



Evaluation of jackfruit (*Artocarpus heterophyllus* Lam.) residues on performance, carcass characteristics, and meat quality of broiler chickens

Liliana Ortega-González¹ , Sergio Soto-Simental¹ , Roberto González-Tenorio¹ , Juan Ocampo-López¹ , Héctor Hernández-Domínguez² , Gerardo Manuel Nava-Morales³ , Maricela Ayala-Martínez^{1*} 

*Corresponding author:
ayalam@uaeh.edu.mx

Received: September 16, 2025

Accepted: May 7, 2026

How to cite: Ortega-González, L.; Soto-Simental, S.; González-Tenorio, R.; Ocampo-López, J.; Hernández-Domínguez, H.; Nava-Morales, G. M. and Ayala-Martínez, M. 2026. Evaluation of jackfruit (*Artocarpus heterophyllus* Lam.) residues on performance, carcass characteristics, and meat quality of broiler chickens. Revista Brasileira de Zootecnia 55:e20250183.
<https://doi.org/10.37496/rbz5520250183>

Editors:

Ines Andretta
Valdir Ribeiro Junior

Copyright: This is an open access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



¹ Universidad Autónoma del Estado de Hidalgo, Instituto de Ciencias Agropecuarias, Santiago Tulantepec de Lugo Guerrero, Hidalgo, México.

² Universidad Autónoma del Estado de Hidalgo, Bioterio, San Agustín Tlaxiaca, Hidalgo, México.

³ Universidad Autónoma de Querétaro, Facultad de Química, Santiago de Querétaro, Querétaro, México.

ABSTRACT - The aim of this study was to evaluate the effects of including different jackfruit fractions (seed, pulp, and peel) in broiler diets on productive performance, carcass and meat quality, and to assess their potential as feed ingredients. A total of 220 one-day-old commercial Cobb chicks were randomly divided into four treatments: Control, 5% pulp powder (PY), 5% seed powder (SY) and 1% peel (CY) powder with five replicates (n = 11 each), with a growth period of 56 days. The highest final weight and feed conversion ratio values were observed in the jackfruit peel group. There were similar results for carcass yield and histology for the small intestine. The skin colour obtained from the groups using jackfruit had higher yellowness values (SY = 23.68 ± 0.4; PY = 25.16 ± 0.5; CY = 24.76 ± 0.5). Meat flavour and overall acceptability were similar among treatments. It was concluded that the inclusion of 1% jackfruit peel in broiler diets can improve growth performance by increasing feed intake and body weight gain, without adversely affecting carcass yield, intestinal morphology, or consumer acceptance of the meat.

Keywords: agricultural by-products, alternative feed ingredients, feed broilers, sensory analysis

1. Introduction

The poultry industry is one of the most important livestock sectors worldwide, and the demand for poultry products continues to increase. Therefore, the industry needs to increase the production without increasing production costs or negatively impacting the environment as well as human health (Ma et al., 2015). To address these challenges, the poultry industry needs to develop long-term strategies that account for the high cost of feed (Sugiharto, 2023).

Several alternatives have been proposed to mitigate the problems associated with the poultry industry, while contributing to improve productive performance in animals. Furthermore, there are

several non-conventional feedstuffs that could be used animal feeding to lower production costs (Orayaga et al., 2015). Some agro-industrial by-products used to feed broilers have shown positive results regarding productive performance, such as gooseberry fruit powder at 0.4% which increase body weight in 5% (Patel et al., 2016). Likewise, feed dried fruit pomace, including cherry, strawberry, and apple (30 g/kg each) increases 1.5% of dressing percentage (Sosnówka-Czajka et al., 2023), whereas the use of blackcurrant and strawberry pomace did not show differences compared with the control group (Colombino et al., 2020). Furthermore, other have indicated improvements in meat quality with agricultural by-products such as dried okra fruit (Ashour et al., 2020). Every year, humans produce 1.3 billion tons of food waste, a large proportion of which is fruits and vegetables (Wadhwa et al., 2015). Recently, the concept of zero waste has gained importance given that food waste is considered an environmental threat, although it also contains bioactive compounds that can be exploited to obtain value-added value products (Antonisamy et al., 2023).

The jackfruit (*Artocarpus heterophyllus* Lam.) is considered the world's largest fruit (Lazarus et al., 2023), and has antiviral, anti-inflammatory, antioxidant, anticancerogenic, and antidiabetic properties that could benefit humans (Natta et al., 2023). However, the processing of this fruit results in waste accumulation which negatively impacts the environment (Adan et al., 2020). Only the pulp is suitable for human consumption, representing 20 to 30% of the total weight, meaning that between 70-80% of the jackfruit is non-edible for humans (Brahma and Ray, 2024).

As mentioned previously, jackfruit that is not used for human consumption, or the by-products obtained from other parts of the fruit can be used for animal feed. In addition, there is little information on the use of different jackfruit sections in poultry feeding. However, there are some studies in ruminants using fermented jackfruit peel with *Aspergillus oryzae* increase digestibility Mashudi and Nurmawati (2022). A previous study has shown an increase in productive performance using toasted jackfruit seed to feed west African dwarf bucks (Eyoh and Udo, 2020). In poultry, using 30% raw seed of jackfruit decrease productive performance (Odukwe et al., 2017), but Eburuaja et al. (2019) using toasted jackfruit seed meal concluded that include 5% improve growth, carcass yield and feed efficiency.

