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IN THE DIET OF BROILERS**

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Complete List of Authors:	Zanetti, Leonardo; Universidade Estadual de Maringa, Departamento de Zootecnia Murakami, Alice; Universidade Estadual de Maringá, Departamento de Zootecnia Diaz-Vargas, Mayra; Universidade Estadual de Maringá, Zootecnia Guerra, Ana; Universidade Estadual de Maringá, departamento de zootecnia Ospina-Rojas, Ivan; Universidade Estadual de Maringá, Departamento de Zootecnia Nascimento, Guilherme; Universidade Estadual de Maringa, Departamento de Zootecnia Santos, Tatiana; Universidade Estadual de Maringá, Animal Science Pintro, Paula Toshimi; Universidade Estadual de Maringa, Agronomia
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BY-PRODUCT OF PASSION FRUIT SEED (*Passiflora edulis*) IN THE DIET OF BROILERS

Leonardo Henrique Zanetti^{1,2}; Alice Eiko Murakami¹; Mayra Diaz-Vargas¹; Ana Flávia Quiles Garcia Guerra¹; Ivan Camilo Ospina-Rojas¹; Guilherme Rodrigues do Nascimento¹; Tatiana Carlesso dos Santos¹ and Paula Toshimi Matumoto Pinto³

¹ Department of Animal Science, Universidade Estadual de Maringá; Av. Colombo, 5790, Bloco J45, 87020-900, Maringá, PR, Brazil

² Corresponding author (e-mail: leohzanetti@yahoo.com.br)

³ Department of Agronomy, Universidade Estadual de Maringá; Av. Colombo, 5790, Bloco J45, 87020-900, Maringá, PR, Brazil

Abstract. Two experiments were performed to determine the chemical composition of by-product of passion fruit seed (BPFS) and to evaluate the performance, blood variables, carcass yield, meat quality and oxidation of broilers fed diets containing increasing levels of BPFS. In experiment 1, a total of 60 21-d-old Cobb male broilers were distributed in a completely randomized design, with two treatments (reference feed and test diet) and five replicates of six birds each. Energy content in BPFS was 3,945 kcal kg⁻¹ of apparent metabolizable energy corrected for nitrogen balance (AMEn) and 10.68 % CP. In experiment 2, a total of 864 1-day-old male Cobb broilers were distributed in a completely randomized design, with six treatments (control, 2.5%, 5.0%, 7.5%, 10%, and 12.5% BPFS) and six replicates of 24 birds each. Feed conversion linearly worsened ($P<0.05$). At 21 days of age, blood triglyceride levels linearly decreased ($P<0.05$). At 42 days, there was a linear decrease in villus height in the jejunum as the inclusion of BPFS. Meat quality was not affected by the different levels of BPFS. For lipid oxidation, used samples of thigh in a 6x3 factorial design (6 levels of addition of BPFS and 3 storage periods) with 4 replications. In the treatments with 5% BPFS, the phenolic compounds present in the byproduct led to a delayed and reduced oxidation. In conclusion, from 1 to 21 and 1 to 42 days, BPFS can be used up to 5% in broiler diets without harming the parameters evaluated.

Keywords: energy, metabolism, nutrition, performance

Introduction

Brazil stands out as the world's largest producer of passion fruit (Mezzalana et al. 2012), and of all national production, the yellow passion fruit (*Passiflora edulis*) accounts for 97% of the planted area and volume traded (Rossi et al. 2001). Estimated that over 60% of this passion variety produced in Brazil is destined for *in natura* consumption, while the rest, ~40%, is used in the processing industry (Rossi et al. 2001). During the passion fruit industrialization process, are generated by-products, which are composed of peels and seeds, accounting for 65% to 70% of the fruit weight (Oliveira et al. 2002).

Thus, an alternative that has been studied is the use of these residues in the animal feeding, once it has already been proved that fruit have high levels of bioactive compounds (vitamins, minerals, antioxidants, polyphenols, food fibers, among others) which have positive effects on health, contributing to prevent several diseases (Ayala-Zavala et al. 2011; Viuda-Martos et al. 2010). Furthermore, the by-products obtained from the production of passion fruit juice can be used as an alternative feed ingredient because of its function as an antioxidant and antibacterial activities (López-Vargas et al., 2013).

Passion fruit seeds are considered as a good source of essential fatty acids such as linoleic acid (omega-6: 55-66%), oleic acid (omega-9; 18-20%), palmitic acid (10-14%), and linolenic acid (omega-3, 0.80-1%) (Leonel et al. 2000). Thereby, the use of passion fruit by-products in broilers diets increased the levels of unsaturated fatty acids omega 3 and omega 6 families in the leg muscles (Togashi et al. 2007).

In addition, a recent study showed that until 5% of the passion fruit seed residue in the feeding of laying hens not to affected the performance and until 12.5% not compromised the quality of the eggs (Zanetti et al. 2016). However, for broilers the literature data are scarce and the best level was not determined, since in the literature only two levels were tested (Togashi et al. 2008). Therefore, the objectives were to determine the energy and protein content of the by-product passion fruit seed and to evaluate the effects of by-product passion fruit seed use in diets for broilers on performance, blood parameters, organ weights, intestinal morphometry, carcass yield and meat quality.

Materials and Methods

The experiments were carried out in the Poultry Farming Sector at the Experimental Farm of Maringá State University, and were approved by the Ethics Committee for Animal Research - CEEA/UEM (approval number 16/2014).

Experiment I - Digestibility assay

A total of 60 21-d-old male broilers were housed in galvanized wire battery cages. The experimental design was entirely randomized with three treatments (reference feed and test diets: reference feed + 20% BPFS) and five replicates with six broilers in each. The BPFS was dried outdoors in the shade (average temperature were 24°C), then milled, and used to partially replace the reference feed, based on corn and soybean meal (45%), by 20% (as-fed basis). The experimental diet (Table 1) was formulated considering the nutritional requirements of male broilers according to Rostagno et al. (2011).

The experimental period lasted 10 days (5 days for acclimation + 5 days for excreta collection), and during that period, birds received feed and water *ad libitum*. Feed was weighed at the start and end of the collection period to determine average feed intake. The method of total excreta collection was used, with ferric oxide (1%) serving as a marker at the start and end of collection. The cages were outfitted with plastic-covered trays, which were removed during at each collection (in 12-h intervals) to collect the excreta. Later the experimental period (day 11), the excreta were thawed, homogenized, weighed, and oven dried for 72 h at 55 °C. The sample were ground milled and sent for analysis of DM, gross energy (GE), and nitrogen (N), was conducted according to the methodology described by Sakomura and Rostagno (2007). Laboratory analyses of the BPFS, diets, and excreta were carried out according to methods described by the Association of Official Analytical Chemists (1990). The GE values were determined using Parr 6100 oxygen bomb calorimeter (Parr instrument Co., Moline, IL, USA). The determination of the total polyphenol content was performed as described by Singleton and Rossi (1965) adapted by Bloor (2001). After laboratory analysis results were obtained for the values of apparent metabolizable energy (AME) and nitrogen-corrected apparent metabolizable energy (AMEn) were calculated using the equation described by Matterson et al. (1965).

