve, to ease the incorporation of the product into the feed.

In order to evaluate the nutritional composition and digestible energy of the passion fruit peel, a digestibility trial was carried out at the UFC Cuniculture Sector, using 24 crossbred rabbits (New Zealand White × Californian) – 12 males and 12 females, at an average age of 50 days and initial average weight of 900 ± 159 g. The animals were housed individually in galvanized wire cages, provided with nylon screens at the bottom of the cages, for total collection of feces, following the distribution of a completely randomized design, consisting of two treatments with 12 replications of one animal per plot, totaling 24 experimental units. The treatments tested were two rations: a reference ration (RR), composed mainly of corn, soybean meal, alfalfa hay, tifton hay and wheat meal, formulated to meet the nutritional requirements of growing rabbits, according to the recommendations of De Blas and Wiseman (2010); and a test ration (TR), composed of 70% of the reference ration and 30% of passion fruit peel. Both the reference and test rations were pelleted (Table 1).

The digestibility trial lasted 11 days, of which seven days were for adaptation of the animals to the facilities and diets, and four days for the collection of feces, with rations and water were provided at will throughout the experimental period.

The feces of each animal were collected in the morning, once a day, weighed and packed in plastic bags and then stored in a freezer at -10 °C. At the end of the experiment, the samples were thawed, homogenized and placed in a forced ventilation oven (55 °C) for 72 hours, for further laboratory analyses. The samples of pre-dried feces, and the samples of feed and passion fruit peel were sent to the Animal Nutrition Laboratory of UFC, where they were subjected to analyses to determine the dry matter, mineral matter, crude protein, ether extract, neutral detergent fiber, and acid detergent fiber contents according to the methodology described by AOAC International (2005) and the gross energy (GE) that was determined in a calorimeter "IKA C200".

From the data obtained in the analyses, the chemical-bromatological composition of the passion fruit peel was determined and the digestibility coefficients of dry matter, protein, ether extract and digestible fibers were calculated using the equations of Matterson *et al.* (1965), as well as the digestible energy, using the equation of Villamide (1996).

Table 1 - Ingredients and chemical composition of control diet

Ingredients	(%)
Ground corn	21.65
Soybean meal	11.59
Wheat bran	24.00
Alfalfa hay	22.08
Tifton hay	17.00
Soybean oil	1.13
Dicalcium phosphate	0.34
Calcitic limestone	0.98
Common salt	0.50
Mineral/vitamin supplement[(1)]	0.30
L-lysine HCl	0.26
DL-methionine	0.17
Total	100.00
Calculated composition[(2)]	
Digestible energy (kcal/kg)	2650.00
Crude protein (%)	16.00
Acid detergent fiber (%)	16.50
Neutral detergent fiber (%)	29.79
Starch (%)	21.96
Calcium (%)	0.60
Total phosphorus (%)	0.40
Met+Cis (%)	0.52
Total lysine (%)	0.70

[(1)] Vitamin-mineral supplement, composition per kilogram of product: vit A: 5,500,000 IU; vit D: 1,000,000 IU; vit E: 6,500 IU; vit K3: 1,250 mg; vit B1: 500 mg; vit B2: 2,502 mg, vit B6: 750 mg; vit B12: 7,500 mcg; biotin: 25 mg; niacin: 17.5 g; pantothenic acid: 6.030 mg; folic acid: 251 mg; choline: 35,000 mg; iron: 25 g; copper, 3,000 mg; cobalt: 50 mg; manganese: 32.5 g; zinc: 22.49 g; iodine: 32 mg; selenium: 100.05 mg. [(2)]Based on the chemical composition values of the raw materials from the diets

For the performance trial, we used 120 rabbits female California X male New Zealand White hybrids, 6 weeks old, 60 males and 60 females, with two rabbits of the same sex per cage as an experimental unit.

It was adopted a randomized block design with a 2x5 factorial arrangement, with 2 sexes (male and female) and 5 levels of inclusion of passion fruit peel (0%, 8%, 16%, 24% and 32%), totaling 10 treatments with 12 replications each. The experimental period lasted from 45 to 90 days of age.

The initial weight of the light block was established at 0.545 ± 0.039 kg for females and 0.584 ± 0.034 kg for males and the heavy block at 0.708 ± 0.057 kg for females and 0.724 ± 0.058 kg for males.

The experimental rations (Table 2) were formulated based on corn, soybean meal, wheat meal, tifton hay and alfalfa hay, in order to meet the nutritional requirements of growing rabbits, according to the recommendations of De Blas and Wiseman (2010), differing in the level of inclusion of passion fruit peel, and were pelleted.

