Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Agroindustrial residues from tropical fruits in swine diets affect performance, digestibility, carcass characteristics, and meat quality

Ceilda Inocêncio dos Santos
UFPB: Universidade Federal da Paraiba
Alice Soares Pereira
UFPB: Universidade Federal da Paraiba
Jorge Luiz Santos de Almeida
UFPB: Universidade Federal da Paraiba
Cícero Jorge de Medeiros
UFPB: Universidade Federal da Paraiba
Gustavo Fideles Rocha
UFPB: Universidade Federal da Paraiba
Mekiciene de Brito Silva
UFPB: Universidade Federal da Paraiba
Marcos Rafael de Souza Rodrigues
UFPB: Universidade Federal da Paraiba
Jorge Vinícius Fernandes Lima Cavalcanti
UFPE: Universidade Federal de Pernambuco
Pedro Henrique Watanabe
UFPB: Universidade Federal da Paraiba
Urbano dos Santos Ruiz
ESALQ-USP: Universidade de Sao Paulo Escola Superior de Agricultura Luiz de Queiroz
Leonardo Augusto Fonseca Pascoal
leonardo@cchsa.ufpb.br

UFPB: Universidade Federal da Paraiba https://orcid.org/0000-0002-7225-5251

Research Article

Keywords: pineapple, acerola, antioxidant, cajá, phenolic compounds, dietary fiber

Posted Date: November 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11405625/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Abstract

The objective of this study was to evaluate the inclusion of agro-industrial by-products of tropical fruits (pineapple, acerola, and cajá) as sources of fiber and bioactive compounds with antioxidant potential on the performance, digestibility, serum biochemical parameters, carcass characteristics, and meat quality of pigs. Twenty-five female pigs from the same commercial genetic line, with an average initial weight of 50.89 ± 3.24 kg, were distributed in a randomized block design. The treatments consisted of: a positive control diet with the inclusion of butylated hydroxytoluene (BHT) (PC), the only diet containing BHT; a negative control diet (NC); a diet containing 7.5% pineapple by-product meal (PB); a diet containing 7.5% acerola by-product meal (AC); and a diet containing 7.5% cajá by-product meal (CJ), totaling five treatments and five replicates. The inclusion of the by-products resulted in distinct responses regarding zootechnical performance, digestibility, meat quality, and biochemical parameters. The treatment with PB resulted in better average daily gain, feed conversion ratio, and nutrient utilization, in addition to maintaining blood parameters within normal ranges and promoting meat with physicochemical characteristics and greater oxidative stability. The inclusion of acerola by-product (AC) had a negative effect on performance and digestibility, interfering with protein oxidation in the meat. The diet containing cajá by-product (CJ) showed higher acetic acid production, possibly related to its type of fiber. It is concluded that the inclusion of agro-industrial by-products of tropical fruits influences performance, digestibility, and pork quality, with pineapple by-product showing the best results.

INTRODUCTION

The use of functional ingredients in pig diets may transfer bioactive compounds to tissues and enrich meat and meat products, in addition to contributing to animal health due to the substances present in these ingredients. Such beneficial properties can be found in agro-industrial fruit by-products, which contain phenolic compounds and antioxidants (TSIPLAKOU et al., 2021). These by-products refer to solid residues such as peels, pits, seeds, and pulp, which represent approximately 50% of the fresh fruit.

The inclusion of by-products such as acerola, pineapple, and cajá in pig diets may provide benefits to animals, since these ingredients are rich in a wide variety of phytochemicals, also known as phytobiotics or phytogenics, such as polyphenols, which exhibit potential antioxidant and antimicrobial effects (SANTANA-MÉRIDAS; GONZÁLEZ-COLOMA; SÁNCHEZ-VIOQUE, 2012).

Agro-industrial fruit by-products are also noteworthy for their content of phenolic compounds, whose antioxidant activity has been reported in the literature (SPIGNO et al., 2017). In addition to acting in the control of oxidative processes, these bioactive compounds may exert additional effects, such as stimulating the immune response, reducing inflammatory processes, promoting intestinal health, and exhibiting antimicrobial activity (ERINLE; ADEWOLE, 2022). Furthermore, substances such as carotenoids and flavonoids may accumulate in animal tissues, increasing the antioxidant capacity of meat and contributing to the maintenance of sensory attributes such as color, flavor, and tenderness (MELÉNDEZ-MARTÍNEZ et al., 2022). Therefore, the use of these by-products in pig diets may benefit both animal health and the quality of animal-derived products.

In addition to the natural factors and beneficial properties present in these by-products, they also stand out as sources of dietary fiber. This aspect becomes important given the growing concern regarding fat content in pork, since the inclusion of fiber in the diet may influence lipid deposition in finishing animals (LI et al., 2022). Moreover, the incorporation of fibrous ingredients derived from these by-products may contribute to the modulation of metabolism and body composition in animals (EGEA et al., 2021).

Due to their fiber and phenolic compound content, agro-industrial by-products have the potential to be safely and functionally included in pig diets when used at moderate levels. VASCONCELOS et al. (2020), when evaluating the use of pineapple meal in finishing pig diets, concluded that up to 10% can be used as an energy diluent without impairing carcass traits or meat quality. Complementing these findings, LEAL *et al*. (2021) showed that 3% acerola by-product in piglet diets improves performance without altering digestibility or metabolic parameters. However, a gap in the literature is observed regarding the use of cajá by-product, highlighting the importance of further research investigating its effects on pig nutrition and its zootechnical impacts.

Therefore, the objective of this study was to evaluate the effects of including 7.5% agro-industrial by-products of acerola, pineapple, and cajá in pig diets on growth performance, nutrient digestibility, blood parameters, carcass characteristics, and meat quality.

MATERIAL AND METHODS

Experimental Site Characterization

The experiment was conducted at the Swine Research Laboratory of the Department of Animal Science, Center for Human, Social and Agrarian Sciences, Campus III, Federal University of Paraíba, Bananeiras, PB, Brazil (6°45'12.9" S latitude, 35°38'57.5" W longitude, and average altitude of 552 m). The study was approved by the Animal Use Ethics Committee (CEUA) of the Federal University of Paraíba under protocol number 2836170122.

Experimental Design, Animals, and Diets

The agro-industrial by-products of pineapple (PB), acerola (AC), and cajá (CJ) were obtained from a juice-processing agro-industry, Indústria Transformadora de Frutas S.A. (Intrafrut), located in João Pessoa, PB, Brazil. Subsequently, the by-products were sun-dried for a period of 72 to 96 h until reaching approximately 18% moisture content. They were then ground in a hammer mill using a 3-mm mesh sieve, equipped with a cyclone exhaust system.

The experiment lasted 56 days and was conducted during the growing and finishing phases. Twenty-five female pigs from the same commercial genetic line, approximately 90 days of age, with an average initial body weight of 50.89 ± 3.24 kg, were used. The animals were housed in pens with solid flooring measuring 2.30 × 1.70 m, equipped with masonry feeders and nipple drinkers. The maximum and minimum temperatures recorded during the experimental period were 23.8°C and 20.0°C, respectively, while relative humidity ranged from 87% to 72%.

A randomized block design was adopted to control differences in initial body weight, dividing the gilts into five treatment groups: Positive control diet with inclusion of synthetic antioxidant (BHT) (PC); Negative control diet without synthetic antioxidant (NC); Diet containing 7.5% pineapple by-product meal (PB); Diet containing 7.5% acerola by-product meal (AC); and Diet containing 7.5% cajá by-product meal (CJ). The experimental diets were formulated to meet the nutritional requirements of animals according to the recommendations of ROSTAGNO et al. (2024) for the growing (Table 1) and finishing (Table 2) phases.

Table 1
Chemical composition and percentage of experimental diets during the growing phase (45 to 70 kg).

Ingredients (g·kg⁻¹)	**Experimental diets (%)**				
	CP	**CN**	**AB**	**AC**	**CJ**
Corn grain, 7.98% CP	75.387	75.387	67.645	67.758	66.728
Soybean meal 45% CP	18.730	18.730	19.034	18.313	19.190
By-product	0.000	0.000	7.500	7.500	7.500
Inert[4]	2.179	2.199	1.020	1.020	1.020
Dicalcium phosphate	1.071	1.071	1.088	1.096	1.035
Limestone	0.707	0.707	0.660	0.600	0.261
Soybean oil	0.500	0.500	1.693	2.287	2.824
Common salt	0.430	0.430	0.411	0.412	0.412
L-Lysine HCl	0.398	0.398	0.381	0.403	0.402
Vit.-Min. Supplement [2]	0.200	0.200	0.200	0.200	0.200
L-Threonine	0.180	0.180	0.172	0.185	0.190
DL-Methionine	0.135	0.135	0.141	0.145	0.152
L-Tryptophan	0.048	0.048	0.043	0.054	0.049
L-Valine	0.015	0.015	0.012	0.025	0.036
BHT	0.020	0.000	0.000	0.000	0.000
Nutrients and energy					
Metabolizable energy (kcal·kg⁻¹) [1]	3250	3250	3250	3250	3250
Crude protein (%)[1]	15.190	15.190	15.190	15.190	15.190
Methionine (%)[1]	0.342	0.342	0.346	0.348	0.351
Lysine (%)[1]	0.944	0.944	0.944	0.944	0.944
Threonine (%)[1]	0.642	0.642	0.642	0.642	0.642
Tryptophan (%)[1]	0.189	0.189	0.189	0.189	0.189
Valine (%)[1]	0.651	0.651	0.651	0.651	0.651
Arginine (%)[1]	0.858	0.858	0.858	0.856	0.842
Histidine (%)[1]	0.362	0.362	0.357	0.342	0.350
Phenylalanine (%)[1]	0.644	0.644	0.647	1.080	0.629
NDF (%)[1]	12.802	12.802	16.324	16.793	17.059
ADF (%)[1]	3.759	3.759	5.301	7.075	8.378
Calcium (%)[1]	0.600	0.600	0.586	0.586	0.586
Available phosphorus (%)[1]	0.277	0.277	0.277	0.277	0.277

Ingredients (g·kg⁻¹)	Experimental diets (%)				
	CP	CN	AB	AC	CJ
Sodium (%)[1]	0.180	0.180	0.172	0.172	0.172
Potassium (%)[1]	0.618	0.618	0.598	0.584	1.927
Chlorine (%)[1]	0.333	0.333	0.316	0.315	0.315
Total phenolics (AG mg/100mL)[3]	12.230	10.700	10.330	13.020	11.180
$ABTS^{+}$ (µmol ET/100g)[3]	482.430	396.730	469.740	624.060	637.480
mg MDA/kg[3]	0.620	0.650	1.170	1.560	1.000

[1]As described by Rostagno et al. (2024); [2]Composition of the mineral and vitamin supplement: vitamin A (IU/kg)- 3.633.333.000; vitamin D3 (IU/kg)- 900.000.000; vitamin K3 (mg/kg)- 1.733.333; vitamin B1 (mg/kg)- 588.000; vitamin B2 (mg/kg)- 2.240.000; vitamin B6 (mg/kg)- 1.155.000; vitamin B12 (mcg/kg)- 13.000.000; vitamin E (IU/kg)- 27.700.000; calcium pantothenate (mg/kg)- 8.676.667; niacin (mg/kg)- 16.529.330; Folic acid (mg/kg) – 192.000; biotin (mg/kg) – 62.667; zinc (mg/kg) – 52.926.660; iron (mg/kg) – 37.100.000; copper (mg/kg) – 5.840.000; manganese (mg/kg) – 17.800.000; iodine (mg/kg) – 447.333; selenium (mg/kg) – 161.333; cobalt (mg/kg) – 82.333; [3]Values analyzed. Positive Control (CP); Negative Control (CN); Pineapple (AB); Acerola (AC); Cajá (CJ); [4]Washed sand.