Experiment II - Performance and meat quality

A total of 864 one-day-old male Cobb broiler chicks were distributed in an entirely randomized experimental design consisting of six treatments (control, 2.5%, 5.0%, 7.5%, 10% and 12.5% BPFS inclusion) and six replicates with 24 birds in each.

All birds were raised in floor pens (2.0 x 1.0 m) with fresh wood shavings as litter and the pens were equipped with one tube feeder and one nipple drinker (6 nipples/pen). Temperature was maintained at 32°C bird acclimation and was gradually reduced to ensure comfort by using a thermostatically controlled heater, exhaust fans, and cool cells. Ventilation

was accomplished by negative air pressure. The lighting program throughout the study consisted of 23 h of light and 1 h of dark. Feed and water were available to the birds *ad libitum*. Experimental diet (Table 2) consisted of corn and soybean meal as recommended in Rostagno et al. (2011).

Birds and experimental diets were weighed at 1, 21 and 42 days old to determine feed intake (obtained through the difference between total feed provided and ortscollected at the end of each period), feed conversion (calculated as the ratio between total feed intake and weight gain, corrected by the weight of dead birds), and body weight gain.

At 21 and 42 d of age, two birds per replicate were selected (mean $\pm$ 5%) and 5.0 mL of blood were collected from the jugular vein to determine serum levels of total cholesterol and triglycerides using enzymatic colorimetric assay (Gold Analisa Diagnostica Ltda, Belo Horizonte, Minas Gerais, Brazil). The readings were performed using spectrophotometer model BIOPLUS 2000 (Bioplus Ltda, Barueri, São Paulo, Brazil).

At 21 and 42 days of age, two birds were selected per replicate (mean $\pm$ 5%) and euthanized. The gastrointestinal tract organs (proventriculus, gizzard, pancreas, liver, and small and large intestine) were collected and weighed on a precision scale to the nearest 0.001 g, and the relative weight of each organ in relation to body weight was calculated using the equation (organ weight/body weight) $\times$ 100. Approximately 2-cm length of each segment of the small intestine (duodenum and jejunum) were collected. The sections were dehydrated in a series of increasing alcohol concentrations, freeze dried in xylol, and embedded in paraffin. Semiseriate and crosssectional, 7-mm-thick, histological sections were made, until five sections per slide were obtained, then stained using the hematoxylin-eosin method. The IMAGE PROPLUS 4 computer imaging software was used for morphometric analysis. Sixty measurements were carried out (30 for villus height and 30 for crypt depth).

At 42 d of age, 12 birds were selected per treatment (mean $\pm$ 5%) for analysis of carcass yields and body parts' yields and abdominal fat percentage. After a 8-hperiod of feed withdrawal, the birds were euthanized, eviscerated, and the carcasses were weighed on a digital scale to determinecarcass and parts' yields. Abdominal fat, determinedas that surrounding the cloaca, cloacal bursa, gizzard, proventriculus, and adjacent abdominal muscles, as described by Smith (1993), was weighed and its relative weight was calculated in relation to dressed carcass weight.

To evaluate the quality of meat, the breast muscle (*Pectoralis major*) and thigh (*Biceps femoris*) were collected. The pH of samples was measured using a pH meter (Model HI 99163, Hanna Instruments, Woonsocket, RI, USA) with a penetration electrode. introduced

directly into the breast fillet 15 minutes after slaughtering, as described by Boulianne and King (1995) and adapted by Olivo et al. (2001). The color was measured after slaughtering, using a Minolta CR-400 colorimeter (Konica Minolta Sensing, Inc., Osaka, Japan) in three different locations of the breast and thigh according to the methodology described by Van Laack et al. (2000). The components L^* (lightness), a^* (redness) and b^* (yellowness) were expressed in the CIELAB color system. The muscle of the left breast of six birds per treatment was used for analysis water-holding capacity (WHC), and the right side for cooking weight loss (CWL) and shear force (SF). For WHC, we used the centrifuge method proposed by Nakamura and Katok (1985).

The cooking weight loss (CWL) was determined in deboned samples using the methodology described by Honikel (1987). Samples with similar size and weight were weighed, packaged, and cooked in a water bath (80°C) for 30 min. After cooling at room temperature, samples were reweighed to determine the CWL, which is expressed as a percentage according to the formula: $(\text{initial weight} - \text{final weight}) \times 100 / \text{initial weight}$. Three subsamples with a cross-sectional area equal to 1 cm², and length approximately equal to 3 cm, were obtained from each cooked sample, placed with the fibres oriented perpendicularly to a Warner-Bratzler shear device coupled to a TA-XT2i texture analyser (Stable Micro Systems, Ltd, Godalming, UK) to determine SF (Lyon et al. 1998). The force required for shearing the samples was expressed in Newton (N).

For evaluation of the lipid oxidation of meat, samples of the thigh meat were used, stored at -18°C and analyzed for three periods of storage (1, 30 and 60), observing the oxidation of malondialdehyde equivalent by the Thiobarbituric Acid Reactive Substance (T-BARS) methodology, according to Sorensen and Jorgensen (1996) in a 6x3 factorial design (with six levels of inclusion of BPFS and three days of storage). For the calculations, a standard curve of malondialdehyde and the data were expressed as mg malondialdehyde (MDA)/kg of sample was used.

The obtained results were analyzed using SAEG (1997). Following analysis of variance (ANOVA), whenever a difference was found, the degrees of freedom were decomposed into polynomials and analyzed by regression for the different relationships - linear or quadratic ($P < 0.05$). For the variables that showed quadratic responses, the point of inflection was calculated as the best relationship. To compare the results, the data were subjected to the Dunnett's test at 5% probability, to compare each of treatments with control.

Results

In the Experiment I, BPFS showed values of dry matter of 92.21%, AMEn of 3,945 kcal/kg, 10.68% crude protein, 43.71% of ADF and 50.22% of NDF. The pectin content of the by-product studied was 18.34%. The metabolization coefficient of nitrogen-corrected apparent metabolizable energy, dry matter and crude protein were 69.34, 66.92 and 63.38%, respectively. The metabolizable coefficients of NDF (50.41%) and ADF (30.53%) were high and can be related to the amount of lignin (5.77%) and pectin (18.34%) found in the byproduct. In passion fruit, there are also phenolic substances present; in most cases these have bioactive properties, such as flavonoids, phenolic acids and polyphenols. The BPFS used showed 4.01 mg GAE/g (gallic acid equivalent) of phenolic compounds.

In the Experiment II, there was no difference ($P>0.05$) in weight gain and feed intake, but feed conversion increased linearly ($P<0.05$) in both periods 1-21 and 1-42 days (Table 3). Total cholesterol values blood at 21 and 42 days showed no difference ($P>0.05$) between treatments (Table 4). At 21 days of age, there was a linear decrease ($P<0.05$) in blood triglycerides, as BPFS increased levels in the diet. The relative weight of the gastrointestinal tract organs (proventriculus, gizzard, small intestine, cecum, liver and pancreas) and length of the small intestine were not affected ($P>0.05$) by the BPFS levels in the diets at 21 days of age, and at 42 days of age only the relative liver weight had an effect ($P>0.05$) (Table 5), behaving quadratically ($P<0.05$), with the lowest weight at the estimated level of 7.42% of BPFS. At 21 days of age, there was no effect ($P>0.05$) on intestinal morphology (villous height, crypt depth and villus: crypt) in the duodenum and jejunum (Table 6). However, at 42 days of age, jejunal villus height decreased ($P<0.05$) as the level of BPFS increased. The carcass yield, cuts and abdominal fat of broilers at 42 days of age (Table 7) showed no differences ($P>0.05$). The pH (15 min post mortem), WHC, CWL and SF of breast meat were not affected ($P>0.05$) by different levels of the BPFS (Table 8). Meat lipid oxidation did not present ($P>0.05$) an interaction between storage time and levels of BPFS, only observable effect on days storage (Table 9).