The chemical composition and digestible energy values of the passion fruit peel considered were those determined in the digestibility trial and the amino acid composition of the passion fruit peel was obtained through analysis of high performance liquid chromatography (HPLC), which presented the values of 0.239% for lysine, 0.192% for methionine, 0.167% for cystine, 0.359% for methionine + cystine and 0.253% for threonine, on the dry matter basis.

The animals were housed in suspended galvanized wire cages, equipped with automatic nipple drinkers and semi-automatic galvanized plate feeders, installed in an open brick shed, provided with the side protection screens, 7.60 m wide, ceiling height of 3 m and covering clay tiles.

The rations and water were provided at will and the leftovers of the experimental rations were weighed daily to assess the animals' performance in terms of daily feed intake, daily weight gain and feed conversion.

At the end of the experimental period, at 90 days of age and after a 12-hour prior fast, all animals were weighed, desensitized and slaughtered by cutting the jugular vein, then blood samples were collected from one animal of each replication. Two blood samples were collected in identified tubes, one with ethylenediamine tetra-acetic acid (EDTA) to perform the analysis of triglycerides (TG), and the other in tubes without EDTA to perform the analysis of total cholesterol. The samples in tubes without EDTA were centrifuged at 1,500 G for 10 minutes, to obtain the supernatant (serum or plasma), with each sample divided into two 2-ml tubes so that each aliquot could be conditioned and later used in the respective determinations. The blood parameters samples of total cholesterol, creatinine, triglycerides and GOT/GPT (glutamic-oxaloacetic transaminase / glutamic-pyruvic transaminase) were processed by the Clinical Pathology Laboratory of the Veterinary College of the State University of Ceará and carried out through enzymatic-colorimetric process using commercial Labtest kits, and a Bio-2000 spectrophotometer.

Subsequently, the head, tail, paws, and skin were removed, then it was performed a complete evisceration, cleaning and weighing of the hot carcass to obtain the hot carcass yield. After that, the edible viscera, the gastrointestinal tract, cecum and visceral fat were weighed and their relative weights determined in relation to the slaughter weight and carcass weight, respectively.

Table 2 - Composition and nutritional levels of the experimental diets for growing rabbits

Ingredients (kg)	Passion fruit peel inclusion level (%)				
	0%	8%	16%	24%	32%
Ground corn	30.25	31.70	32.82	33.50	32.90
Alfafa hay	27.95	19.98	12.87	6.21	0.00
Soybean meal (45%)	12.10	13.37	14.64	15.91	17.19
Tifton hay	12.51	9.98	6.69	3.08	0.47
Wheat bran	14.00	14.00	14.00	14.00	14.00
Passion fruit peel	0.00	8.00	16.00	24.00	32.00
Soybean oil	2.00	1.63	1.50	1.50	1.50
Calcitic limestone	0.15	0.28	0.38	0.60	0.49
Dicalcium phosphate	0.22	0.23	0.25	0.27	0.56
Common salt	0.50	0.49	0.49	0.56	0.56
Mineral/vitamin supplement(1)	0.25	0.25	0.25	0.25	0.25
L-lysineHCl	0.08	0.08	0.11	0.11	0.08
TOTAL	100.00	100.00	100.00	100.00	100.00
Calculated nutritional and energy composition(2)					
Digestible energy (kcal/kg)	2650.00	2650.00	2650.00	2650.00	2650.00
Crude protein (%)	16.00	16.00	16.00	16.00	16.40
Neutral detergent fiber (%)	40.21	38.68	35.09	34.92	34.77
Acid detergent fiber (%)	20.40	20.00	20.49	20.14	20.33
Ether extract (%)	3.59	2.17	0.71	0.71	0.67
Total lysine (%)	0.80	0.80	0.80	0.80	0.82
Total methionine + cystine (%)	0.52	0.52	0.52	0.52	0.54
Calcium (%)	0.60	0.60	0.60	0.60	0.65
Total phosphorus (%)	0.40	0.40	0.40	0.42	0.45
Sodium (%)	0.22	0.22	0.22	0.22	0.22

(1) Vitamin-mineral supplement - Composition per kg of product: vit A: 5,500,000 IU; vit D: 1,000,000 IU; vit E: 6,500 IU; vit K3: 1,250 mg; vit B1: 500 mg; vit B2: 2,502 mg, vit B6: 750 mg; vit B12: 7,500 mcg; biotin: 25 mg; niacin: 17.5 g; pantothenic acid: 6.030 mg; folic acid: 251 mg; choline: 35,000 mg; iron: 25 g; copper, 3,000 mg; cobalt: 50 mg; manganese: 32.5 g; zinc: 22.49 g; iodine: 32 mg; selenium: 100.05 mg. (2) Based on the chemical composition values of the raw materials from the diets

The caecal pH measure was performed using a digital electrode pH-meter, which was introduced directly into the caecal content, right after weighing.