Table 2
Chemical composition and percentage of experimental diets during the finishing phase (70 to 100 kg).

Ingredients (g·kg⁻¹)	**Experimental diets (%)**				
	CP	**CN**	**AB**	**AC**	**CJ**
Corn grain, 7.98% CP	81.900	81.900	74.940	75.018	73.989
Soybean meal 45% CP	12.350	12.350	12.522	11.807	12.684
By-product	0.000	0.000	7.500	7.500	7.500
Inert[4]	2.565	2.565	1.020	1.020	1.020
Dicalcium phosphate	0.931	0.931	0.946	0.954	0.893
Limestone	0.600	0.600	0.588	0.539	0.199
Soybean oil	0.300	0.300	1.183	1.785	2.321
Common salt	0.377	0.377	0.378	0.381	0.381
L-Lysine HCl	0.410	0.410	0.394	0.416	0.415
Vit.-Min. Supplement [2]	0.200	0.200	0.200	0.200	0.200
L-Threonine	0.168	0.168	0.158	0.172	0.177
DL-Methionine	0.106	0.106	0.108	0.113	0.119
L-Tryptophan	0.053	0.053	0.048	0.059	0.054
L-Valine	0.020	0.020	0.014	0.035	0.047
BHT	0.020	0.000	0.000	0.000	0.000
Nutrients and energy					
Metabolizable energy (kcal·kg⁻¹) [1]	3250	3250	3250	3250	3250
Crude protein (%)[1]	12.790	12.790	12.790	12.790	12.790
Methionine (%)[1]	0.288	0.288	0.287	0.289	0.293
Lysine (%)[1]	0.801	0.801	0.800	0.800	0.800
Threonine (%)[1]	0.545	0.545	0.544	0.544	0.540
Tryptophan (%)[1]	0.169	0.169	0.160	0.160	0.160
Valine (%)[1]	0.554	0.554	0.552	0.560	0.560
Arginine (%)[1]	0.681	0.681	0.681	0.679	0.665
Histidine (%)[1]	0.307	0.307	0.301	0.286	0.294
Phenylalanine (%)[1]	0.531	0.531	0.534	0.497	0.516
NDF (%)[1]	12.980	12.980	16.597	17.062	17.328
ADF (%)[1]	3.518	3.518	5.076	6.850	8.153
Calcium (%)[1]	0.508	0.508	0.506	0.510	0.510
Available phosphorus (%)[1]	0.240	0.240	0.240	0.240	0.240

Ingredients (g·kg⁻¹)	Experimental diets (%)				
	CP	CN	AB	AC	CJ
Sodium (%)[1]	0.159	0.159	0.159	0.160	0.160
Potassium (%)[1]	0.305	0.305	0.299	0.307	0.300
Chlorine (%)[1]	14.720	11.700	12.050	18.540	9.010
Total phenolics (AG mg/100mL)[3]	443.990	439.640	516.600	836.990	531.090
$ABTS^+$ (µmol ET/100g)[3]	0.520	0.730	1.040	1.440	0.820

[1]As described by Rostagno et al. (2024); [2]Composition of the mineral and vitamin supplement: vitamin A (IU/kg)- 2.440.000.000; vitamin D3 (IU/kg) 596.666.600; vitamin K3 (mg/kg)- 1.161.333; vitamin B1 (mg/kg)- 392.000; vitamin B2 (mg/kg)- 1.477.333; vitamin B6 (mg/kg)- 772.200; vitamin B12 (mcg/kg)- 8.533.333; vitamin E (IU/kg)- 15.900.000; calcium pantothenate (mg/kg)-5.801.333; niacin (mg/kg)- 11.054.400; Folic acid (mg/kg) – 128.000; biotin (mg/kg) – 42.00; zinc (mg/kg) – 35.400.800; iron (mg/kg) – 24.852.800; copper (mg/kg) – 3.915.200; manganese (mg/kg) – 11.900.000; iodine (mg/kg) – 296.867; selenium (mg/kg) – 108.833; cobalt (mg/kg) – 81.067; [3]Values analyzed. Positive Control (PC); Negative Control (NC); Pineapple (PC); Acerola (AC); Cajá (CJ); [4]Washed sand.

Performance and Digestibility

Female pigs were weighed at the beginning of the experiment and on days 28 and 56, corresponding to the end of the growing 2 and finishing phases, respectively. Average body weight (BW) and average daily gain (ADG, kg/day) were calculated for each experimental unit using the live weight of the female pigs. To obtain average daily feed intake (ADFI, kg/day) per experimental unit, the remaining feed was subtracted from the total feed supplied during the period and divided by the number of days in the experimental period. Feed conversion ratio (FCR, kg/kg) was calculated as the ratio between ADFI and ADG.

For the evaluation of digestibility of the experimental diets, the partial fecal collection method was adopted, with feces collected directly from the animals' rectum at the end of each phase of the performance trial. During the growing period, collection was performed between days 108 and 114, and during the finishing period, between days 137 and 143. Celite® 545 at 1% was used as an indigestibility marker and was added to the diet. The feed containing the marker was supplied for three consecutive days to stabilize marker flow throughout the gastrointestinal tract. After this period, feces were collected for four consecutive days during the morning and afternoon. Subsequently, the samples were homogenized and placed in plastic bags and stored at -18°C until analysis. Feed samples were also collected and stored under the same conditions for laboratory evaluation.

For analysis, fecal samples were thawed at room temperature, homogenized, pre-dried at 55°C in a forced-air oven, and ground in a knife mill (E650, Marconi®, Piracicaba, SP, Brazil). Subsequently, dry matter (DM), mineral matter (MM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) were determined according to AOAC (2005). Gross energy (GE) was determined by bomb calorimetry (Parr® 6100, Parr Instrument Company, Moline, IL, USA). Marker recovery was performed using acid-insoluble ash (AIA) according to the procedures described by Scott and Boldaji (1997).

Blood Biochemical Analysis

At the end of each period (118 and 146 days of age), approximately 13 mL of blood was collected directly from the jugular vein of each animal and centrifuged at 3,900 rpm for 10 minutes to obtain blood serum. The serum was subsequently stored in a freezer at approximately – 18°C until analysis.

Blood serum samples were analyzed using an automated biochemical analyzer (Labmax 240) with the following commercial Labtest® kits: Aspartate aminotransferase (AST), AST Liquiform kit (ref. 109); gamma-glutamyl transferase (GGT), GGT Liquiform kit (ref. 105); urea (UR), Urea UV Liquiform kit (ref. 104); creatinine (CRE), Creatinine K kit (ref. 96); total cholesterol (TC), Cholesterol

Liquiform kit (ref. 76); triglycerides (TRIG), Triglycerides Liquiform kit (ref. 87); high-density lipoprotein (HDL), HDL kit (ref. 145); and low-density lipoprotein (LDL), LDL kit (ref. 146).

Slaughter

At the end of the experimental period, the animals were slaughtered following the humane slaughter procedures described by CONCEA and MAPA (2020), after a 12-hour feed withdrawal period to avoid interference with cecal content collection, blood sampling, and meat quality assessments.

On the day of slaughter, the animals were weighed to obtain slaughter weight. Subsequently, animals within each block were initially stunned by electronarcosis, followed by exsanguination through the jugular vein.

Thereafter, the abdominal cavity was opened, viscera were removed, and the liver, spleen, and kidneys were collected and weighed to calculate relative organ weights. The carcasses were then washed with chlorinated water, split longitudinally, and weighed to determine hot carcass weight. Carcasses were stored under refrigeration (4–6°C) for 24 h to allow rigor mortis development and subsequent evaluations.

Short-Chain Fatty Acids

For short-chain fatty acid analysis, 10 mL of cecal content was collected and mixed with 30 mL of formic acid. The samples were then centrifuged to collect the supernatant and maintained under refrigeration until analysis.

Samples were analyzed by gas chromatography using an HP 5890 gas chromatograph equipped with a flame ionization detector. Injector temperature was 180°C, oven temperature 130°C, and detector temperature 180°C.

A volume of 5 µL of sample was injected into a J&W column (60 m length, 0.5 mm internal diameter, and 1 µm stationary phase thickness). Hydrogen was used as the mobile phase at a flow rate of 2 mL/min with a split ratio of 1:10, following adaptations of Erwin, Marco and Emery (1961), Sigma-Aldrich Co. (1998), and Wilson (1971).

Carcass Trait Analysis

On the day of slaughter, animals were weighed before slaughter to obtain slaughter weight, which was used to calculate carcass and cut yields. After evisceration, carcasses were split longitudinally, cleaned, weighed to obtain hot carcass weight (HCW), and carcass pH and temperature were measured using a digital pH meter (AKSO AK 103) 45 minutes after evisceration. Carcasses were then transferred to a cold chamber (4°C) for 24 h. After this period, cold carcass weight (CCW), pH, and temperature were measured again, allowing carcass yield calculations according to Bridi and Silva (2007).