Discussion

The pectin content of the by-product was being considered high (more than 15% in dry matter basis) when compared to fruits such as apple pomace, beet and citrus fruits present 15-20%, 15-20% and 30-35%, respectively (Thibault et al. 1980). These soluble fibers, such as pectin, form a smooth surface layer along the small intestine mucosa and serve as a barrier to the absorption of some nutrients, decreasing metabolism, especially sugars and fats (Wascheck et al. 2008).

The levels of ash (3.52%), Ca (0.08%) and P (0.43%) obtained were higher than those reported by Romo and Nava (2007), and these differences may be linked to the soil characteristics and fertilization where the fruits were grown, because mineral nutrition is an important factor in the quality of the fruit of passion fruit (Mendonça et al. 2006).

In relation to phenolic compounds, López-Vargas et al. (2013) found value of 4.31 mg GAE/g of phenolic compounds, similar to this experiment. Many of these phenolic compounds have a range of biological and pharmacological effects with antioxidant, antibacterial, antiviral, anti-inflammatory, anti-allergic and vasodilatory actions (Zeraik et al. 2010).

As for performance, the feed conversion increased linearly ($P < 0.05$) in both periods, but comparing each level of inclusion of BPFS with the control treatment, there was worse feed conversion ($P < 0.05$) for levels of 7.5, 10.0 and 12.5%, which may have been related to the high insoluble fiber content of BPFS, as fibers can be considered a diluent, or antinutritional factor, in the diet. The BPFS used in this study has 50.22% NDF and 43.71% ADF. High fiber content causes earlier satiety and reduces feed intake (Scheideler et al. 1998; González-Alvarado et al. 2007).

It was expected that cholesterol levels decrease with the inclusion of BPFS in diets due to this high pectin content, since this compound in large quantities can reduce the total cholesterol and cholesterol LDL in blood (Ramos et al. 2007). Baker (1994) suggests that the effect of reducing plasma cholesterol pectin is evidenced only in cases of individuals with high cholesterol or consuming diets rich in cholesterol. It was not observed in this experiment because the broilers were slaughtered young (42 days). However, blood triglycerides was a linear decrease at 21 days of age. The consumption of insoluble fiber derived from passion fruit seed could effectively reduce serum levels of triglycerides in rodents (Chau and Huang 2005), also observed in broiler.

The relative liver weight had an effect quadratic, however, when comparing the level of inclusion of BPFS with the control, it a difference was observed for treatments 5.0, 7.5 and 10.0%. The increase in the relative liver weight may be due to the presence of elevated levels of lipids, especially polyunsaturated fatty acids in the BPFS.

At 42 days of age, jejunal villus height decreased as the level of BPFS increased; comparing each treatment with control, there was lower villus height in the jejunum levels with 10.0 and 12.5% inclusion of BPFS. This shows a worsening in the health of the villi of the small intestine, which is precisely the portion responsible for the absorption of nutrients. The high fiber content of the BPFS (43.71% ADF and 50.22% NDF) can promote a sensation of satiety, especially in relation to pectin (18.34%), whereas it also has a high gelling ability and

acts as a stabilizer (Kim et al. 2005), which may have increased the viscosity of the diet, thus causing these changes in intestinal morphology (Gracia et al. 2003). This reduction in villus height may be associated with the large amount of fiber in food causing increased friction in the mucosa.

The breast meat were not affected by different levels of the BPFS, only the color of the thigh was affected, the redness presented a quadratic response ($P < 0.05$), with lower color estimated for the level of 9.85% BPFS. Comparing the mean of each treatment with the control, thighs of birds fed the levels of 2.5 and 5% BPFS had lower ($P < 0.05$) redness than the thigh of birds receiving the diet control. No changes were found for body color, despite the presence of passion fruit pigments (Mercadante et al. 1998), and the main trans- β -carotene (Godoy and Rodriguez-Amaya, 1994).

Meat lipid oxidation was observed effect on days storage. On day 1, the samples had a higher ($P < 0.05$) malondialdehyde content, indicating the highest oxidation. These high levels may result from the type of storage, since after collection, the thighs were kept refrigerated at 4°C until time of analysis and the remaining samples were placed in a freezer. On day 30, samples with 5% BPFS inclusion of oxidation showed similar values ($P > 0.05$) to the control treatment and on day 60 smaller value ($P < 0.05$), indicating that the 5% phenolic compounds level (4.01 mg GAE g⁻¹ found in the studied byproduct) delays and reduces lipid oxidation meat (Figure 1). It is important to note that meat from birds fed diets including BPFS tends to have a higher lipid oxidation due to the higher content of fatty acids contained in the diet. The BPFS is characterized by the presence of a high content of fatty acids, among which stand out linoleic acid (63.98%), oleic acid (19.53%), palmitic acid (11.29%), stearic (3.54%), linolenic acid (0.40%).

The good oxidative stability found in this work can be attributed to vegetable oils containing natural antioxidants such as isoflavones, tocopherols and polyphenols (Vernaza et al. 2012). The analyses carried out on days 30 and 60 of storage had lower ($P < 0.05$) oxidation compared to the first day of storage, because such samples were stored in a freezer at -20°C after slaughter. Freezing is one of the best meat preservation methods, since it effectively inhibits enzymatic and chemical reactions. Oxidation of the meat begins in the post-mortem period, with the conversion of muscle meat, caused by biochemical changes that offer favorable conditions for the occurrence of oxidation, initially being in the fraction of phospholipids, highlighting the importance of polyunsaturated fatty acids (Pikul et al. 1989).

Conclusion

The byproduct of passion fruit seed presented 3,945 kcal of AMEn and 10.68% crude protein. In the periods from 1 to 21 and 1 to 42 days old, by-products of passion fruit seed can be used at levels of up to 5.0% inclusion in broiler diets without impairing performance, carcass yield, blood parameters, intestinal morphometry and meat quality.

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Figure 1. Evolution of lipid oxidation in meat of broiler chickens fed with by-product of passion fruit seed levels.

Table 1. Ingredients and nutritional composition of the experimental diet.