The hind legs were weighed, dissected and the right leg used to obtain the meat / bone ratio according to the equation $M/BR = \frac{MW}{BW}$, where M/BR is the meat / bone ratio, MW is the weight of the meat (g) and BW is the weight of the bones (g) (RAO *et al*., 1978).

In order to evaluate the economic viability of including passion fruit peel in the rations, the cost of the ration was determined based on the prices of the ingredients in the city of Fortaleza - CE during the experimental period. The feeding cost (U$F) was determined from the total consumption of ration by the animals and the cost of the ration in the respective period. The average ration cost per kilogram of live weight (U$FLW) was calculated as a function of the daily consumption and weight gain and the cost of the ration. From the average ration cost per live weight, the economic efficiency index (EEI) and the average cost of ration consumed index (CI) were calculated, according to Fialho *et al*. (1992) using the equations: $EEI = (LCei / CTei) \times 100$ and $CI = (CTei / LCei) \times 100$, where: LCei = lowest ration cost per kilogram of gain observed between treatments; CTei = cost of treatment i considered.

The data were submitted to analysis of variance, and the means were compared to the treatment without passion fruit peel (0%) by the Dunnett test, at 5% of probability using the Statiscal Analysis System software (SAS University Edition). The means, except for those of the treatment without passion fruit peel (0%), were submitted to regression analysis up to the third degree.

RESULTS AND DISCUSSION

The chemical composition analysis results of the passion fruit peel (Table 3), indicated that this residue after the drying process in the sun presented dry matter values similar to those found by Cruz *et al.* (2011), who evaluated the chemical composition of dehydrated passion fruit peel, and found a dry matter content of 85.00%. The moisture content is related to its stability, quality and composition. According to Córdova *et al*. (2005), high moisture contents in the passion fruit peel imply the need for drying for a better preservation of the product, since high moisture contents favor the proliferation of microorganisms and can compromise its quality.

The crude protein content found was lower than the one reported by Lousada Júnior *et al.* (2006) and Cruz *et al.* (2011), who evaluated the use of passion fruit peel for ruminants, and found values of 12.36% and 13.40%, respectively. Also, Souza, Ferreira and Vieira (2008), reported a crude protein content in passion fruit peel flour of 12.52%. On the other hand, Córdova *et al*. (2005) and Cazarin *et al*. (2014), found much lower values: 1.50% and 3.94%, respectively.

Regarding the ether extract content, the value found was higher than the ones reported by Córdova *et al*. (2005), Souza, Ferreira and Vieira (2008), and Cruz *et al*. (2011), which were 0.80%, 1.75%, and 2.90%, respectively.

The mineral matter content in the passion fruit peel corroborates the one found by Cazarin *et al*. (2014), who evaluated the chemical composition of the passion fruit peel flour, and observed an ash content of 6.88%. However, it was lower than the ones found by Córdova *et al*. (2005), 8.68%; Cruz *et al*. (2011), 9.90% and Souza, Ferreira and Vieira (2008), 8.66%.

Regarding the acid detergent soluble fibers, the value found was slightly below the one obtained by Cruz *et al*. (2011), 49.20%; and greater than the one reported by Souza, Ferreira and Vieira (2008), 41.67%. As for the neutral detergent soluble fibers, the result was similar to the one found by Rezende and Groff (2015), which varied from 42.05 to 54.27%, while Cruz *et al*. (2011) found a higher content, which was 59.00%.

However, the digestibility trial showed that the amounts of nutrients and energy present in the dry matter of the passion fruit peel are not fully utilized by rabbits, since the high levels of NDF can result in a lower intake of dry matter, mainly due to the feeling of satiety, and through the reduction of gastric emptying and intestinal transit by the viscous gels formed in the stomach by the pectin present in the passion fruit peel which compromises the digestibility of the energy, as the gel formed increases the viscosity of the digesta and, upon reaching the intestine, it blocks the absorption of fat from food and glucose, contributing to less enzymatic action and digestion of nutrients.

The coefficient value found for the apparent digestibility of the crude protein of the passion fruit peel (79.60), shows that the increase in the fiber content in the ration does not raise the amount of protein required and no significant relationship was observed between protein digestibility and fiber content. Similar crude protein digestibility data from fruit peels were obtained by Prastiya *et al.* (2019), who tested the skin of the dragon fruit and obtained a variation of 73.88 to 76.30% in the protein digestibility.

Variations in the values of chemical composition of the residues generated by agro-industries are acceptable, as they depend mainly on the fruit's maturation stage, considering that ripening leads to moisture loss, which causes the concentration of the other constituents, in addition to other factors such as soil, climate, the species of the cultivars and the processing methods to which the products are submitted (LOUSADA JÚNIOR *et al*., 2006).