Measurements of loin depth (LD) and backfat thickness (BT) were obtained between the last and penultimate ribs, six centimeters from the dorsal midline. These measurements were taken on the same chilled carcass using a caliper to simulate the reading obtained with a carcass-grading probe. Backfat thickness over the Longissimus thoracis muscle was measured according to Bridi and Silva (2007).

Using HCW and CCW values, chilling loss was calculated. Loin eye area and fat area were also measured to calculate the meat-to-fat ratio according to Bridi and Silva (2007).

After evisceration, organs (spleen, liver, and kidneys) and the main commercial cuts, including shoulder, Boston shoulder, loin, ham, head, belly, and ribs, were weighed according to adaptations from ABCS (2014) to calculate yields. The loin cut, corresponding to the Longissimus muscle, was initially weighed to determine yield and subsequently deboned to obtain boneless loin for physicochemical and oxidative analyses of the meat.

For color analysis, loin samples 2.5 cm thick were exposed to room temperature for 40 minutes to allow myoglobin oxygenation (SHIMOKOMAKI, 2003). Color measurements were then performed to obtain L* (lightness), a* (redness), and b* (yellowness) values using a Konica Minolta CR-400 colorimeter with a D65 standard illuminant and a 10° viewing angle.

RESULTS

Nutritional Analysis of the By-Products

The chemical composition of the agro-industrial by-products used in the experiment, pineapple, acerola, and cajá, is presented in Table 3.

Table 3
Nutritional analysis of agroindustrial by-products (pineapple, acerola, and cajá) used in this experiment (% of dry matter).

By-products	Variables								
	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	Hemi (%)	EE (%)	GE (kcal/ cal/g)	PHE (mg/100mL)
Pineapple	87.58	4.19	4.01	81.59	38.97	42.62	0.66	3666.36	11.43
Acerola	86.32	3.56	9.74	69.04	49.24	19.80	0.96	3740.62	23.68
Cajá	90.00	2.99	4.28	74.75	61.12	13.63	2.25	3747.25	19.97

Dry matter (DM); Ash (MM); Crude protein (CP); Neutral detergent fiber (NDF); Acid detergent fiber (ADF); Hemicellulose (Hemi); Ether extract (EE); Gross energy (GE); Total phenolics (Phen). *Calculations based on dry matter.

Animal performance

For performance variables, in Period I there was no difference ($P > 0.05$) for initial weight, weight at 118 days, ADG, ADFI, and FCR (Table 4). In Period II, only ADFI showed no difference ($P > 0.05$). For final weight, ADG, and FCR, diet effects were observed ($P < 0.05$).

Table 4
Productive performance of female pigs fed different experimental diets.

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
Period I (90 to 118 days)							
Body weight at 118 days (kg)	78.12	80.36	79.32	77.68	79.92	0.6574	0.7231
ADG (Kg)	0.97	1.06	1.11	0.90	1.02	0.0344	0.1858
ADFI (Kg)	3.20	3.39	3.24	3.01	3.08	0.0430	0.0976
FCR (Kg)	3.32	3.22	2.89	2.99	3.02	0.0774	0.0693
Period II (90 to 146 days)							
Final body weight (kg)	103.82^{ab}	109.57^{ab}	113.02^{a}	100.28^{b}	107.74^{ab}	1.2944	0.0203
ADG (Kg)	0.94^{ab}	1.05^{ab}	1.11^{a}	0.88^{b}	1.01^{ab}	0.0257	0.0209
ADFI (Kg)	3.21	3.44	3.32	2.95	3.27	0.0608	0.1722
FCR (Kg)	3.42^{a}	3.29^{ab}	2.98^{b}	3.35^{ab}	3.25^{ab}	0.0481	0.0485

Average daily gain (ADG); average daily feed intake (ADFI); feed conversion ratio (FCR); standard error of the mean (SEM). Different letters (a, b, c) in the same row indicate significant differences ($p < 0.05$) among treatment means.

Animals fed diets containing pineapple by-product showed improvements in productive responses, with higher final body weight, average daily gain, and better feed conversion ratio ($P < 0.05$) compared to the other treatments. Conversely, animals fed acerola

by-product diets had lower final body weight and average daily gain (P < 0.05) compared to the pineapple group, with no differences when compared to the other diets.

Apparent nutrient digestibility

In Period I, differences (P < 0.05) were observed among treatments for all variables, except for gross energy digestibility (CDGE; P = 0.0809). Diets containing pineapple by-product showed the highest digestibility values for dry matter (92,95%) and crude protein (79,52%), differing from positive control, negative control, and acerola diets. The cajá by-product diet also presented high dry matter digestibility (93,21%), similar to pineapple, but lower for crude protein, while the negative control diet recorded the lowest coefficient (65,97%). For fiber, the pineapple by-product diet stood out with the highest values of CDNDF digestibility (74.86%) and CDADF digestibility (57,46%). In Period II, pineapple diets maintained the best results for CDNDF digestibility (78,48%) and CDADF digestibility (56,42%), differing from the other treatments (P < 0.05). For CDADF digestibility, pineapple diets were similar to positive control, negative control, and acerola diets, but superior to cajá, which showed the lowest coefficient.

Table 5
Digestibility coefficients of experimental diets in female pigs fed different treatments.

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
Period I (108 to 114 days)							
CDDM	86.98^{b}	87.14^{b}	92.95^{a}	88.14^{b}	93.21^{a}	0.7634	0.0020
CDCP	70.40^{bc}	65.97^{c}	79.52^{a}	73.17^{abc}	76.43^{ab}	1.3253	0.0038
CDNDF	47.34^{c}	49.83^{bc}	74.86^{a}	52.20^{bc}	62.12^{b}	2.4912	0.0004
CDADF	20.18^{c}	38.22^{abc}	57.46^{a}	31.72^{bc}	46.39^{ab}	3.3683	0.0036
CDGE	77.91	79.05	78.73	77.69	83.30	0.6951	0.0809
Period II (137 to 143 days)							
CDDM	93.60	91.99	94.18	93.20	94.68	0.4143	0.3379
CDCP	74.85	71.98	71.44	70.33	74.38	0.8451	0.3588
CDNDF	56.15^{b}	55.98^{b}	78.40^{a}	58.58^{b}	58.93^{b}	1.9799	< .0001
CDADF	45.33^{ab}	41.68^{ab}	56.28^{a}	41.13^{ab}	32.63^{b}	2.5867	0.0764
CDGE	83.58	81.10	81.06	80.40	81.36	0.4827	0.3081

Coefficient of dry matter digestibility (CDDM); coefficient of crude protein digestibility (CDCP); coefficient of neutral detergent fiber digestibility (CDNDF); coefficient of acid detergent fiber digestibility (CDADF); coefficient of gross energy digestibility (CDGE); standard error of the mean (SEM). Lowercase letters (a, b, c) in the same row indicate significant differences (p < 0.05) among treatment means.

Short-chain fatty acids in cecal content

As shown in Fig. 1, differences (P < 0.05) were observed among treatments for acetic acid and propionic acid concentrations, while no differences were found for butyric acid (P > 0.05). The highest concentration of acetic acid was observed in the cecal content of animals fed the diet containing cajá by-product (1.73 g/L), differing from the negative control diet (1.29 g/L) and the pineapple by-product diet (1.33 g/L). For propionic acid, the highest value was recorded in the cecal content of animals fed the positive control diet (1.27 g/L), whereas the lowest was observed in animals fed the pineapple by-product diet (0.70 g/L). Butyric acid concentrations ranged from 0.37 to 0.60 g/L, with no differences among treatments.

Serum parameters

For serum parameters (Table 6), no differences (P > 0.05) were observed for cholesterol (CHOL) and LDL. For the other biochemical parameters, effects of collection period and treatments were observed.

Table 6
Serum biochemical parameters of female pigs fed different experimental diets.

Variables		Experimental diets						Diets	Per	D*P	SEM
	Per	Positive	Negative	Pineapple	Acerola	Cajá	Mean				
AST (UI/L)	I	26.67	24.05	21.91	28.60	36.72	28.39y	0.5827	< 0.001	0.1413	4.6674
	II	64.30	55.45	62.39	50.15	55.26	57.37x				
Mean		45.49	39.69	42.15	39.54	44.98					
GGT (UI/L)	I	35.67	33.06	27.30	25.40	27.15	29.56y	0.0002	< 0.001	0.2951	1.7942
	II	50.69	52.72	36.03	36.81	31.62	40.69x				
Mean		43.18^{a}	41.72^{a}	31.66^{b}	31.10^{b}	29.38^{b}					
UREA (mg/dL)	I	24.24	20.45	18.92	18.37	24.12	21.38	0.0072	0.5260	0.2848	0.8947
	II	20.31	22.04	21.56	13.91	24.19	20.36				
Mean		22.27^{a}	21.33^{a}	20.24^{a}	15.89^{b}	24.47^{a}					
CRE (mg/dL)	I	1.20	1.06	1.14	1.09	1.08	1.51y	0.4021	< 0.001	0.8544	0.0375
	II	1.55	1.54	1.59	1.46	1.42	1.12x				
Mean		1.37	1.34	1.37	1.30	1.25					
CHOL (mg/dL)	I	88.17	88.33	76.41	80.70	81.39	82.82	0.0582	0.8437	0.9180	2.1947
	II	93.78	84.83	76.47	79.40	83.74	83.62				
Mean		90.97	86.49	76.44	80.05	82.36					
TRIG (mg/dL)	I	18.95	35.97	28.49	16.71	19.13	22.44x	0.0030	0.0008	0.2084	1.4069
	II	17.31	18.72	19.31	10.40	15.78	16.59y				
Mean		18.13^{ab}	24.02^{a}	23.87^{a}	13.52^{b}	17.46^{ab}					
HDL (mg/dL)	I	31.20^{Ba}	33.15^{Aa}	27.15^{Aa}	27.96^{Aa}	28.86^{Aa}	29.41	0.0003	0.0768	0.0393	0.9265
	II	39.85$_{Aa}$	32.17^{Aab}	30.64^{Ab}	28.79^{Ab}	27.11^{Ab}	32.08				
Mean		35.53	32.32	28.90	28.37	28.55					
LDL (mg/dL)	I	53.38	50.92	45.00	48.74	49.85	49.62	0.1679	0.2733	0.8675	1.0959
	II	49.97	48.81	43.53	42.21	50.88	47.08				
Mean		51.67	50.02	44.26	45.48	50.37					

Period (Per); aspartate aminotransferase (AST); gamma-glutamyltransferase (GGT); urea (UREA); creatinine (CRE); cholesterol (CHOL); triglycerides (TRIG); high-density lipoprotein (HDL); low-density lipoprotein (LDL); standard error of the mean (SEM). Lowercase letters (a, b) in the same row indicate significant differences (p < 0.05) among treatment means. Lowercase letters (x, y) in the same column indicate significant differences (p < 0.05) among treatment means.