Ingredients	(%)
Maize	64.72
Soybean meal 45%	29.22
Dicalcium phosphate	1.15
Limestone	0.76
Soybean oil	2.88
Salt	0.300
DL-Methionine 99%	0.249
L-Lysine HCl 78.5%	0.266
L-Threonine 98%	0.047
Vitamin and mineral supplements ^a	0.400
Total	100
Calculated nutritional composition^b	
Crude protein (%)	18.75
Metabolizable energy (kcal kg ⁻¹)	3125
Digestible lysine (%)	1.08
Digestible Met + Cys (%)	0.76
Digestible threonine (%)	0.68
Available phosphorus (%)	0.32
Sodium (%)	0.14
Calcium (%)	0.69
Chlorine (%)	0.23
Potassium (%)	0.72
Electrolyte balance (mEq kg ⁻¹)	179

Note: ^aVitamin and mineral supplements (content per kg ration): Vit. A 9000.00 UI; Vit. D3 1800.00 UI; Vit. E 28.00 UI; Vit. K3 1.67 mg; Vit. B1 1.20 mg; Vit. B2 4.00 mg; Vit. B12 12.00 mcg; Niacin 28.00 mg; Calcium pantothenate 10.00 mg; Folic acid 0.56 mg; Biotin 0.06 mg; Fe 50.00 g; Cu 12.00 mg; I 1.00 mg; Zn 50.00 g; Mn 0.60 g; Se 0.30 mg; Co 0.20 mg.

^bCalculated based on Rostagno et al. (2011).

Table 2. Ingredients and nutritional composition of the experimental diets from 1 to 21 days and from 22 to 42 days of age.

Ingredientes	Levels by-product of passion fruit seed inclusion (%)											
	1 to 21 days						22 to 42 days					
	Control	2.5	5.0	7.5	10.0	12.5	Control	2.5	5.0	7.5	10.0	12.5
Maize	57.06	55.19	53.31	51.44	49.56	47.69	64.70	62.83	60.95	59.08	57.20	55.33
Soybean meal 45%	36.76	36.44	36.12	35.80	35.47	35.15	29.23	28.90	28.58	28.26	27.94	27.61
By-product of passion fruit seed	0.00	2.50	5.00	7.50	10.00	12.50	0.00	2.50	5.00	7.50	10.0	12.5
Dicalcium phosphate	1.70	1.70	1.69	1.68	1.67	1.67	1.15	1.14	1.13	1.13	1.12	1.11
Limestone	0.82	0.82	0.82	0.83	0.83	0.83	0.76	0.76	0.77	0.77	0.78	0.78
Soybean oil	2.20	1.87	1.54	1.20	0.87	0.53	2.89	2.56	2.22	1.89	1.55	1.22
Salt	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
DL-Methionine 99%	0.321	0.330	0.339	0.348	0.358	0.367	0.249	0.258	0.268	0.277	0.286	0.295
L-Lysine HCl 78.5%	0.244	0.259	0.275	0.290	0.305	0.320	0.266	0.281	0.297	0.312	0.327	0.343
L-Threonine 98%	0.078	0.088	0.098	0.109	0.119	0.129	0.047	0.058	0.068	0.078	0.089	0.099
Vitamin and mineral supplements ^{a, b}	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
BHT ^c	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated nutritional composition ^d												
Crude protein (%)	21.60	21.60	21.60	21.60	21.60	21.60	18.75	18.75	18.75	18.75	18.75	18.75
Metabolizable energy (kcal kg ⁻¹)	2.980	2.980	2.980	2.980	2.980	2.980	3.125	3.125	3.125	3.125	3.125	3.125
Digestible lysine (%)	1.24	1.24	1.24	1.24	1.24	1.24	1.08	1.08	1.08	1.08	1.08	1.08
Digestible Met + Cys (%)	0.90	0.90	0.90	0.90	0.90	0.90	0.76	0.76	0.76	0.76	0.76	0.76
Digestible threonine (%)	0.81	0.81	0.81	0.81	0.81	0.81	0.68	0.68	0.68	0.68	0.68	0.68
Available phosphorus (%)	0.43	0.43	0.43	0.43	0.43	0.43	0.32	0.32	0.32	0.32	0.32	0.32
Sodium (%)	0.18	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.14	0.14	0.14	0.14
Calcium (%)	0.87	0.87	0.87	0.87	0.87	0.87	0.69	0.69	0.69	0.69	0.69	0.69
Chlorine (%)	0.29	0.29	0.29	0.29	0.29	0.29	0.23	0.23	0.23	0.23	0.23	0.23
Potassium (%)	0.83	0.83	0.82	0.80	0.79	0.78	0.72	0.71	0.70	0.69	0.68	0.67
Crude fiber	2.93	3.54	4.15	4.76	5.37	5.98	2.66	3.27	3.88	4.49	5.11	5.72
Electrolyte balance (mEq kg ⁻¹)	209	207	204	201	199	196	179	176	173	171	168	165

Note: ^a (1 to 21 days of age) Vitamin supplement (content per kg ration): Vit. A 11666.68 UI; Vit. D3 2333.32 UI; Vit. E 35.00 UI; Vit. K3 1.73 mg; Vit. B1 1.63 mg; Vit. B2 5.33 mg; Vit. B12 16.67 mg; Niacin 35.93 mg; Calcium pantothenate 12.67 mg; Folic acid 0.80 mg; Biotin 0.10 mg. Mineral supplement (content per kg ration): Fe 50.40 g; Cu 12.29 mg; I 0.99 mg; Zn 50.40 g; Mn 0.06 g; Se 0.24 mg; Co 0.20 mg.

^b (22 to 42 days of age) Vitamin supplement (content per kg ration): Vit. A 9000.00 UI; Vit. D3 1800.00 UI; Vit. E 28.00 UI; Vit. K3 1.67 mg; Vit. B1 1.20 mg; Vit. B2 4.00 mg; Vit. B12 12.00 mcg; Niacin 28.00 mg; Calcium pantothenate 10.00 mg; Folic acid 0.56 mg; Biotin 0.06 mg. Mineral supplement (content per kg ration): Fe 50.00 g; Cu 12.00 mg; I 1.00 mg; Zn 50.00 g; Mn 0.60 g; Se 0.30 mg; Co 0.20 mg.

^cBHT, antioxidant butylhydroxytoluene.

^dCalculated based on Rostagno et al. (2011).

Table 3. Performance (mean $\pm$ standard error) of 1 to 21 and 1 to 42d-old male broilers fed diets with levels of inclusion of BPFS.

	Levels by-product of passion fruit seed inclusion (%)						CV (%)	R
	Control	2.5	5.0	7.5	10.0	12.5		
1 to 21 days								
Weight gain (g)	756.85±15.26	744.63±8.52	769.00±11.93	749.83±11.87	743.88±11.54	734.66±13.67	3.67	NS
Feed intake (g)	1057.71±13.88	1060.09±14.18	1095.73±18.68	1078.44±18.78	1083.95±10.71	1080.58±16.65	3.27	NS
Feed conversion	1.398±0.013	1.424±0.009	1.425±0.014	1.438±0.011*	1.458±0.017*	1.471±0.011*	1.98	0.001 ^a
1 to 42 days								
Weight gain (g)	2728.70±22.64	2671.30±30.59	2781.64±42.97	2674.18±44.19	2696.01±39.16	2649.49±36.66	3.05	NS
Feed intake (g)	4427.38±37.67	4431.92±35.43	4628.08±70.38	4489.59±55.60	4551.65±39.03	4562.91±64.20	2.59	NS
Feed conversion	1.623±0.006	1.660±0.016	1.664±0.009	1.680±0.014*	1.689±0.019*	1.722±0.010*	1.77	0.001 ^b

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

^aY = 1.4047 + 0.0051x; R² = 0.94

^bY = 1.6377 + 0.006x; R² = 0.91

Table 4. Total cholesterol and triglycerides (mean $\pm$ standard error) of 21- and 42-d-old broilers fed diets with levels of inclusion of BPFS.