Table 3 - Nutritional and energetic composition of passion fruit peel for growing rabbits

Nutrients and energy	Passion fruit peel	Digestibility coefficient (%)	Digestible nutrients and digestible energy
Dry matter (%)	89.20	60.58	54.04
Crude protein (%)	10.99	79.60	8.75
Ether extract (%)	6.25	77.65	4.85
Mineral matter (%)	5.95	42.02	2.50
ADF (%)	47.40	24.86	11.78
NDF (%)	54.66	41.43	22.65
Gross energy (kcal/kg)	4,156.50	53.96	2,242.97

*Values expressed on the dry matter basis of the food. ADF: acid detergent fiber; NDF: neutral detergent fiber

Although the digestibility coefficients of nutrients and energy varied between 24.86 and 79.60%, the values of nutrients and digestible energy are similar to those of other products that have been used in the feeding of rabbits, such as alfalfa hay and citrus pulp (RETORE *et al.*, 2010), therefore, that shows that the passion fruit peel has the potential to be used in the feeding of rabbits.

According to the results (Table 4), there was no significant effect of the interaction between the levels of inclusion of passion fruit peel and sex on the performance variables assessed.

The use of increasing levels of passion fruit peel did not significantly influence the final weight and weight gain of the rabbits from 45 to 90 days of age, however when comparing the results obtained with the different levels of inclusion of the passion fruit peel to the control ration, it was observed that rabbits fed the level of 32% of inclusion of PFP consumed less ration, with no negative effect on weight gain nor on the final weight.

In the regression analysis, there was a linear improvement of feed conversion ($Y = 3.375 - 0.0225X$; $R^2 = 0.85$) as the inclusion of passion fruit peel increased.

Considering that the voluntary ration consumption is regulated mainly by the energy density of the diet and that the rations were formulated to be iso-nutritive and iso-caloric, the physical effect of gastric distension appears as the most likely hypothesis for reduced consumption, since the presence of higher levels of pectin in the ration with 32% of PFP, causes a delay in the gastric emptying and intestinal transit due to the water retention capacity and formation of viscous gels (MARIA *et al.*, 2013), referring to the nerve responses of neurotransmitters located in the gastric and intestinal mucosa, which stimulate the vagus nerve, sending satiety information to the brain (FÉLIX *et al.*, 2010 *quoted in* ZANATTA *et al.*, 2016).

Although the increase in soluble fiber in the ration keeps the digestive tract full for a longer time, it also allows a greater use of nutrients due to this longer retention time, favoring fermentative activity and consequently a better use of the soluble fraction of the cell wall (RETORE *et al.*, 2010).

The carcass characteristics, relative organ weight, visceral fat and caecal pH (Table 5) were not significantly affected by the interaction between the levels of inclusion of passion fruit peel and sex, as well as no significant

Table 4 - Performance of growing rabbits fed different levels of passion fruit peel

Inclusion level (%)	Parameters			
	Final weight (kg)	Feed intake (g/day)	Body weight gain (g/day)	Feed conversion
0	2.10	86.11	26.03	3.37
8	2.00	81.30	22.71	3.63
16	2.09	85.07	25.30	3.39
24	2.11	79.08	25.98	3.09
32	2.06	75.33*	24.26	3.13
Sex				
Male	2.07	81.22	24.09	3.43
Female	2.08	81.54	25.61	3.21
Mean	2.07	81.38	24.85	3.32
CV[1]	9.39	7.41	14.28	12.02
ANOVA[2]	*P*-value			
Level	0.7306	0.0116	0.3272	0.0854
Sex	0.8354	0.8693	0.1911	0.0892
Level x Sex	0.8376	0.0526	0.4837	0.9649
Regression for level				
Linear	0.4464	0.0748	0.3176	0.0102
Quadratic	0.3044	0.1992	0.0662	0.3321

[1]CV: coefficient of variation; [2]ANOVA: analysis of variance; *Differs from control (0%) by Dunnett test ($P<0.05$)

effect was found in the comparison of the treatments that had the inclusion of passion fruit peel with the treatment without the ingredient. However, an effect of the inclusion of the passion fruit peel was observed on the sex of the animals, regarding the greater relative weight of the gastrointestinal tract and the higher percentage of visceral fat deposition in females when compared to males. These effects inherent to sexual dimorphism corroborate with Gomes *et al*. (2018), who stated that abdominal fat deposits tend to be larger in female rabbits in comparison to males.