There was an effect (P < 0.05) of diets and periods on GGT and triglyceride values. GGT levels increased from Period I to Period II, being higher in animals fed control diets compared to those fed fruit by-product diets. For triglycerides, the opposite occurred: values decreased from Period I to Period II. Among treatments, animals fed acerola by-product diets showed the lowest values

(13.52 mg/dL), differing from pineapple by-product (23.87 mg/dL) and negative control diets (24.02 mg/dL), while the others did not differ statistically.

Plasma urea was also influenced by diets ($P < 0.05$), with lower values in animals fed acerola by-product compared to the other treatments. For AST, values increased between periods, rising from 28.39 U/L in Period I to 57.37 U/L in Period II. For creatinine, a reduction was observed, with higher values in Period I (1.51 mg/dL) compared to Period II (1.12 mg/dL).

Regarding HDL, there was a significant interaction between period and diet ($P < 0.05$). The lowest values were recorded in the negative control group during Period I (27.15 mg/dL), while the highest were observed in animals fed cajá by-product in Period II (39.85 mg/dL).

Carcass traits and meat quality

Experimental diets influenced ($P < 0.05$) hot carcass weight (HCW), cold carcass weight (CCW), and carcass yield (CY) (Table 7).

Table 7
Carcass traits and meat quality of female pigs fed different experimental diets.

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
Peso abate (Kg)	107.88	111.54	115.43	105.31	111.31	1.4488	0.2347
HCW (Kg)	83.27^{ab}	87.46^{a}	89.27^{a}	77.81^{b}	83.28^{ab}	1.1786	0.0179
CCW (Kg)	81.89^{ab}	86.06^{a}	87.51^{a}	76.47^{b}	81.80^{ab}	1.1627	0.0209
CL (Kg)	1.38	1.40	1.76	1.34	1.48	0.0978	0.2063
CY (Kg)	77.21^{ab}	78.50^{a}	77.92^{a}	73.98^{b}	74.92^{ab}	0.6472	0.0171
RY (Kg)	12.97	12.20	12.71	13.32	12.70	0.1930	0.5500
LY (Kg)	21.28	22.27	20.13	20.36	19.97	0.3768	0.3170
HY (Kg)	27.24	26.76	28.19	28.50	27.00	0.3404	0.4546
SY (Kg)	13.02	13.19	12.59	12.78	12.82	0.1655	0.8800
BBY (Kg)	8.18	7.84	8.39	7.78	8.00	0.2102	0.8325
BY (Kg)	5.80	6.24	6.14	6.32	5.73	0.1463	0.5049
HYD (Kg)	7.00	7.31	7.53	8.43	7.61	0.1593	0.0808
CLEN (cm)	101.42	101.58	101.48	97.76	99.86	0.8421	0.7796
SBT (cm)	25.61	28.76	24.78	24.13	28.79	0.7996	0.2830
LTBT (cm)	19.02	20.84	18.86	17.50	17.70	0.7132	0.7060
MD (cm)	57.90	60.67	67.05	60.78	58.31	1.2522	0.0713
LEA (cm²)	40.20	45.20	47.60	41.00	45.20	1.0725	0.0876
SFA (cm²)	18.20	24.75	22.00	17.50	19.20	1.0354	0.2989
Carne/gordura (cm²/ cm²)	2.28	1.83	2.40	2.51	2.41	0.1334	0.7363
pH 45 min	6.33	6.24	6.37	6.36	6.38	0.0404	0.8043
pH 24 horas	5.66	5.69	6.63	5.52	5.66	0.0278	0.3348

Total hot carcass weight (HCW); total cold carcass weight (CCW); chilling loss (CL); carcass yield (CY); rib yield (RY); loin yield (LY); ham yield (HY); shoulder yield (SY); Boston butt yield (BBY); belly yield (BY); head yield (HYD); carcass length (CLEN); subcutaneous

backfat thickness (SBT); Longissimus thoracis backfat thickness (LTBT); muscle depth (MD); loin eye area (LEA); subcutaneous fat area (SFA); standard error of the mean (SEM). Different letters (a, b, c) in the same row indicate significant differences ($p < 0.05$) among treatment means.

Animals fed diets containing acerola by-product showed lower ($P < 0.05$) hot and cold carcass weights and carcass yield compared to the negative control and pineapple by-product diets, which presented the highest results.

No differences ($P > 0.05$) were observed for the other variables analyzed, including yields of primary cuts (rib, loin, ham, shoulder, Boston butt, belly, and head), carcass length, backfat thickness, muscle depth, loin eye area (LEA), subcutaneous fat area (SFA), and meat-to-fat ratio.

According to the data presented in Table 8, no differences ($P > 0.05$) were observed among treatments for variables related to organ weights of the evaluated animals.

Table 8
Organ weights of female pigs fed different experimental diets.

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
Liver (Kg)	1.53	1.56	1.71	1.48	1.59	0.0411	0.5218
Spleen (Kg)	0.17	0.18	0.18	0.17	0.17	0.0049	0.7347
Kidneys (Kg)	0.31	0.31	0.34	0.33	0.35	0.0077	0.0667

Standard error of the mean (SEM). Lowercase letters (a, b, c) in the same row indicate significant differences ($p < 0.05$) among treatment means.

Proximate composition, color, chroma, and hue of meat

Data regarding the proximate composition of meat from female pigs fed different experimental diets are presented in Table 9. Treatments did not affect the levels of dry matter, moisture, crude protein, or ether extract in the meat.

Table 9
Proximate composition of meat from female pigs fed different experimental diets (% of dry matter).

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
Dry matter (%)	33.16	33.63	32.99	34.41	33.07	0.580	0.990
Moisture (%)	66.84	66.37	67.01	65.59	61.79	1.017	0.512
Crude protein (%)	20.99	21.58	21.16	20.57	20.66	0.205	0.606
Ether extract (%)	3.37	2.66	2.26	3.35	3.50	0.209	0.284

Standard error of the mean (SEM). Lowercase letters (a, b, c) in the same row indicate significant differences ($p < 0.05$) among treatment means.

Proximate composition, meat color, chroma, and hue

For meat color variables, including red intensity (a*), yellow intensity (b*), lightness (L*), chroma, and hue, similar results were observed among treatments, with no effects ($P > 0.05$), as shown in Table 10. However, an effect ($P < 0.05$) was observed for centrifugation loss. Meat from animals fed the positive control diet, acerola by-product, and cajá by-product showed higher values compared to the negative control diet.

Table 10
Characteristics of red color intensity (a*), yellow color intensity (b*), lightness (L*), and centrifugation loss (CL) of meat from female pigs fed different experimental diets.

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
a*	8.32	9.40	7.56	8.32	7.51	0.2810	0.2139
b*	15.80	16.46	15.48	16.29	14.33	0.2848	0.1876
L*	49.08	49.84	48.30	50.60	47.38	0.4113	0.1204
Chroma	16.15	16.66	15.40	16.79	13.71	0.4137	0.0719
Hue	2.00	2.61	2.50	2.79	1.57	0.2655	0.7633
CL	33.23^{a}	27.68^{b}	29.13^{ab}	32.57^{a}	32.94^{a}	0.8569	0.0211

Standard error of the mean (SEM). Lowercase letters (a, b, c) in the same row indicate significant differences ($p < 0.05$) among treatment means.

Texture Profile Analysis (TPA)

The results of texture profile analysis are shown in Table 11. No effect ($P > 0.05$) was observed for adhesiveness and adhesive force. However, an effect ($P < 0.05$) was found for resilience, firmness, cohesiveness, springiness, chewiness, chewiness index, and gumminess.

Table 11
Texture profile analysis (TPA) of meat from female pigs fed different experimental diets.

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
Adhesiveness (mJ)	0.08	0.12	0.08	0.08	0.16	0.0178	0.5913
Resilence (N)	0.18^{ab}	0.21^{a}	0.20^{ab}	0.16^{b}	0.17^{b}	0.0049	0.0087
Firmness (N)	80.28^{b}	77.76^{b}	93.09^{b}	119.48^{a}	129.29^{a}	5.0130	0.0001
Adhesive force (N)	0.05	0.07	0.07	0.05	0.06	0.0040	0.5611
Cohesiveness (N)	0.59^{a}	0.57^{a}	0.57^{a}	0.52^{b}	0.57^{a}	0.0067	0.0021
Springiness (mm)	3.93^{b}	4.94^{a}	3.72^{b}	3.84^{b}	3.66^{b}	0.1173	< .0001
Chewiness (mJ)	144.30^{b}	147.92^{b}	170.96^{b}	346.57^{a}	259.14^{ab}	19.1899	0.0037
CI(N)	31.47^{b}	31.33^{b}	27.64^{b}	40.50^{ab}	45.29^{a}	1.8768	0.008
Gumminess (N)	39.38^{c}	50.60^{bc}	53.63^{bc}	60.92^{ab}	70.09^{a}	2.8668	0.006

Chewiness index (CI); standard error of the mean (SEM). Different letters (a, b, c) in the same row indicate significant differences ($p < 0.05$) among treatment means.

Texture profile and oxidative stability of pork meat

Regarding resilience, higher values were observed in meat from animals fed the negative control diet (0.21), compared to acerola by-product (0.17) and cajá by-product (0.17). Elasticity was also superior in this group (4.94 mm), differing from the other diets. For firmness, the highest records ($P < 0.05$) were found in meat from animals fed acerola by-product (119.48 N) and cajá by-product (129.29 N), compared to positive control (80.28 N), negative control (77.76 N), and pineapple by-product (109.48 N). Cohesiveness

indices were higher (P < 0.05) in positive control (0.59), negative control (0.57), pineapple by-product (0.57), and cajá by-product (0.57), compared to acerola by-product (0.52).