	Levels by-product of passion fruit seed inclusion (%)							R
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	
21 days								
Total cholesterol (mg dL ⁻¹)	109.90±2.72	108.71±5.68	107.72±6.24	107.62±2.86	107.51±8.18	107.26±4.50	12.21	NS
Triglycerides (mg dL ⁻¹)	111.06±9.00	101.78±8.80	98.69±3.61	94.17±4.24	85.72±5.15	84.02±7.34	17.13	0.019 ^a
42 days								
Total cholesterol (mg dL ⁻¹)	118.08±4.89	112.05±7.65	109.17±4.57	105.40±6.91	105.62±4.71	103.31±2.43	12.31	NS
Triglycerides (mg dL ⁻¹)	70.40±4.03	70.00±6.54	69.79±1.61	69.83±8.47	65.76±3.36	64.12±2.92	18.13	NS

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

^aY = 107.42 - 1.9396x; R² = 0.96

Table 5. Relative weights of gastrointestinal tract organs and small intestine length (mean ± standard error) in broilers fed diets with levels of inclusion of BPFS, at 21 and 42 d of age.

	Levels by-product of passion fruit seed inclusion (%)						CV (%)	R
	Control	2.5	5.0	7.5	10.0	12.5		
21 days								
Proventriculus (%)	0.59±0.03	0.55±0.02	0.58±0.003	0.60±0.03	0.57±0.01	0.62±0.03	8.07	NS
Gizzard (%)	2.05±0.11	2.22±0.13	2.18±0.08	2.10±0.11	2.35±0.22	2.31±0.05	13.10	NS
Small intestine (%)	3.95±0.23	3.87±0.16	4.08±0.13	4.05±0.17	3.89±0.11	3.97±0.04	8.47	NS
Cecum (%)	0.79±0.03	0.70±0.05	0.77±0.04	0.72±0.02	0.80±0.04	0.90±0.05	11.77	NS
Liver (%)	3.36±0.16	3.32±0.13	3.38±0.08	3.45±0.08	3.30±0.14	3.42±0.14	8.30	NS
Pancreas (%)	0.35±0.03	0.34±0.02	0.38±0.02	0.38±0.02	0.34±0.01	0.37±0.03	13.72	NS
Small intestine (cm)	147.67±4.94	156.17±5.98	148.50±2.60	159.60±3.67	153.83±5.90	146.67±5.88	7.34	NS
42 days								
Proventriculus (%)	0.29±0.01	0.28±0.01	0.31±0.035	0.30±0.01	0.30±0.02	0.29±0.02	15.42	NS
Gizzard (%)	1.14±0.05	1.28±0.10	1.25±0.07	1.42±0.16	1.35±0.06	1.30±0.05	15.85	NS
Small intestine (%)	2.34±0.12	2.42±0.10	2.46±0.08	2.28±0.15	2.40±0.03	2.35±0.13	10.34	NS
Cecum (%)	0.48±0.02	0.53±0.04	0.54±0.01	0.50±0.03	0.63±0.03	0.54±0.04	12.86	NS
Liver (%)	2.10±0.09	1.97±0.06	1.85±0.073*	1.82±0.08*	1.80±0.07*	2.02±0.08	8.93	0.012 ^a
Pancreas (%)	0.19±0.01	0.20±0.01	0.20±0.02	0.22±0.01	0.19±0.01	0.20±0.01	13.74	NS
Small intestine (cm)	219.00±6.95	211.80±3.87	224.83±6.02	202.00±6.76	217.83±6.68	219.83±6.69	6.47	NS

Note: *Significant by Dunnett’s test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.
^aY = 2.2196 – 0.1157x + 0.0078x²; R² = 0.90

Table 6. Villus height, crypt depth and villus height: crypt depth ratio (mean $\pm$ standard error) of 21 and 42-d-old broilers fed diets with levels of inclusion of BPFS.

	Levels by-product of passion fruit seed inclusion (%)							
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	R
21 days								
Villus height (μm)								
Duodenum	1201.81±55.21	1149.93±46.43	1069.17±71.76	1132.05±81.83	1188.81±53.79	1132.95±71.07	11.26	NS
Jejunum	604.46±37.91	549.56±47.88	643.62±44.06	504.01±49.75	605.50±44.99	585.78±30.68	14.78	NS
Crypt depth (μm)								
Duodenum	47.57±1.94	41.77±2.36	47.11±2.00	43.30±0.61	44.47±2.84	44.88±0.65	8.00	NS
Jejunum	36.17±1.96	34.17±1.84	39.78±3.63	39.12±1.79	41.05±2.52	41.25±1.59	12.08	NS
Villus height : crypt depth ratio								
Duodenum	26.39±0.25	29.46±3.27	21.01±0.63	26.11±1.75	28.52±1.00	25.26±1.63	14.12	NS
Jejunum	16.92±1.64	16.23±1.58	16.60±1.98	12.85±1.01	14.84±1.05	14.26±0.88	18.54	NS
42 days								
Villus height (μm)								
Duodenum	1369.93±45.75	1383.93±27.39	1308.12±35.87	1420.45±26.53	1295.00±8.40	1363.23±0.58	4.21	NS
Jejunum	954.82±9.73	914.31±12.47	979.00±61.60	943.90±9.00	841.76±37.53*	737.35±3.76*	6.92	0.001 ^a
Crypt depth (μm)								
Duodenum	44.45±0.81	43.78±2.27	51.37±3.08	45.40±2.05	51.52±1.89	45.71±2.52	9.43	NS
Jejunum	42.30±0.91	41.62±1.93	50.46±1.53*	46.47±1.57	38.96±2.27	40.65±1.63	7.81	NS
Villus height : crypt depth ratio								
Duodenum	29.09±0.87	30.18±1.19	24.63±1.41	32.50±1.17	24.51±1.54	28.86±2.45	10.79	NS
Jejunum	22.61±0.70	22.12±1.19	19.60±1.83	20.36±0.49	21.74±1.13	15.79±0.72*	10.84	NS

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

^aY = 1070.6 – 27.647x; R² = 0.65

Tabela 7. Carcass and parts yields (mean ± standard error) of broilers fed diets with levels of inclusion of BPFS and slaughtered at 42 d of age.

	Levels by-product of passion fruit seed inclusion (%)							R
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	
Carcass (%)	71.99±0.51	72.62±0.45	72.21±0.39	72.43±0.58	71.95±0.66	72.24±0.60	1.67	NS
Breast (%)	40.00±0.58	40.46±0.90	41.65±1.13	42.05±0.95	40.95±0.90	40.90±0.91	4.95	NS
Thigh (%)	31.02±0.43	30.42±0.43	30.31±0.77	31.67±2.40	31.19±0.74	31.50±0.92	8.38	NS
Wing (%)	10.14±0.22	10.09±0.33	9.71±0.26	10.15±0.32	9.80±0.21	10.05±0.24	5.99	NS
Back (%)	18.62±0.36	16.07±2.59	18.09±0.58	17.88±0.44	17.73±0.78	18.18±0.68	14.91	NS
Fat (%)	2.32±0.23	2.18±0.34	2.22±0.17	2.26±0.27	2.08±0.25	1.67±0.29	27.89	NS

Note: *Significant by Dunnett’s test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

Table 8. Breast and thigh meat quality parameters (mean ± standard error) of broilers fed diets with levels of inclusion of BPFS and slaughtered at 42 d of age.