According to the regression analysis, except for the control treatment, the carcass yield (Y = 55.01 - 0.1003X; R^2 = 0.65), decreased linearly with the inclusion of passion fruit peel in the rations. This result may be due to the greater relative weight of the cecum (Y = 4.34 + 0.0492X; R^2 = 0.93), which increased linearly with the inclusion of passion fruit peel, because of the greater occupation of the gastrointestinal tract, corroborating the results obtained by Gomes *et al*. (2018), who found a reduction in the carcass yield of rabbits with more fibrous diets, suggesting an effect on the transit speed of the digesta and a longer retention time for fermentative activity, although no difference in yield was observed between the treatments with inclusion of the ingredient in comparison to the treatment without it.

As for the deposition of visceral fat in the rabbits, there was a quadratic effect ($Y = 1.829 + 0.1503X - 0.0038X^2$; R^2 = 0.91), where the maximum estimated value for this variable occurred at the level of 20% of inclusion, indicating that, up to this level, rabbits deposit a higher percentage of abdominal fat in the carcass due to the greater weight gain, and it decreases after that, but also not showing any significant difference in comparison to the control ration.

Regarding the blood parameters evaluated (Table 6), it was observed that there was no significant effect of the interaction between the levels of inclusion of passion fruit peel and sex.

According to the regression analysis, the increased inclusion of passion fruit peel in the diets provides a linear reduction of total cholesterol (Y = 126.25 - 1.777X; R^2 = 0.95).

The reduction of cholesterol with the inclusion of passion fruit peel corroborates the results obtained by Grosseli *et al*. (2014), in which rabbits with experimental hypercholesterolemia that were treated

Table 5 - Carcass traits and relative weight of liver, kidneys, heart, visceral fat, gastrointestinal tract, cecum and cecal Ph of growing rabbits fed different levels of passion fruit peel

Inclusion level (%)	Parameters[1]								
	CY (%)	M/B	Liver (%)	Kidneys (%)	Heart (%)	VF (%)	GIT (%)	Cecum (%)	Ph Cecum
0	53.41	5.93	2.23	0.56	0.25	2.92	13.58	5.59	6.80
8	53.58	5.90	2.17	0.56	0.29	2.75	13.18	4.86	6.88
16	53.99	5.53	2.09	0.59	0.28	3.37	13.09	4.99	6.77
24	53.33	5.92	1.98	0.55	0.26	3.17	13.98	5.42	6.73
32	51.12	6.13	1.97	0.62	0.27	2.82	14.62	6.03	6.79
Sex									
Male	52.99	5.65	2.06	0.57	0.26	2.75 b	12.73 b	4.97 b	6.77
Female	53.18	6.11	2.12	0.58	0.28	3.27 a	14.65 a	5.79 a	6.81
Mean	53.09	5.88	2.09	0.58	0.27	3.01	13.69	5.38	6.79
CV[2]	4.60	14.84	11.08	11.06	16.33	14.88	12.29	18.05	2.27
ANOVA[3]					*P*-value				
Level	0.1895	0.738	0.1399	0.1896	0.5945	0.0652	0.3751	0.1509	0.4551
Sex	0.8022	0.114	0.4982	0.6253	0.2648	0.0016	0.0018	0.0151	0.3177
Level x Sex	0.9421	0.601	0.5756	0.1417	0.9695	0.2897	0.8362	0.9545	0.4597
Regression for level									
Linear	0.0424	0.4365	0.0831	0.2610	0.3581	0.9809	0.1156	0.0275	0.2790
Quadratic	0.1237	0.3510	0.6945	0.6228	0.5884	0.0261	0.6227	0.5248	0.1809

[1]CY: Carcass yield; M/B: Meat/bone ratio; VF: Visceral fat; GIT: gastrointestinal tract; [2]CV: coefficient of variation; [3]ANOVA: Analysis of variance. Means followed by different letters in the column are significantly different (P<0.05) by F. *Differs from control (0%) by Dunnett test (P<0.05)

with passion fruit peel in the proportion of 10g/kg, showed a reduction of 75% (168 to 93mg / dL) of the total cholesterol levels. This effect was associated with the presence of pectin in the passion fruit peel.

There was a decrease in serum cholesterol as compared to control with the inclusion of 32% of passion fruit peel, which may be associated with higher concentrations of pectin in the feed, which would act by reducing the absorption of bile acids, due to the bonding of those with the soluble fibers in the intestinal lumen, forming micelles and causing a decrease in reabsorption, which is the possible mechanism through which dietary fibers reduce serum lipid levels (GIROTTO *et al.*, 2017; RETORE *et al*., 2010).

Other authors also reported the hypocholesterolemia potential of pectin in animals (SILVA *et al*., 2011).

As for creatinine, a linear increase was observed in the blood of rabbits ($Y = 1.31 + 0.0134X$; $R^2 = 0.82$) as the inclusion of passion fruit peels increased. Creatinine is a product of creatine and phosphocreatine degradation in the muscle, and it is generally produced at a virtually constant rate by animals, this rate being directly proportional to muscle mass gain (BEZERRA *et al*., 2016), that is, the greater the meat / bone ratio, the higher this rate. It is also used to assess renal function, which in this study was not compromised by the use of passion fruit peel.