Chewiness showed the highest values (P < 0.05) in meat from animals fed acerola by-product (346.57 mJ), followed by cajá by-product (259.14 mJ), while the other treatments presented lower results. For the chewiness index (CI), differences among treatments were observed, with cajá by-product diet standing out over positive control, negative control, and pineapple by-product. Regarding gumminess, the highest indices were found in meat from animals fed cajá by-product, while the lowest occurred in the positive control group.

Oxidative stability and antioxidant capacity of pork meat

Based on the evaluated parameters of lipid oxidation (TBARS), protein oxidation (carbonyls), antioxidants (ABTS), and total phenolics (Table 12), no statistical differences (P > 0.05) were observed for ABTS, TBARS, and total phenolics. However, differences (P < 0.05) were found in carbonyl concentration, with meat from animals fed acerola by-product showing the highest values, followed by the positive control diet, which presented similar results to meat from animals fed cajá by-product.

Table 12
Parameters of lipid oxidation, protein oxidation, antioxidant activity, and total phenolics of meat from female pigs fed different experimental diets.

Variables	Experimental diets					SEM	Pr > F
	Positive	Negative	Pineapple	Acerola	Cajá		
ABTS	123.17	135.68	95.41	81.28	109.12	29.8525	0.2406
TBARS	0.13	0.11	0.13	0.11	0.11	0.0169	0.0522
Phenolics	29.13	29.07	28.39	28.46	27.53	1.8831	0.6577
Carbonyls	5.53^{b}	3.94^{c}	3.05^{c}	7.07^{a}	6.18^{ab}	1.6863	< 0.0001

2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS); thiobarbituric acid reactive substances (TBARS); standard error of the mean (SEM). Different letters (a, b, c) in the same row indicate significant differences (p < 0.05) among treatment means.

DISCUSSION

Fruits intended for pulp production are highly perishable, which limits their commercialization in natura (Pazdiora et al., 2019). To reduce losses, they are processed into frozen pulps or whole juices, generating co-products such as peels, seeds, and bagasse. These residues, besides representing an environmental challenge, can be used as alternative ingredients in animal nutrition, as they contain fibers and bioactive compounds capable of influencing metabolism and health in pigs (Lousada Junior et al., 2005).

The composition of these agroindustrial residues is variable and depends on factors such as cultivated species, agronomic management, and processing type. Pazdiora et al. (2019) demonstrated this variability by comparing pineapple and acerola residues, reporting marked differences in dry matter, crude protein, and fiber fractions. Rocha et al. (2020) also described distinct composition for cajá residue, with lower protein and dry matter contents. This variability is biologically relevant, as it determines digestibility potential and nutrient availability, reinforcing the need for detailed characterization prior to dietary inclusion.

In the present study, the nutritional analysis of pineapple, acerola, and cajá residues (Table 3) confirmed this compositional variability, which explains the distinct effects observed on animal performance. Pineapple residue, with a higher proportion of soluble fiber, favored better energy utilization, whereas acerola residue, richer in insoluble fiber, limited digestibility and reduced productive efficiency. Cajá residue presented intermediate composition, resulting in intermediate performance outcomes (Table 4).

The superior performance associated with pineapple residue may be explained by its higher hemicellulose content, a more soluble and fermentable fiber fraction. This fraction enhances volatile fatty acid production, which serves as an energy source, particularly in finishing pigs with a more developed digestive capacity. Han et al. (2015) also reported positive effects on digestibility and

weight gain when using pineapple leaf silage in pig diets, reinforcing that different parts of the plant can contribute to animal performance due to their fibrous composition and bioactive compounds.

The lower performance associated with acerola residue may be linked not only to the reduced degradability of its fibers (Ferreira, 2016), but also to the high levels of phenolic compounds and malondialdehyde (MDA) identified in Table 2. In excess, these compounds may exert antinutritional effects, negatively modulating gut microbiota or accelerating digesta transit, thereby reducing nutrient absorption. This interpretation helps explain why, despite studies such as Leal et al. (2021) reporting positive effects of acerola in piglets, results may vary depending on production phase, inclusion level, and specific physicochemical characteristics of the residue.

Beyond chemical composition, the structural properties of dietary fiber also influence digestibility. Even with the same inclusion level (7.5%), differences in fermentability, particle size, and physical density of fiber directly affect nutrient utilization. As highlighted by Brambillasca et al. (2015), fiber conformation can accelerate intestinal transit and reduce contact time with digestive enzymes, limiting effective nutrient absorption. This reinforces that not only the quantity but also the structural quality of fiber must be considered in diet formulation.

As shown in Table 5, pineapple residue provided the best digestibility coefficients in both growth and finishing phases. This result can be explained by the higher hemicellulose content of this residue (Table 3), a fiber fraction that is more soluble and fermentable. The greater availability of this fraction favors volatile fatty acid production, which is used as an energy source, contributing to improved metabolic efficiency and productive performance.

Hemicellulose, being easily fermented by intestinal microbiota, enhances nutrient utilization, especially in finishing pigs with greater digestive capacity. These findings reinforce the positive effects observed on performance and carcass traits in the pineapple-fed group. Similar results were reported by Lee et al. (2022), when evaluating fiber-rich residues such as beet pulp, citrus pulp, and rice husk. The authors emphasized that fiber type is decisive: while soluble fiber favors digestibility, energy losses may occur during fermentation. Thus, balancing chemical composition and physical structure of fiber is essential to optimize animal performance.

In addition to performance and digestibility, blood parameters were evaluated to identify possible metabolic changes resulting from the inclusion of agroindustrial residues in the diets. As presented in Table 6, the biochemical markers analyzed (triglycerides, total cholesterol, HDL, LDL, AST, GGT, urea, and creatinine) provided a comprehensive view of lipid, hepatic, and renal metabolism, offering complementary information on the systemic impact of the tested ingredients.

The variation observed in triglyceride levels suggests a direct relationship with nutrient utilization. The acerola-fed group, which showed lower productive performance, also recorded reduced concentrations of this marker, indicating a possible limitation in lipid absorption and utilization. This association reinforces the hypothesis that lipid metabolism may reflect digestive efficiency, since animals with better performance tend to present greater energy availability from fermentation and absorption of fatty acids.

The reduction in triglycerides between the initial and finishing phases suggests greater efficiency in lipid utilization or lower fat deposition as animals approach slaughter weight. This physiological behavior indicates metabolic adaptation to the production stage, with nutrients being directed more toward muscle protein deposition. Lanferdini et al. (2013), when using citrus by-products in pig diets, observed a decrease in cholesterol without changes in triglycerides, reinforcing that metabolic responses to plant residues are complex and depend on the specific chemical composition of each ingredient.

Another relevant aspect was the increase in HDL concentrations in groups fed pineapple, acerola, and cajá residues, as shown in Table 6. HDL plays a protective role in lipid metabolism, being associated with reduced risk of cardiovascular disease (John et al., 2023). The observed increase may be related to the higher oil content in the formulations, as well as the action of dietary fiber and phenolic compounds, which positively modulate cholesterol metabolism. Rodríguez et al. (2006) highlighted that fiber contributes to serum cholesterol regulation, supporting the hypothesis that the residues used exerted beneficial effects on this variable.

Although no significant differences were observed in total cholesterol and LDL levels, the behavior of HDL across diets suggests positive modulation promoted by residues with higher phenolic content and antioxidant activity, such as acerola and cajá. As evidenced in Tables 1 and 2, the elevated ABTS values reinforce the functional potential of these ingredients. This association is

consistent with studies such as John et al. (2023), which demonstrated that antioxidant-rich plant residues can increase HDL and improve lipid profile, corroborating the positive findings of this study.

Metabolic results were also reflected in liver function, monitored through AST and GGT enzymes. The increase in AST between phases indicates greater metabolic demand during finishing, consistent with advancing age and higher feed intake. Nevertheless, values remained within physiological ranges, suggesting no hepatic impairment. GGT showed higher values in animals fed control diets, which may be related to bile acid action on cell membranes, but also remained within normal limits (Jain, 1993; Meyer; Harvey, 2004).

Muscle and nitrogen metabolism were assessed through creatinine and urea. The reduction in creatinine during finishing reflects the slowdown in muscle growth typical of this phase, with lower protein synthesis and greater fat deposition (Bovo et al., 2025).

Lower urea levels observed in the acerola-fed group suggest better protein utilization or reduced excretion of nitrogenous compounds. This behavior may be associated with antioxidant compounds, which reduce protein degradation and favor nitrogen efficiency (Aymerich et al., 2022; Perri et al., 2017).

Finally, the oxidative profile of the diets must be considered. The MDA content present in residues, especially pineapple and acerola, indicates a higher load of oxidized lipids in the ingredients, as shown in Tables 1 and 2. This lipid peroxidation marker is related to oxidative stability of feedstuffs and, in excess, may contribute to inflammatory processes and oxidative stress, affecting physiological variables such as AST and GGT, and indirectly influencing productive performance (Campos et al., 2013).

Similar results were reported by Perondi et al. (2014), when evaluating passion fruit seed meal inclusion in growing pig diets. In that study, no impairment of serum biochemical parameters was observed, although cholesterol levels increased. This comparison is pertinent because, like acerola, pineapple, and cajá residues used in the present work, passion fruit seed meal represents an agroindustrial co-product with nutritional potential. The combined analysis highlights that different residues can modulate metabolism in distinct ways, depending on chemical composition and bioactive compound profile, reinforcing the importance of monitoring plasma indicators in formulations that incorporate alternative ingredients.

Considering the previously discussed metabolic effects, it is relevant to evaluate how these nutritional responses translate into final zootechnical parameters. Carcass traits, presented in Table 7, represent one of the main indicators of the physiological utilization of the diet, allowing measurement of the impact of agroindustrial residues on productive efficiency and the quality of the product destined for the market.

The positive effects of pineapple residue were also reflected in carcass traits of female pigs, with higher hot and cold carcass weights. This result can be explained by the greater rate of body mass deposition, favored by the fermentable carbohydrates and hemicellulose present in this residue. These components are fermented in the intestine, producing volatile fatty acids (VFA) that, once absorbed, contribute to energy supply and tissue synthesis (Lee et al., 2022).

Carcass yield followed the trend observed in higher hot and cold carcass weights in females fed pineapple residue. Although no differences were observed in commercial cuts such as ham or loin, the increase in yield indicates a greater proportion of usable body mass, suggesting more efficient and balanced growth. This result demonstrates that the positive effects of pineapple residue were not limited to total weight but also reflected in better conversion of live weight into carcass, a desirable trait from both industrial and commercial perspectives.