	Levels by-product of passion fruit seed inclusion (%)							R
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	
Breast								
<i>L</i> *	46.54±2.01	47.49±1.63	46.74±1.13	46.73±1.51	47.12±0.72	45.68±1.77	7.28	NS
<i>a</i> *	4.54±0.43	4.61±0.30	4.85±0.97	5.47±0.60	4.21±0.64	5.54±0.43	27.60	NS
<i>b</i> *	6.31±1.09	6.21±0.81	6.76±0.78	6.56±0.49	5.96±0.63	6.31±0.74	27.36	NS
pH	6.33±0.08	6.40±0.06	6.33±0.06	6.47±0.06	6.41±0.08	6.41±0.07	2.48	NS
Water-holding capacity (%)	64.68±1.73	64.75±1.36	65.38±1.09	67.04±0.76	67.00±0.65	66.03±0.64	3.78	NS
Cooking weight loss (%)	29.33±0.91	31.33±2.14	31.41±0.93	30.33±1.45	30.40±1.27	30.09±2.15	11.46	NS
Shear force (N)	42.85±0.43	48.93±0.96	49.82±0.98	49.62±0.62	55.01±0.47	50.50±1.04	35.06	NS
Thigh								
<i>L</i> *	55.12±0.65	52.20±0.88	54.73±0.89	54.03±0.37	55.11±0.52	53.12±1.22	3.33	NS
<i>a</i> *	6.33±0.29	7.64±0.75*	7.09±0.80*	6.54±0.27	6.31±0.48	6.64±0.69	19.11	0.017 ¹
<i>b</i> *	6.90±0.53	7.73±0.51	6.23±0.89	6.42±0.78	6.31±1.23	6.50±0.97	28.67	NS

Note: *Significant by Dunnett’s test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant; *L* * - lightness; *a* * - redness; *e b* * - yellowness.
^aY= 8,7167 - 0,467x + 0,0237x²; R² = 0,97

Table 9. Malondialdehyde production (mg kg^{-1}) in meat of broilers fed diets with levels of inclusion of BPFS in different days of storage.

BPFS (%)	Day			Regression
	1	30	60	
Control	0.878	0.850	0.909	NS
2.5	1.340	0.981	0.978	0.021 ^a
5.0	1.243	0.860	0.894	0.013 ^b
7.5	1.293	0.916	0.994	NS
10.0	1.103	0.878	0.988	NS
12.5	1.390	0.934	0.950	NS
CV (%)	26.90			
Level	0.1511			
Day	< 0.001			
Day x Level	0.6666			

Note: CV = coefficient of variation; NS = nonsignificant

^a $1.2847 - 0.0061x$; $R^2 = 0.75$

^b $1.263 - 0.0207x + 0.0002x^2$; $R^2 = 0.99$

Figure 1. Evolution of lipid oxidation in meat of broiler chickens fed with by-product of passion fruit seed levels.

Table 1. Ingredients and nutritional composition of the experimental diet.

Ingredients	(%)
Maize	64.72
Soybean meal 45%	29.22
Dicalcium phosphate	1.15
Limestone	0.76
Soybean oil	2.88
Salt	0.300
DL-Methionine 99%	0.249
L-Lysine HCl 78.5%	0.266
L-Threonine 98%	0.047
Vitamin and mineral supplements ^a	0.400
Total	100
Calculated nutritional composition^b	
Crude protein (%)	18.75
Metabolizable energy (kcal kg ⁻¹)	3125
Digestible lysine (%)	1.08
Digestible Met + Cys (%)	0.76
Digestible threonine (%)	0.68
Available phosphorus (%)	0.32
Sodium (%)	0.14
Calcium (%)	0.69
Chlorine (%)	0.23
Potassium (%)	0.72
Electrolyte balance (mEq kg ⁻¹)	179

Note: ^aVitamin and mineral supplements (content per kg ration): Vit. A 9000.00 UI; Vit. D3 1800.00 UI; Vit. E 28.00 UI; Vit. K3 1.67 mg; Vit. B1 1.20 mg; Vit. B2 4.00 mg; Vit. B12 12.00 mcg; Niacin 28.00 mg; Calcium pantothenate 10.00 mg; Folic acid 0.56 mg; Biotin 0.06 mg; Fe 50.00 g; Cu 12.00 mg; I 1.00 mg; Zn 50.00 g; Mn 0.60 g; Se 0.30 mg; Co 0.20 mg.

^bCalculated based on Rostagno et al. (2011).

Table 2. Ingredients and nutritional composition of the experimental diets from 1 to 21 days and from 22 to 42 days of age.

Ingredientes	Levels by-product of passion fruit seed inclusion (%)											
	1 to 21 days						22 to 42 days					
	Control	2.5	5.0	7.5	10.0	12.5	Control	2.5	5.0	7.5	10.0	12.5
Maize	57.06	55.19	53.31	51.44	49.56	47.69	64.70	62.83	60.95	59.08	57.20	55.33
Soybean meal 45%	36.76	36.44	36.12	35.80	35.47	35.15	29.23	28.90	28.58	28.26	27.94	27.61
By-product of passion fruit seed	0.00	2.50	5.00	7.50	10.00	12.50	0.00	2.50	5.00	7.50	10.0	12.5
Dicalcium phosphate	1.70	1.70	1.69	1.68	1.67	1.67	1.15	1.14	1.13	1.13	1.12	1.11
Limestone	0.82	0.82	0.82	0.83	0.83	0.83	0.76	0.76	0.77	0.77	0.78	0.78
Soybean oil	2.20	1.87	1.54	1.20	0.87	0.53	2.89	2.56	2.22	1.89	1.55	1.22
Salt	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
DL-Methionine 99%	0.321	0.330	0.339	0.348	0.358	0.367	0.249	0.258	0.268	0.277	0.286	0.295
L-Lysine HCl 78.5%	0.244	0.259	0.275	0.290	0.305	0.320	0.266	0.281	0.297	0.312	0.327	0.343
L-Threonine 98%	0.078	0.088	0.098	0.109	0.119	0.129	0.047	0.058	0.068	0.078	0.089	0.099
Vitamin and mineral supplements ^{a, b}	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
BHT ^c	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated nutritional composition^d												
Crude protein (%)	21.60	21.60	21.60	21.60	21.60	21.60	18.75	18.75	18.75	18.75	18.75	18.75
Metabolizable energy (kcal kg ⁻¹)	2.980	2.980	2.980	2.980	2.980	2.980	3.125	3.125	3.125	3.125	3.125	3.125
Digestible lysine (%)	1.24	1.24	1.24	1.24	1.24	1.24	1.08	1.08	1.08	1.08	1.08	1.08
Digestible Met + Cys (%)	0.90	0.90	0.90	0.90	0.90	0.90	0.76	0.76	0.76	0.76	0.76	0.76
Digestible threonine (%)	0.81	0.81	0.81	0.81	0.81	0.81	0.68	0.68	0.68	0.68	0.68	0.68
Available phosphorus (%)	0.43	0.43	0.43	0.43	0.43	0.43	0.32	0.32	0.32	0.32	0.32	0.32
Sodium (%)	0.18	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.14	0.14	0.14	0.14
Calcium (%)	0.87	0.87	0.87	0.87	0.87	0.87	0.69	0.69	0.69	0.69	0.69	0.69
Chlorine (%)	0.29	0.29	0.29	0.29	0.29	0.29	0.23	0.23	0.23	0.23	0.23	0.23
Potassium (%)	0.83	0.83	0.82	0.80	0.79	0.78	0.72	0.71	0.70	0.69	0.68	0.67
Crude fiber	2.93	3.54	4.15	4.76	5.37	5.98	2.66	3.27	3.88	4.49	5.11	5.72
Electrolyte balance (mEq kg ⁻¹)	209	207	204	201	199	196	179	176	173	171	168	165