When compared by the Dunnett's test (5%), the 32% inclusion level of PFP showed a result for serum creatinine levels significantly higher than those obtained with the control group. This result may be directly linked to the fact that rabbits fed the highest level of PFP have shown a tendency to increase in the M / B ratio, since this parameter is related to the volume of body mass.

Regarding triglycerides, there was a decrease in serum levels with the inclusion of passion fruit peel in comparison to the control, which can be explained by the fact that triacylglycerols are emulsified and then hydrolyzed by lipolytic enzymes to later be absorbed in the intestinal lumen and with the bonding with the fibers present in the peel, there may have been a decrease in this absorption (GIROTTO *et al*., 2017), as previously reported.

The serum levels of GOT and GPT were not affected by the consumption of ration containing passion fruit peel, remaining below the range described by Spinelli *et al.* (2012) for the species (GOT: 46.81±15 U/L for males; 56.80±17.09 U/L for females) and (GPT: 48.56 ± 8.32 U/L for males; 41.00 ± 16.91 U/L for females), confirming the absence of possible liver or muscle damage. Toledo *et al*.

Table 6 - Blood parameters of growing rabbits subjected to different levels of inclusion of passion fruit peel

Inclusion level (%)	Parameters				
	CHOL[1] (mg/dL)	Creatinine (mg/dL)	TG[2] (mg/dL)	GOT[3] (U/L)	GPT[4] (U/L)
0	115.25	1.33	89.63	27.63	26.50
8	115.88	1.47	70.75	28.88	36.13
16	92.50	1.43	59.38*	24.63	37.63
24	81.13	1.66	57.88*	21.50	37.88
32	71.75*	1.75*	57.38*	29.50	37.63
Sex					
Male	87.20	1.56	67.65	29.95	36.00
Female	103.50	1.49	66.35	26.90	34.30
Mean	95.35	1.53	67.00	28.43	35.15
CV[5]	30.61	19.69	31.54	31.23	34.23
ANOVA[6]	*P*-value				
Level	0.0141	0.0606	0.0207	0.6768	0.2857
Sex	0.0874	0.4646	0.8471	0.5835	0.6582
Level x Sex	0.7629	0.6627	0.7696	0.5013	0.5266
Regression for level					
Linear	0.0007	0.0402	0.0785	0.6678	0.8082
Quadratic	0.4185	0.5616	0.2949	0.8501	0.8440

[1]Total cholesterol; [2]Triglycerides; [3]Glutamic-oxalacetic transaminase; [4]Glutamic-pyruvic transaminase; [5]Coefficient of variation; [6]ANOVA: analysis of variance; *Differs from control (0%) by Dunnett test ($P<0.05$)

(2013), on the other hand, reported that the consumption of mango pulp by rats was related to the increase of serum levels of these enzymes (GOT / GPT), suggesting a pro-oxidative action in the liver. An initial step to detect liver problems is a blood test to determine the presence of these enzymes in the blood. Under normal circumstances, these enzymes reside within the liver cells. But when the liver is in trouble, these enzymes are spilled into the blood stream.

There was also no effect of the inclusion of passion fruit peel on the sex of the animals, disagreeing with the results obtained by Oliveira *et al*. (2004), who reported that due to the action of estrogen and progesterone hormones, female rabbits have a higher total cholesterol value in comparison to males, as part of the cholesterol produced would be used in these hormonal productions. Perhaps, this effect was not observed in this study due to the fact that the animals were slaughtered at 90 days of age, a period prior to the female rabbits' puberty stage.

The inclusion of passion fruit peel in the feeding of growing rabbits significantly improved all economic variables in comparison to the control diet (Table 7). Except for the control treatment, there was a linear reduction in the cost of feeding (Y = 6.67 - 0.1028X; $R^2 = 0.98$), and this reduction provided a lower average cost per kilogram of live weight (Y = 6.46 - 0.1104 X; $R^2 = 0.98$) and cost index (Y = 207.36 - 3.5284X; $R^2 = 0.98$). There was also a linear increase in the economic efficiency index (Y = 39.32 + 1.9315X; $R^2 = 0.99$) as the passion fruit peel was included in the rations.

The best economic efficiency and cost ratios were obtained with the inclusion of 32% of passion fruit peel in the rations, which resulted in a 51.66% reduction in feeding costs when compared to the control ration, showing that the inclusion of this residue presents economic viability at the maximum assessed level.