Similar results were reported by Fachinello et al. (2015), when evaluating passion fruit seed meal inclusion in diets for pigs in the initial phase. In that study, no impairment of zootechnical performance or carcass traits was observed, evidencing that agroindustrial residues can be safely used when properly balanced. This comparison is pertinent to the present work, as it reinforces that, like passion fruit seed meal, acerola, pineapple, and cajá residues can also be incorporated into diets without productive losses. In the specific case of pineapple, the positive effects observed on carcass weight and yield confirm the potential of these co-products as viable nutritional alternatives, provided that inclusion levels and dietary balance are respected.

Although no significant differences were observed in commercial carcass cuts, qualitative aspects of meat, such as pH, must also be considered, as they may indicate changes resulting from pre-slaughter stress and directly impact industrial acceptance of the

product. Evaluating this variable is essential to ensure that the use of agroindustrial residues does not compromise final meat quality.

Even though all animals were subjected to the same management and slaughter protocol, the analysis of meat pH is justified by the possibility of metabolic modulation via diet. Alternative ingredients such as pineapple, acerola, and cajá residues may influence energy metabolism, affecting the amount of muscle glycogen available at slaughter. Since post mortem pH is directly related to glycogen degradation and lactic acid production, dietary composition may result in differences in meat quality.

According to Adzitey & Nurul (2011), PSE (pale, soft, exudative) meat presents pH below 6.0 about 45 minutes after slaughter, whereas DFD (dark, firm, dry) meat has pH equal to or above 6.0 between 12 and 48 hours post mortem. Based on the results in Table 7, the meat of the analyzed females presented pH values within normal ranges, not being classified as PSE or DFD. This suggests that the use of residues in the diet did not compromise the physiological well-being of the animals nor generate negative alterations in meat quality, reinforcing the feasibility of utilizing these ingredients under good management and slaughter practices.

The effects of diets are not restricted to external variables such as zootechnical performance and carcass traits. It is equally important to consider possible repercussions on less apparent physiological parameters, such as the development and morphology of internal organs, which may reflect the degree of adaptation of animals to different feeding strategies. As presented in Table 8, although absolute organ weights did not differ statistically among treatments, this evaluation is relevant, since organ size can indicate the physiological capacity for adaptation and metabolism in pigs (Elefson et al., 2021). Variations in this parameter are often associated with the use of growth-promoting additives, nutritional imbalances, or sanitary challenges (Dávila-Ramírez et al., 2020).

Flores et al. (2023) also reported similar results when partially replacing corn with ground pecan shell by-products. Despite being a fibrous ingredient, no negative influence was observed on performance, carcass traits, or organ weights, reinforcing that agroindustrial residues can be used without compromising physiological parameters, provided they are properly balanced.

Beyond anatomical aspects, residues with high levels of fermentable fiber promote important metabolic modulations. One example is the production of short-chain fatty acids (SCFA), such as acetate, propionate, and butyrate, resulting from microbial fermentation in the large intestine. These metabolites act as signaling molecules involved in the regulation of several metabolic reactions, providing benefits such as increased intestinal motility and reduced blood concentrations of cholesterol, glucose, and insulin (Liu et al., 2018).

SCFA play key roles in metabolic regulation, including lipid synthesis and gluconeogenesis (Chambers et al, 2015; Williams et al., 2017). Their production is directly influenced by diet composition, particularly the content of fermentable fibers and phenolic compounds, which act synergistically in modulating the intestinal microbiota (Hashemi & Davoodi, 2011; Mahfuz et al, 2021). Thus, the agroindustrial residues used in this study not only impacted performance and morphology but also contributed to metabolic adjustments that may favor health and productive efficiency.

Variations in SCFA concentrations among treatments appear to be associated with the fermentative quality of the residues. Pineapple residue, for instance, showed high hemicellulose content (Table 3), indicating good fermentative potential. However, its lower concentration of phenolic compounds may have limited microbial modulation and, consequently, the production of certain acids such as acetate. This hypothesis is reinforced by the more expressive results observed in the cajá group, which contained higher phenolic content and favored the growth of fermentative bacteria.

The positive control diet, containing the synthetic antioxidant BHT, may have promoted greater intestinal stability, since this liposoluble compound is accumulative and resistant to oxidation. This characteristic creates an environment less prone to lipid degradation (Bottoli, 2022; Silva et al., 2019) may have contributed to a more active microbiota and, therefore, greater SCFA production (Fig. 1). Among them, propionate deserves emphasis, as it is known to inhibit hepatic cholesterol synthesis and participate in glycemic regulation.

Studies such as Low et al. (2021) demonstrate that tropical fruit residues, including mango and apple, also influence SCFA production. These findings reinforce that more than the origin of fiber, its structure and association with bioactive compounds are decisive in fermentative dynamics and intestinal health in pigs. The results obtained in this study suggest that variation in SCFA

proportions and concentrations is less related to total fiber content and more to the interaction between fermentable carbohydrates and natural antioxidants, particularly phenolics.

Finally, it is important to note that SCFA were analyzed only during the finishing phase, whereas digestibility was monitored throughout the entire production cycle. This temporal difference may explain the absence of a direct correspondence between final fermentation and digestibility indices, since the metabolic profile of pigs changes with age and dietary adaptation. Thus, the results highlight the need to evaluate different production phases jointly to better understand the effects of agroindustrial residues on animal metabolism.

From the physiological and fermentative dynamics discussed above, it becomes essential to assess how these mechanisms are reflected in the final quality of pork, the main product of commercial interest. The physical, chemical, and biochemical attributes of meat can directly or indirectly express the effects of diet and animal metabolism, allowing an integrated analysis between zootechnical performance, intestinal health, and technological characteristics of pork (Biondi et al., 2020; Migdał et al., 2020). Recent studies demonstrate that functional ingredients and plant residues can influence factors such as water-holding capacity, color, and texture of meat through modulation of oxidative metabolism, muscle fiber integrity, and intestinal fermentative activity (Giuliani et al., 2024; Hashemi & Davoodi, 2011).

In this context, the proximate composition data of pork (Table 9), although not subjected to comparative statistical analysis among treatments, reveal potential reflections of diet composition, particularly regarding ether extract, fermentable fiber, and bioactive compounds. Variations in intramuscular fat, moisture, and protein content may be related to the presence of natural antioxidants and the modulatory action of fibers and phenolics from residues such as acerola and cajá. These components, recognized for their effects on microbiota and lipid metabolism (Mahfuz et al., 2021), may have favored preservation of muscle integrity and oxidative stability of meat, albeit subtly.

Thus, the results reinforce that even without formally tested significant differences, the composition of experimental diets plays a relevant role in the physicochemical quality of pork. This highlights the feasibility of agroindustrial residues as functional nutritional alternatives in animal production. The subsequent analysis of parameters such as color, water loss, and texture expands this discussion by emphasizing the sensory and technological effects promoted by the formulations used.

Regarding the visual appearance of meat, attributes such as color, chroma, and hue were analyzed, representing important sensory quality indicators directly associated with consumer acceptance (Valous et al., 2009). As shown in Table 10, no effect ($P > 0.05$) was observed for color parameters (a, *b*, L*), chroma, or hue. This result suggests that residues, despite containing carotenoids, did not interfere with meat coloration, reinforcing their viability as alternative ingredients without compromising visual traits of the product.

Beyond appearance, water-holding capacity is a determining factor in technological quality of meat, as it directly affects processing yield and consumer acceptance. In this context, the analysis of centrifugation loss (CL), presented in Table 10, allows inference on post-slaughter exudation behavior. A significant effect ($P < 0.05$) was observed in meat from females fed positive control, acerola, and cajá diets. This result may be related to exudate formation intensity, influenced by rigor mortis, membrane permeability to water, and the degree of protein denaturation (Kristensen; Purslow, 2001).

The negative control diet showed the lowest CL value, reflecting greater water-holding capacity of meat. This contrasts with acerola and cajá residues, which resulted in higher exudation rates. Although these residues possess antioxidant properties, their inclusion may have promoted alterations in muscle protein structure, leading to greater water release during processing.

Complementary studies reinforce the importance of evaluating technological quality of meat when using plant residues. Biondi et al. (2020) found that inclusion of 15% tomato residue did not compromise zootechnical performance and promoted nutritional improvements, such as increased polyunsaturated fatty acids (PUFA) and vitamin A. Giuliani et al. (2024), when using grape pomace, observed that up to 10% could be included without negatively affecting performance, although carcass quality was altered, with greater fat thickness and reduced lean meat percentage. On the other hand, intramuscular fat increased and fatty acid profile improved, with oxidative stability preserved. These studies are highlighted because, as in the present work, they explore the use of agroindustrial residues in pig diets and demonstrate that, beyond maintaining productive performance, such ingredients can modify qualitative aspects of meat, evidencing the functional potential of these co-products.

Texture profile analysis (TPA) is equally relevant, as it describes the transversal structure of muscle tissue and provides distinct indicators of meat quality (Migdał et al., 2020). As shown in Table 11, inclusion of acerola and cajá residues significantly influenced physical characteristics of pork, promoting greater firmness, chewiness, and gumminess. These results suggest a more compact muscle structure resistant to deformation, possibly associated with lower elasticity and resilience observed in these treatments. Conversely, meat from females fed negative control and pineapple residue diets resulted in more elastic and resilient meat, traits generally associated with softer and juicier texture. Such differences may be related to the type and content of bioactive compounds present in residues, their interaction with muscle proteins, and their influence on water retention and fiber integrity.

Watanabe et al. (2010) observed that the inclusion of citrus pulp in qualitative feed restriction programs for pigs resulted in increased weight of digestive organs, indicating greater fermentative activity. Despite reductions in final weight and carcass yield, no impairment of meat quality was reported. Additionally, a linear increase in pH 24 hours post mortem and a negative effect on color were recorded, resulting in paler meat. These findings are relevant to the present study, as they reinforce that plant residues can alter physiological and technological parameters of meat without compromising fundamental productive indicators, highlighting fermentative potential as a trait of interest.