Note: ^a (1 to 21 days of age) Vitamin supplement (content per kg ration): Vit. A 11666.68 UI; Vit. D3 2333.32 UI; Vit. E 35.00 UI; Vit. K3 1.73 mg; Vit. B1 1.63 mg; Vit. B2 5.33 mg; Vit. B12 16.67 mg; Niacin 35.93 mg; Calcium pantothenate 12.67 mg; Folic acid 0.80 mg; Biotin 0.10 mg. Mineral supplement (content per kg ration): Fe 50.40 g; Cu 12.29 mg; I 0.99 mg; Zn 50.40 g; Mn 0.06 g; Se 0.24 mg; Co 0.20 mg.
^b (22 to 42 days of age) Vitamin supplement (content per kg ration): Vit. A 9000.00 UI; Vit. D3 1800.00 UI; Vit. E 28.00 UI; Vit. K3 1.67 mg; Vit. B1 1.20 mg; Vit. B2 4.00 mg; Vit. B12 12.00 mcg; Niacin 28.00 mg; Calcium pantothenate 10.00 mg; Folic acid 0.56 mg; Biotin 0.06 mg. Mineral supplement (content per kg ration): Fe 50.00 g; Cu 12.00 mg; I 1.00 mg; Zn 50.00 g; Mn 0.60 g; Se 0.30 mg; Co 0.20 mg.
^c BHT, antioxidant butylhydroxytoluene.
^d Calculated based on Rostagno et al. (2011).

Table 3. Performance (mean $\pm$ standard error) of 1 to 21 and 1 to 42d-old male broilers fed diets with levels of inclusion of BPFS.

	Levels by-product of passion fruit seed inclusion (%)						CV (%)	R
	Control	2.5	5.0	7.5	10.0	12.5		
1 to 21 days								
Weight gain (g)	756.85±15.26	744.63±8.52	769.00±11.93	749.83±11.87	743.88±11.54	734.66±13.67	3.67	NS
Feed intake (g)	1057.71±13.88	1060.09±14.18	1095.73±18.68	1078.44±18.78	1083.95±10.71	1080.58±16.65	3.27	NS
Feed conversion	1.398±0.013	1.424±0.009	1.425±0.014	1.438±0.011*	1.458±0.017*	1.471±0.011*	1.98	0.001 ^a
1 to 42 days								
Weight gain (g)	2728.70±22.64	2671.30±30.59	2781.64±42.97	2674.18±44.19	2696.01±39.16	2649.49±36.66	3.05	NS
Feed intake (g)	4427.38±37.67	4431.92±35.43	4628.08±70.38	4489.59±55.60	4551.65±39.03	4562.91±64.20	2.59	NS
Feed conversion	1.623±0.006	1.660±0.016	1.664±0.009	1.680±0.014*	1.689±0.019*	1.722±0.010*	1.77	0.001 ^b

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

^aY = 1.4047 + 0.0051x; R² = 0.94

^bY = 1.6377 + 0.006x; R² = 0.91

Table 4. Total cholesterol and triglycerides (mean $\pm$ standard error) of 21- and 42-d-old broilers fed diets with levels of inclusion of BPFS.

	Levels by-product of passion fruit seed inclusion (%)							R
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	
21 days								
Total cholesterol (mg dL ⁻¹)	109.90±2.72	108.71±5.68	107.72±6.24	107.62±2.86	107.51±8.18	107.26±4.50	12.21	NS
Triglycerides (mg dL ⁻¹)	111.06±9.00	101.78±8.80	98.69±3.61	94.17±4.24	85.72±5.15	84.02±7.34	17.13	0.019 ^a
42 days								
Total cholesterol (mg dL ⁻¹)	118.08±4.89	112.05±7.65	109.17±4.57	105.40±6.91	105.62±4.71	103.31±2.43	12.31	NS
Triglycerides (mg dL ⁻¹)	70.40±4.03	70.00±6.54	69.79±1.61	69.83±8.47	65.76±3.36	64.12±2.92	18.13	NS

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

^aY = 107.42 - 1.9396x; R² = 0.96

Table 5. Relative weights of gastrointestinal tract organs and small intestine length (mean ± standard error) in broilers fed diets with levels of inclusion of BPFS, at 21 and 42 d of age.

	Levels by-product of passion fruit seed inclusion (%)							
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	R
21 days								
Proventriculus (%)	0.59±0.03	0.55±0.02	0.58±0.003	0.60±0.03	0.57±0.01	0.62±0.03	8.07	NS
Gizzard (%)	2.05±0.11	2.22±0.13	2.18±0.08	2.10±0.11	2.35±0.22	2.31±0.05	13.10	NS
Small intestine (%)	3.95±0.23	3.87±0.16	4.08±0.13	4.05±0.17	3.89±0.11	3.97±0.04	8.47	NS
Cecum (%)	0.79±0.03	0.70±0.05	0.77±0.04	0.72±0.02	0.80±0.04	0.90±0.05	11.77	NS
Liver (%)	3.36±0.16	3.32±0.13	3.38±0.08	3.45±0.08	3.30±0.14	3.42±0.14	8.30	NS
Pancreas (%)	0.35±0.03	0.34±0.02	0.38±0.02	0.38±0.02	0.34±0.01	0.37±0.03	13.72	NS
Small intestine (cm)	147.67±4.94	156.17±5.98	148.50±2.60	159.60±3.67	153.83±5.90	146.67±5.88	7.34	NS
42 days								
Proventriculus (%)	0.29±0.01	0.28±0.01	0.31±0.035	0.30±0.01	0.30±0.02	0.29±0.02	15.42	NS
Gizzard (%)	1.14±0.05	1.28±0.10	1.25±0.07	1.42±0.16	1.35±0.06	1.30±0.05	15.85	NS
Small intestine (%)	2.34±0.12	2.42±0.10	2.46±0.08	2.28±0.15	2.40±0.03	2.35±0.13	10.34	NS
Cecum (%)	0.48±0.02	0.53±0.04	0.54±0.01	0.50±0.03	0.63±0.03	0.54±0.04	12.86	NS
Liver (%)	2.10±0.09	1.97±0.06	1.85±0.073*	1.82±0.08*	1.80±0.07*	2.02±0.08	8.93	0.012 ^a
Pancreas (%)	0.19±0.01	0.20±0.01	0.20±0.02	0.22±0.01	0.19±0.01	0.20±0.01	13.74	NS
Small intestine (cm)	219.00±6.95	211.80±3.87	224.83±6.02	202.00±6.76	217.83±6.68	219.83±6.69	6.47	NS

Note: *Significant by Dunnett’s test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.
^aY = 2.2196 – 0.1157x + 0.0078x²; R² = 0.90

Table 6. Villus height, crypt depth and villus height: crypt depth ratio (mean $\pm$ standard error) of 21 and 42-d-old broilers fed diets with levels of inclusion of BPFS.