Normally, agro-industrial residues have lower prices than conventionally used feeds, thus, their inclusion ends up contributing to reduce the cost of the kilogram of feed, as shown in Table 7. Moreover, considering that the increased participation of this ingredient in the feed composition did not result in impaired rabbit performance, naturally this will reflect on greater economic efficiency, as it has been demonstrated in other studies that tested alternative agro-industrial feedstuffs in the diet of rabbits (GOMES *et al*., 2018; LIMA *et al*., 2017).

Considering that, during the growth phase, the weight gain and carcass characteristics of rabbits fed

Table 7 - Influence of passion fruit peel level in rabbit diets on economic evaluation

Inclusion level (%)	Parameters			
	Feeding cost (US$/rabbit)	CFKBW[1] (US$/kg rabbit)	Economic efficiency index (%)	Cost Index (%)
0	1.29	1.13	52.45	194.78
8	1.07*	1.06	55.25	183.10
16	0.97*	0.86*	68.13*	148.52*
24	0.77*	0.67*	88.28*	115.55*
32	0.62*	0.58*	100.00*	100.00*
Sex				
Male	0.94	0.89	70.85	153.72
Female	0.95	0.83	75.35	143.01
Mean	0.95	0.86	73.10	148.37
CV[2]	7.88	12.15	12.30	12.14
ANOVA[3]	*P*-value			
Level	<.0001	<.0001	<.0001	<.0001
Sex	0.9410	0.0745	0.1291	0.0748
Level x Sex	0.0722	0.9017	0.9959	0.9028
Regression for level				
Linear	<.0001	<.0001	<.0001	<.0001
Quadratic	0.4671	0.1281	0.9761	0.1276

[1]Cost of feed per kilogram of body weight; [2]CV: coefficient of variation; [3]ANOVA: Analysis of variance. *Differs from control (0%) by Dunnett test (P<0.05)

the level of 32% of inclusion of passion fruit peel were similar to those fed the control ration (0%) and that increasing the inclusion of this ingredient in the diets improved the economic viability, it can be inferred that it is possible to include up to 32% of passion fruit peel in rations for rabbits destined for slaughter without changes in performance and carcass characteristics.

CONCLUSIONS

1. The nutritional and energetic value of the passion fruit peel found was, 10.99% CP, 6.25% EE, 5.95% MM, 47.40% ADF, 54.66% NDF and 4,156.50 kcal of DE/kg of dry matter;
2. It is concluded that the passion fruit peel has potential to being used without damage to the nutritional efficiency of diets fed to growing rabbits to the level of 32% and that the inclusion of passion fruit peel improves production yield and viability economic production.

REFERENCES

AOAC International. **Official methods of analysis**. 18 th ed. Gaithersburg, MD: AOAC International, 2005.

BEZERRA, B. M. O. *et al.* Fatores inerentes às fases de creche, crescimento e terminação influenciam marcadores da atividade muscular, do metabolismo proteico e do estresse oxidativo em suínos. **Revista Brasileira de Medicina Veterinária**, v. 38, n. 4, p. 371-376, 2016.

CAZARIN, C. B. B. *et al.* Capacidade antioxidante e composição química da casca de maracujá (*Passiflora edulis*). **Ciência Rural**, v. 44, n. 9, p. 1699-1704, 2014.

COELHO, A. A.; CENCI, S. A.; RESENDE, E. D. Rendimento em suco e resíduos do maracujá em função do tamanho dos frutos em diferentes pontos de colheita para o armazenamento. **Revista Brasileira de Produtos Agroindustriais**, v. 13, n. 1, p. 55-63, 2011.

CÓRDOVA, K. R. V. *et al.* Características físico-químicas da casca do maracujá amarelo (*Passiflora edulis flavicarpa Degener*) obtida por secagem. **Boletim Centro de Pesquisa de Processamento de Alimentos**, v. 23, n. 2, p. 221-230, 2005.

CRUZ, B. C. C. *et al.* Silagens de capim elefante com diferentes proporções de casca desidratada de maracujá em dietas de cordeiros Santa Inês. **Revista Brasileira de Saúde e Produção Animal**, v. 12, n. 1, p. 107-116, 2011.

DE BLAS, C.; WISEMAN, J. **The nutrition of the rabbit**. 2nd ed. Cambridge: CAB International, 2010. 325 p.

DIAS, D. G. *et al.* Production and postharvest quality of irrigated passion fruit after n-k fertilization. **Revista Brasileira de Fruticultura**, v. 39, n. 3, e-553, 2017.

FIALHO, E. T. *et al.* Utilização da cevada suplementada com óleo de soja para suínos em crescimento e terminação. **Pesquisa Agropecuária Brasileira**, v. 27, n. 10, p. 1467-1475, 1992.

GIROTTO, C. *et al.* Effect of chitosan consumption in lipidic parameters, glycemics and intestinal microflora in rats Wistar. **Revista Brasileira de Análises Clinicas**, v. 49, n. 2, p. 170-175, 2017.