Beyond physical-technological aspects, biochemical parameters related to lipid and protein oxidation of pork were also evaluated (Table 12). Among the variables analyzed, only carbonyl concentration showed differences ($P < 0.05$), indicating specific alterations in protein stability. Meat from females fed acerola residue, although recognized for its antioxidant activity, under certain conditions may favor oxidative reactions, stimulating free radical formation that contributes to cellular damage and degradation of myofibrillar proteins.

Conversely, meat from females fed pineapple residue and the negative control diet showed the lowest carbonyl levels, which may be related to the presence of bromelain, a natural proteolytic enzyme in pineapple that, in addition to favoring digestibility, may preserve muscle protein integrity by modulating meat texture and indirectly protecting against oxidation. These biochemical changes were directly reflected in the physical characteristics presented in Table 11. Meat from acerola and cajá diets showed greater firmness, gumminess, and chewiness, consistent with higher oxidation and possible tissue stiffening. In contrast, meat from females fed pineapple residue and negative control diets showed greater elasticity and resilience, associated with lower protein degradation and higher water-holding capacity. These results demonstrate that bioactive compounds present in agroindustrial residues can influence not only oxidative stability of meat but also its technological and sensory properties.

Giuliani et al. (2024) demonstrated that inclusion of up to 10% grape pomace in pig diets resulted in a significant reduction in TBARS values, indicating greater oxidative stability of meat. In addition, decreased carbonyl concentrations and increased antioxidant activity measured by the ABTS method were observed. The study also reported increased phenolic compound concentrations in meat, suggesting transfer of dietary antioxidants to muscle tissue. These findings directly align with the present study, reinforcing that plant by-products can act as functional ingredients capable of improving meat quality and contributing to animal metabolic health.

The inclusion of 7.5% acerola, pineapple, and cajá agroindustrial residues in diets for growing and finishing pigs did not compromise zootechnical performance, digestibility, blood parameters, or carcass traits, demonstrating safety in the use of these co-products. Pineapple residue stood out for its superior nutritional utilization and carcass yield, while acerola and cajá influenced specific aspects of meat quality, such as texture and oxidative stability. Thus, it can be concluded that the evaluated residues present potential as alternative functional ingredients, contributing to sustainability of production without impairing animal health or meat quality.

Declarations

Ethical approval

This research was submitted to Ethics Committee onthe Use of Animals (CEUA) of the University Federal of Paraíba (UFPB), João Pessoa, Paraíba, protocol number 2836170122

Competing of interest

The authors declare that they have no competing financial interests or personal relationships that could have influenced the study reported in this paper.

FUNDING

This project was funded by the Research Support Foundation of the State of Paraíba (FAPESQ), whose support was fundamental for the execution of the experimental activities and the development of this research.

AUTHOR INFORMATION

Authors and Affiliations

Federal University of Paraíba, Paraíba, Brazil

Ceilda Inocêncio dos Santos, Leonardo Augusto Fonseca Pascoal, …

Contributions

The project was developed by Cícero Jorge Medeiros under the supervision of Leonardo Augusto Fonseca Pascoal. The experiment execution, data analysis, and manuscript preparation were carried out by Ceilda Inocêncio dos Santos, while statistical analysis was conducted by Leonardo Augusto Fonseca Pascoal.

Corresponding Author

Correspondence should be addressed to Leonardo Augusto Fonseca Pascoal.

Ethics Statement

The project was approved by the Animal Ethics Committee (CEUA) of the Federal University of Paraíba (UFPB) under protocol number 2836170122.

Funding

The present study was funded by Fundação de Amparo à Pesquisa do Estado Paraiba (FAPESQ) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES – Finance code 001).

Acknowledgements

The authors acknowledge the Paraiba Research Foundation (FAPESQ),the Federal University of Paraiba (UFPB), and the Coordination for the Improvement of Higher Education Personnel (CAPES) for their support.

Data availability

The datasets generated in the current study are available from the corresponding author on reasonable request.

References

1. ADZITEY, F.; NURUL, H. Pale soft exudative (PSE) and dark firm dry (DFD) meats: causes and measures to reduce these incidences - a mini review. International Food Research Journal, [*s. l.*], p. 11–20, 2011.
2. AOAC. Association of Official Analytical Chemists (AOAC). 18. ed. Maryland, USA: [*s. d.*], 2005. vol. 2
3. ASSOCIAÇÃO BRASILEIRA DOS CRIADORES DE SUÍNOS (ABCS). Manual de Industrialização de Suínos. 1. ed. Brasilia: ABSC, 2014.

4. AYMERICH, P. *et al.* O51 Effects of increasing dietary lysine to crude protein ratio on growth performance, blood urea nitrogen and fecal consistency of growing pigs. Animal - science proceedings, Espanha, vol. 13, nº 3, p. 306–307, 2022.
5. BIONDI, L. *et al.* Meat quality from pigs fed tomato processing waste. Meat Science, [*s. l.*], 2020.
6. BOTTOLI, A.H.S.V. AVALIAÇÃO DA CAPACIDADE ANTIOXIDANTE DE EXTRATOS NATURAIS NO CONTROLE DA OXIDAÇÃO DE LINGUIÇAS FRESCAIS. 2022. Dissertação - Universidade Tecnológica Federal do Paraná, Toledo, 2022.
7. BOVO, S. *et al.* High-throughput untargeted metabolomics reveals metabolites and metabolic pathways that differentiate two divergent pig breeds. animal, Itália, vol. 19, nº 1, p. 101393, 2025.
8. BRAMBILLASCA, S.; ZUNINO, P.; CAJARVILLE, C. Addition of inulin, alfalfa and citrus pulp in diets for piglets: Influence on nutritional and faecal parameters, intestinal organs, and colonic fermentation and bacterial populations. Livestock Science, [*s. l.*], vol. 178, p. 243–250, 2015.
9. BRIDI, A. M; SILVA, C. A. Métodos de Avaliação da Carcaça e da Carne Suína. 1. ed. Londrina: MIDIOGRAF, 2007. vol. 1
10. CAMPOS, A.G. *et al.* Análise hematológica e bioquímica comparativa em suínos submetidos à obstrução biliar experimental. Vet e Zootec, [*s. l.*], vol. 20 (4), p. 592–603, 2013.
11. CHAMBERS, E.S.; MORRISON, D.J.; FROST, G. Control of appetite and energy intake by SCFA: what are the potential underlying mechanisms?. Proceedings of the Nutrition Society, [*s. l.*], p. 328–336, 2015.
12. DÁVILA-RAMÍREZ, J. L. *et al.* Addition of a Mixture of Plant Extracts to Diets for Growing-Finishing Pigs on Growth Performance, Blood Metabolites, Carcass Traits, Organ Weight as a Percentage of Live Weight, Quality and Sensorial Analysis of Meat. Animals, [*s. l.*], vol. 10, nº 7, p. 1229, 2020.
13. EGEA, M. *et al.* Use of Mediterranean By-Products to Produce Entire Male Large White Pig: Meat and Fat Quality. Animals, [*s. l.*], vol. 11, nº 11, p. 3128, 2021.
14. ELEFSON, S.K. *et al.* Assessment of visceral organ growth in pigs from birth through 150 kg. Journal of Animal Science, [*s. l.*], vol. 99, nº 9, 2021.
15. ERINLE, T.J.; ADEWOLE, D.I. Fruit pomaces—their nutrient and bioactive components, effects on growth and health of poultry species, and possible optimization techniques. Animal Nutrition, [*s. l.*], vol. 9, p. 357–377, 2022.
16. ERWIN, W.S.; MARCO, G.J.; MERY, E.M. Volatile fat acid analyses of blood an rumen fluid by gas cromatography. Journal of Dairy Science, Hampign, vol. 44, p. 71–1768, 1961.
17. FACHINELLO, M.R. *et al.* Effect of passion fruit seed meal on growth performance, carcass, and blood characteristics in starter pigs. Tropical Animal Health and Production, [*s. l.*], vol. 47, nº 7, p. 1397–1403, 2015.
18. FLORES, E.S. *et al.* Influence of including pecan shelling by-product into pig diets: performance, carcass traits and visceral organ weights. Archivos Latinoamericanos de Producción Animal, [*s. l.*], vol. 31, nº Suplemento, p. 135–139, 2023.
19. GIULIANI, C.S. *et al.* Meat quality of pigs fed grape pomace in different production systems. Anais da Academia Brasileira de Ciências, [*s. l.*], vol. 96, nº 1, 2024.
20. HAN, J. *et al.* How the Pineapple Leaf Residue Silage Influence the Finishing Pigs' Growing Performance and Biochemical Parameters of the Blood. 2015, Paris, France. Proceedings of the 2015 6th International Conference on Manufacturing Science and Engineering. Paris, France: Atlantis Press, 2015.
21. HASHEMI, S.R.; DAVOODI, H. Herbal plants and their derivatives as growth and health promoters in animal nutrition. Veterinary Research Communications, [*s. l.*], p. 169–180, 2011.
22. JAIN, N. C. Essentials of Veterinary Hematology. Philadelphia: Lea & Febiger, 1993.
23. JOHN, M. O. *et al.* Dried cabbage (*Brassica oleracea var. capitata*) waste meal decreases blood cholesterol but does not alter growth performance, and physiological indices of weaned pigs. Veterinary and Animal Science, [*s. l.*], vol. 22, p. 100320, 2023.
24. KRISTENSEN, L.; PURSLOW, P.P. The effect of ageing on the water-holding capacity of pork: role of cytoskeletal proteins. Meat Science, [*s. l.*], vol. 58, nº 1, p. 17–23, 2001.
25. LANFERDINI, E. *et al.* Digestibilidade de dietas e metabolismo de suínos alimentados com dietas contendo extratos cítricos. Arch. Zootec, [*s. l.*], vol. 62, p. 307–310, 2013.
26. LEAL, Isabela Ferreira *et al.* Acerola seed meal (Malpighia emarginata) as a source of dietary fibre in starter piglet diets. Semina:Ciencias Agrarias, [*s. l.*], vol. 42, nº 3, p. 1209–1228, 2021.