	Levels by-product of passion fruit seed inclusion (%)							
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	R
21 days								
Villus height (μm)								
Duodenum	1201.81±55.21	1149.93±46.43	1069.17±71.76	1132.05±81.83	1188.81±53.79	1132.95±71.07	11.26	NS
Jejunum	604.46±37.91	549.56±47.88	643.62±44.06	504.01±49.75	605.50±44.99	585.78±30.68	14.78	NS
Crypt depth (μm)								
Duodenum	47.57±1.94	41.77±2.36	47.11±2.00	43.30±0.61	44.47±2.84	44.88±0.65	8.00	NS
Jejunum	36.17±1.96	34.17±1.84	39.78±3.63	39.12±1.79	41.05±2.52	41.25±1.59	12.08	NS
Villus height : crypt depth ratio								
Duodenum	26.39±0.25	29.46±3.27	21.01±0.63	26.11±1.75	28.52±1.00	25.26±1.63	14.12	NS
Jejunum	16.92±1.64	16.23±1.58	16.60±1.98	12.85±1.01	14.84±1.05	14.26±0.88	18.54	NS
42 days								
Villus height (μm)								
Duodenum	1369.93±45.75	1383.93±27.39	1308.12±35.87	1420.45±26.53	1295.00±8.40	1363.23±0.58	4.21	NS
Jejunum	954.82±9.73	914.31±12.47	979.00±61.60	943.90±9.00	841.76±37.53*	737.35±3.76*	6.92	0.001 ^a
Crypt depth (μm)								
Duodenum	44.45±0.81	43.78±2.27	51.37±3.08	45.40±2.05	51.52±1.89	45.71±2.52	9.43	NS
Jejunum	42.30±0.91	41.62±1.93	50.46±1.53*	46.47±1.57	38.96±2.27	40.65±1.63	7.81	NS
Villus height : crypt depth ratio								
Duodenum	29.09±0.87	30.18±1.19	24.63±1.41	32.50±1.17	24.51±1.54	28.86±2.45	10.79	NS
Jejunum	22.61±0.70	22.12±1.19	19.60±1.83	20.36±0.49	21.74±1.13	15.79±0.72*	10.84	NS

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

^aY = 1070.6 – 27.647x; R² = 0.65

Tabela 7. Carcass and parts yields (mean $\pm$ standard error) of broilers fed diets with levels of inclusion of BPFS and slaughtered at 42 d of age.

	Levels by-product of passion fruit seed inclusion (%)							
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	R
Carcass (%)	71.99±0.51	72.62±0.45	72.21±0.39	72.43±0.58	71.95±0.66	72.24±0.60	1.67	NS
Breast (%)	40.00±0.58	40.46±0.90	41.65±1.13	42.05±0.95	40.95±0.90	40.90±0.91	4.95	NS
Thigh (%)	31.02±0.43	30.42±0.43	30.31±0.77	31.67±2.40	31.19±0.74	31.50±0.92	8.38	NS
Wing (%)	10.14±0.22	10.09±0.33	9.71±0.26	10.15±0.32	9.80±0.21	10.05±0.24	5.99	NS
Back (%)	18.62±0.36	16.07±2.59	18.09±0.58	17.88±0.44	17.73±0.78	18.18±0.68	14.91	NS
Fat (%)	2.32±0.23	2.18±0.34	2.22±0.17	2.26±0.27	2.08±0.25	1.67±0.29	27.89	NS

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant.

Table 8. Breast and thigh meat quality parameters (mean $\pm$ standard error) of broilers fed diets with levels of inclusion of BPFS and slaughtered at 42 d of age.

	Levels by-product of passion fruit seed inclusion (%)							
	Control	2.5	5.0	7.5	10.0	12.5	CV (%)	R
	Breast							
<i>L</i> *	46.54±2.01	47.49±1.63	46.74±1.13	46.73±1.51	47.12±0.72	45.68±1.77	7.28	NS
<i>a</i> *	4.54±0.43	4.61±0.30	4.85±0.97	5.47±0.60	4.21±0.64	5.54±0.43	27.60	NS
<i>b</i> *	6.31±1.09	6.21±0.81	6.76±0.78	6.56±0.49	5.96±0.63	6.31±0.74	27.36	NS
pH	6.33±0.08	6.40±0.06	6.33±0.06	6.47±0.06	6.41±0.08	6.41±0.07	2.48	NS
Water-holding capacity (%)	64.68±1.73	64.75±1.36	65.38±1.09	67.04±0.76	67.00±0.65	66.03±0.64	3.78	NS
Cooking weight loss (%)	29.33±0.91	31.33±2.14	31.41±0.93	30.33±1.45	30.40±1.27	30.09±2.15	11.46	NS
Shear force (N)	42.85±0.43	48.93±0.96	49.82±0.98	49.62±0.62	55.01±0.47	50.50±1.04	35.06	NS
	Thigh							
<i>L</i> *	55.12±0.65	52.20±0.88	54.73±0.89	54.03±0.37	55.11±0.52	53.12±1.22	3.33	NS
<i>a</i> *	6.33±0.29	7.64±0.75*	7.09±0.80*	6.54±0.27	6.31±0.48	6.64±0.69	19.11	0.017 ¹
<i>b</i> *	6.90±0.53	7.73±0.51	6.23±0.89	6.42±0.78	6.31±1.23	6.50±0.97	28.67	NS

Note: *Significant by Dunnett's test at 5%; R = Regression; CV = coefficient of variation; NS = nonsignificant; L^* - lightness; a^* - redness; $e b^*$ - yellowness.

$$^aY = 8,7167 - 0,467x + 0,0237x^2; \quad R^2 = 0,97$$

Table 9. Malondialdehyde production (mg kg^{-1}) in meat of broilers fed diets with levels of inclusion of BPFS in different days of storage.

BPFS (%)	Day			Regression
	1	30	60	
Control	0.878	0.850	0.909	NS
2.5	1.340	0.981	0.978	0.021 ^a
5.0	1.243	0.860	0.894	0.013 ^b
7.5	1.293	0.916	0.994	NS
10.0	1.103	0.878	0.988	NS
12.5	1.390	0.934	0.950	NS
CV (%)	26.90			
Level	0.1511			
Day	< 0.001			
Day x Level	0.6666			

Note: CV = coefficient of variation; NS = nonsignificant

^a $1.2847 - 0.0061x$; $R^2 = 0.75$

^b $1.263 - 0.0207x + 0.0002x^2$; $R^2 = 0.99$