GOMES, T. R. *et al.* Dehydrated cashew apple meal in the feeding of growing rabbits. **Semina: Ciências Agrárias**, v. 39, n. 2, p. 757-770, 2018.

GROSSELI, M. *et al.* Uso da polpa e da casca do maracujá (*Passiflora Edulis F. Flavicarpa*) sobre o colesterol em coelhos com hipercolesterolemia experimental. **Revista Pesquisa e Inovação Farmacêutica**, v. 6, n. 2, p. 12-20, 2014.

LIMA, P. J. D. O. *et al.* Dried brewers grains in growing rabbits: nutritional value and effects on performance. **World Rabbit Science**, v. 25, p. 251-260, 2017.

LOUSADA JÚNIOR, J. E. *et al.* Caracterização físico-química de subprodutos obtidos do processamento de frutas visando seu aproveitamento na alimentação animal. **Revista Ciência Agronômica**, v. 37, n. 1, p. 70-76, 2006.

MARIA, B. G. *et al.* Digestibilidade da polpa cítrica desidratada e efeito de sua inclusão na dieta sobre o desempenho de coelhos em crescimento. **Acta Scientiarum Animal Sciences**, v. 35, p. 85-92, 2013.

MATTERSON, L. D. *et al.* The metabolizable energy of feed ingredients for chickens. **Research Report**, v. 7, n. 1, p. 11-14, 1965.

MELETTI, L. M. M. Avanços na cultura do maracujá no Brasil. **Revista Brasileira de Fruticultura**, v. 33, p. 83-91, 2011. Volume especial.

MELO, W. O. Utilização de subprodutos agroindustriais na alimentação de coelhos. **Revista Eletrônica Nutritime**, v. 8, n. 1, p. 1391-1400, 2011.

OLIVEIRA, T. T. *et al.* Efeito de diferentes doses de rutina sobre lipídeos no soro de coelhos machos e fêmeas. **Revista Brasileira de Análises Clínicas**, v. 36, n. 4, p. 213-215, 2004.

PRASTIYA, R. A. *et al.* Red dragon fruit peel (*Hylocereus polyrhizus*) in rabbit nutrition. **The Indian Veterinary Journal**, v. 96, n. 10, p. 36-38, 2019.

RAO, D. R. *et al.* Effect of weaning and slaughter ages on rabbit meat production II. carcass quality and composition. **Journal of Animal Science**, v. 46, n. 3, p. 578-583, 1978.

RETORE, M. *et al.* Efeito da fibra de coprodutos agroindustriais e sua avaliação nutricional para coelhos. **Arquivos Brasileiros de Medicina Veterinária e Zootecnia**, v. 62, n. 5, p. 1 232-1240, 2010.

REZENDE, F. A.; GROFF, A. M. Composição química da casca de maracujá azedo (*Passiflora edulis sims f. Flavicarpa degener*) e suas possíveis utilizações. **Anais Eletrônico**, v. 1, p. 1-1, 2015.

SILVA, D. C. *et al.* Pectim from Passiflora edulis shows anti-inflammatory action as well as hypoglycemic and hypotriglyceride micproperties in diabetic rats. **Journal of Medicinal Food**, v. 14, n. 10, p. 1118-1126, 2011.

SILVA, E. C. O. *et al.* Obtaining and characterization of passion fruit albedo flour (*Passiflora edulis f. Flavicarpa*) for food use. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 11, n. 3, p. 69- 74, 2016.

SOUZA, M. W. S.; FERREIRA, T. B. O.; VIEIRA, I. F. R. Centesimal composition and functional technological properties of passion fruit rind flour. **Alimentos e Nutrição**, v. 19, n. 1, p. 33-36, 2008.

SPINELLI, M. O. *et al*. Estudo dos analitos bioquímicos no plasma de coelhos (Nova Zelândia) mantidos no biotério da Faculdade de Medicina da Universidade de São Paulo. **Revista da Sociedade Brasileira de Ciência em Animais de Laboratório**, v. 1, n. 2, p. 163-168, 2012.

TOLEDO, R. C. L. *et al*. Efeito da ingestão da polpa de manga (*Mangifera indica L.*) sobre os parâmetros bioquímicos séricos e integridade hepática em ratos. **Bioscience Journal**, v. 29, n. 2, p. 516-525, 2013.

VILLAMIDE, M. J. Methods of energy evaluation of feeds ingredients for rabbits and their accuracy. **Animal Feed Science and Technology**, v. 57, n. 3, p. 211-223, 1996.

ZANATTA, C. P. *et al.* Fatores que regulam o consumo e a preferência alimentar em cães. **Scientia Agraria Paranaensis**, v. 15, n. 2, p. 109-114, 2016.