27. LEE, G.I. *et al.* Influence of dietary fibre on nutrient digestibility and energy utilisation in growing pigs fed diets varying in soluble and insoluble fibres from co-products. animal, [*s. l.*], vol. 16, nº 5, 2022.
28. LI, Jie *et al.* Effects of alfalfa levels on carcass traits, meat quality, fatty acid composition, amino acid profile, and gut microflora composition of Heigai pigs. Frontiers in Nutrition, [*s. l.*], vol. 9, 2022.
29. LIU, H. *et al.* Butyrate: A Double-Edged Sword for Health?. Advances in Nutrition, [*s. l.*], p. 21–29, 2018.
30. LOUSADA JUNIOR, J.E. *et al.* Consumo e digestibilidade de subprodutos do processamento de frutas em ovinos. Revista Brasileira de Zootecnia, [*s. l.*], vol. 34, nº 2, p. 659–669, 2005.
31. LOW, D.Y. *et al.* Isolated pectin (apple) and fruit pulp (mango) impact gastric emptying, passage rate and short chain fatty acid (SCFA) production differently along the pig gastrointestinal tract. Food Hydrocolloids, [*s. l.*], p. 106723, 2021.
32. MAHFUZ, Shad; SHANG, Qinghui; PIAO, Xiangshu. Phenolic compounds as natural feed additives in poultry and swine diets: a review. Journal of Animal Science and Biotechnology, [*s. l.*], vol. 12, nº 1, p. 48, 2021.
33. MELÉNDEZ-MARTÍNEZ, A. J. *et al.* A comprehensive review on carotenoids in foods and feeds: status quo, applications, patents, and research needs. Critical Reviews in Food Science and Nutrition, [*s. l.*], vol. 62, nº 8, p. 1999–2049, 2022.
34. MEYER, D. J.; HARVEY, J.W. Veterinary Laboratory Medicine. 3. ed. Philadelphia: [*s. d.*], 2004.
35. MIGDAŁ, W. *et al.* Meat Texture Profile and Cutting Strength Analyses of Pork Depending on Breed and Age. Annals of Animal Science, [*s. l.*], vol. 20, nº 2, p. 677–692, 2020.
36. ÖZÜNLÜ, Orhan; ERGEZER, Haluk; GÖKÇE, Ramazan. Improving physicochemical, antioxidative and sensory quality of raw chicken meat by using acorn extracts. LWT, [*s. l.*], vol. 98, p. 477–484, 2018.
37. PAZDIORA, R.D. *et al.* Digestibilidade, comportamento ingestivo e desempenho de ovinos alimentados com resíduos de agroindústrias processadoras de frutas. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, [*s. l.*], vol. 71, nº 6, p. 2093–2102, 2019. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-09352019000602093&tlng=pt.
38. PERONDI, D. *et al.* Passion fruit seed meal at growing and finishing pig (30–90 kg) feeding. Ciência e Agrotecnologia, [*s. l.*], vol. 38, nº 4, p. 390–400, 2014.
39. PERRI, A.M. *et al.* Hematology and biochemistry reference intervals for Ontario commercial nursing pigs close to the time of weaning. The Canadian veterinary journal = La revue veterinaire canadienne, [*s. l.*], vol. 58, nº 4, p. 371–376, 2017.
40. ROBERTA, R. *et al.* Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Biology and Medicine, [*s. l.*], vol. 26, nº 9–10, p. 1231–1237, 1999.
41. ROCHA, J.C. *et al.* Yellow mombin pulp residue valorization for pectinases production by Aspergillus niger IOC 4003 and its application in juice clarification. Biocatalysis and Agricultural Biotechnology, [*s. l.*], vol. 30, p. 101876, 2020. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S1878818120311981.
42. RODRÍGUEZ, R. *et al.* Dietary fibre from vegetable products as source of functional ingredients. Trends in Food Science & Technology, [*s. l.*], vol. 17, nº 1, p. 3–15, 2006.
43. ROSMINI, M.R. *et al.* TBA test by an extractive method applied to 'paté'. Meat Science, [*s. l.*], vol. 42, nº 1, p. 103–110, 1996.
44. ROSTAGNO, H.S. *et al.* Tabelas Brasileiras para Aves e Suínos Rostagno et al. (2024). 5. ed. Visconde do Rio Branco: Suprema, 2024.
45. RUFINO, M.S.M. *et al.* Metodologia Científica: Determinação da Atividade Antioxidante Total em Frutas pela Captura do Radical Livre ABTS +. Embrapa, [*s. l.*], 2007.
46. SANTANA-MÉRIDAS, O.; GONZÁLEZ-COLOMA, A.; SÁNCHEZ-VIOQUE, R. Agricultural residues as a source of bioactive natural products. Phytochemistry Reviews, [*s. l.*], p. 447–466, 2012.
47. SCOTT, TA; BOLDAJI, F. Comparison of inert markers [chromic oxide or insoluble ash (Celite)] for determining apparent metabolizable energy of wheat- or barley-based broiler diets with or without enzymes. Poultry Science, [*s. l.*], vol. 76, nº 4, p. 594–598, 1997.
48. SIGMA-ALDRICH CO. Analyzing Fatty Acids by Packed Column gas Chromatofraphy. SUPELCO – Bulletin 856B, [*s. l.*], 1998.
49. SILVA, E.S. *et al.* CONSERVAÇÃO DE ALIMENTOS PELO USO DE ADITIVOS: UMA REVISÃO. B.CEPPA, Curitiba, 2019.

50. SPIGNO, G.; MARINONI, L.; GARRIDO, G.D. State of the Art in Grape Processing By-Products. *In*: HANDBOOK OF GRAPE PROCESSING BY-PRODUCTS. [*S. l.*]: Elsevier, 2017. p. 1–27.
51. TSIPLAKOU, E. *et al.* Plant Feed Additives as Natural Alternatives to the Use of Synthetic Antioxidant Vitamins in Livestock Animal Products Yield, Quality, and Oxidative Status: A Review. Antioxidants, [*s. l.*], vol. 10, nº 5, p. 780, 2021.
52. VALOUS, N.A. *et al.* Colour calibration of a laboratory computer vision system for quality evaluation of pre-sliced hams. Meat Science, [*s. l.*], p. 132–141, 2009.
53. VASCONCELOS, T.S. *et al.* Evaluation of pineapple byproduct at increasing levels in heavy finishing pigs feeding. Animal Feed Science and Technology, [*s. l.*], vol. 269, p. 114664, 2020.
54. WATANABE, P.H. *et al.* Carcass characteristics and meat quality of heavy swine fed different citrus pulp levels. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, [*s. l.*], vol. 62, nº 4, p. 921–929, 2010.
55. WATERHOUSE, A. L. Determination of total phenolics. Current Protocols in Food Analytical Chemistry, [*s. l.*], 2002.
56. WILLIAMS, B. *et al.* Gut Fermentation of Dietary Fibres: Physico-Chemistry of Plant Cell Walls and Implications for Health. International Journal of Molecular Sciences, [*s. l.*], p. 2203, 2017.
57. WILSON, R.K.A. A rapid accurate method for messureng volatile fatty acids and lactic acid in silage. Research Report, Dublin, p. 7, 1971.

Figures

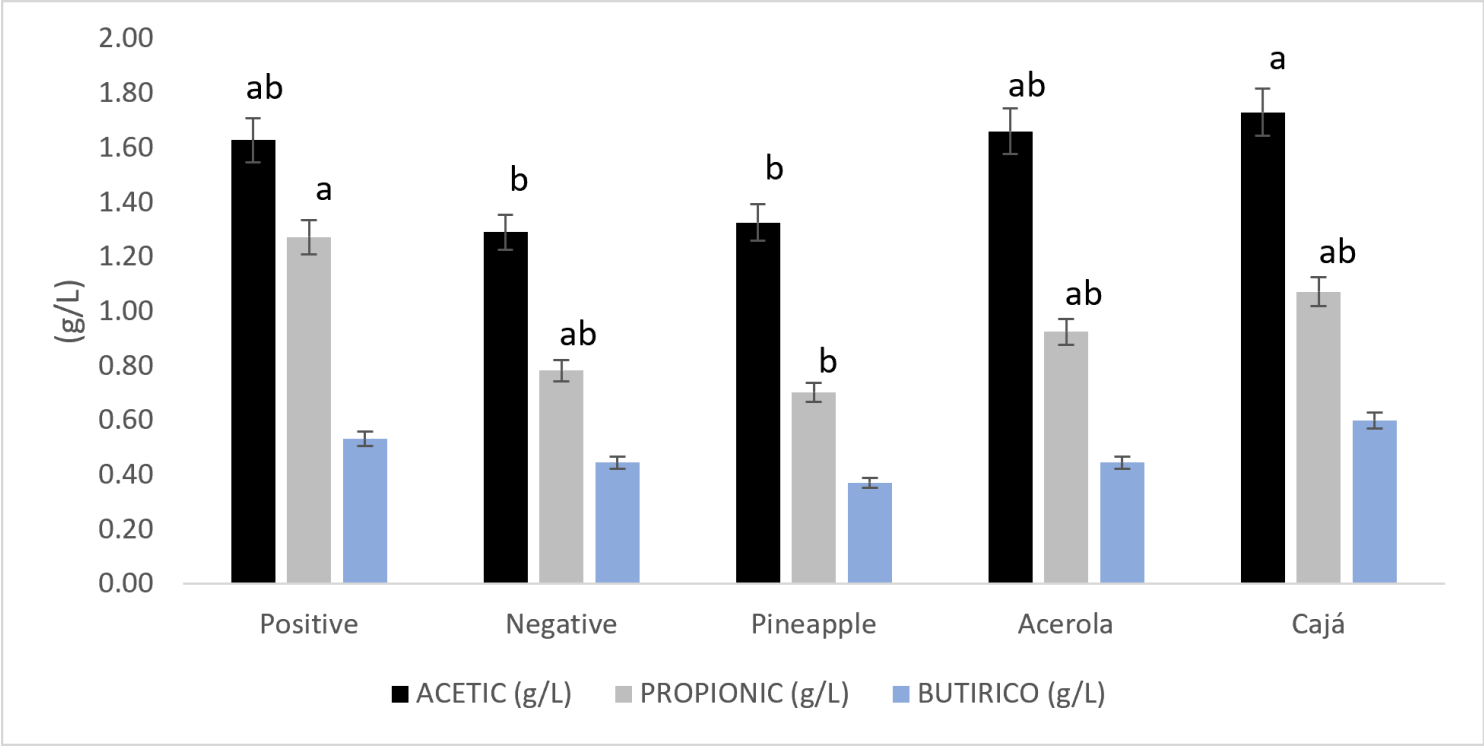

Figure 1

Short-chain fatty acids in the cecal content of female pigs fed different experimental diets.