The aim of this study was to evaluate the effects of feeding different jackfruit sections (seed, pulp, and peel) to broilers and the effect on productive performance, carcass traits, meat characteristics, shelf life, and sensory analysis to assess the suitability of jackfruit as an ingredient or feed additive for broilers.

2. Material and methods

This study was approved by the institutional committee for the care and use of the animal laboratory at the Universidad Autónoma del Estado de Hidalgo under the act number: CICUAL-V-I/011/2023. The study was performed in Santiago Tulantepec, Hidalgo, Mexico (20°03'40" N and 98°23'00" W).

A total of 220 Cobb-500 one-day-old male broilers were randomly assigned to four treatment groups, with each group consisting of five replications of 11 birds. The animals in each replication were housed in a 1 m² cage which was adapted with a drinking cup, a manual feeder, with wood chip used as broiler litter. All animals were given feed and water *ad libitum*.

Animals were fed with four diets which were the following: a control group (C), 5% pulp powder (PY), 5% seed powder (SY) and 1% peel powder (CY). The percentage of incorporation for each part of the jackfruit was chosen based on their respective protein and fibre content. Three diets were designed to feed the birds: beginning (1 to 7 days), growing (8 to 30 days), and finishing (31 to 56 days; Table 1). All diets were isoproteic (beginning = 22%, growing = 20%, and finishing = 18%, crude protein), isoenergetic (beginning = 2.8 Mcal kg⁻¹ DM; growing and finishing= 3.0 Mcal kg⁻¹ DM) and isofibrous (4% crude fibre) according to the nutritional requirements of poultry (Rostagno et al., 2024), while the nutritional composition of the ingredients was calculated using data from Fundación Española para el Desarrollo de la Nutrición Animal (FEDNA, 2019). All ingredients were mixed using an ASF MZ50 double helicoidal mixer (Molinos y Mezcladoras Industriales S.A. de C.V. Mexico City, Mexico), and subsequent pellets were obtained using a SKJ120 pelletiser (Shandong, China).

Table 1 - Ingredients (g kg⁻¹ dry matter) and calculated nutrients of diets with different parts of jackfruit (*Artocarpus heterophyllus* Lam.) added to feed broilers

Item	Treatments ¹											
	C	SY	PY	CY	C	SY	PY	CY	C	SY	PY	CY
	Beginning				Growing				Finishing			
Ingredient (g kg ⁻¹ DM)												
Barley	20	-	-	10	-	-	-	10	10	-	-	-
Corn	210	210	210	210	300	350	350	320	550	545	540	550
Sorghum	260	235	235	260	250	200	200	210	20	-	-	20
Biscuit waste	30	30	30	30	30	30	30	30	60	60	60	60
Soybean meal	390	385	385	390	350	300	300	350	290	275	280	290
Soybean oil	60	60	60	60	40	40	40	40	40	40	40	40
Vitamins and minerals premix ²	30	30	30	30	30	30	30	30	30	30	30	30
Jackfruit seed	-	50	-	-	-	50	-	-	-	50	-	-
Jackfruit pulp	-	-	50	-	-	-	50	-	-	-	50	-
Jackfruit peel	-	-	-	10	-	-	-	10	-	-	-	10
Calculated nutrient												
Protein (%)			22				20				18	
Crude fibre (%)			4				4				4	
Digestible energy (Mcal kg ⁻¹ DM)			2.8				3				3	

¹ C - control; SY - 5% jackfruit seed; PY - 5% jackfruit pulp; CY - 1% jackfruit peel.

² Premix composition [calcium carbonate, calcium orthophosphate, sodium bicarbonate, sodium chloride, amino acids (lysine, methionine, threonine), minerals (magnesium, zinc, iron, copper, iodine, selenium) vitamins (A, D3, E, K3, C, B1, B2, B6, B12, biotin, folic acid, niacin, pantothenic acids, choline), natural pigment, mycotoxin binder, phytase].

To obtain peel, seed, and pulp, 175 kg of commercially mature jackfruit were obtained from Xicotepec de Juárez in Puebla state, Mexico. First, the fruit was washed, cut and divided into separate sections (seed, pulp, and peel) which were dried at 60 °C for 72 h using a Riossa HCF-82 dryer (TPM Equipos, Mexico City, Mexico). Subsequently, the samples were ground in a Swissmex SW610350 grinder (Swissmex-Rapid, Lagos de Moreno, Jalisco, Mexico). The yield of each sections of the jackfruit were 51±6; 31.5±5 and 13.5±2% for peel, pulp and seed, respectively). The chemical proximate analysis of the different sections of jackfruit can be observed in Table 2.

During the growth period, productive parameters were measured, which were daily feed intake and weekly animal weight using a Mettria MTNUV-40 scale (Mettria, Mexico City, Mexico). The data obtained were used to calculate the weight gain considered as the difference between the initial and final weight every week. In addition, the feed conversion ratio was calculated.

The broilers were slaughtered when 56 d old according to the national legislation for the slaughter of animals (NOM-033-SAG/ZOO-2014). Subsequently, samples from the small intestine (duodenum, jejunum, and ileum) were obtained from broilers fed with all treatments (n = 5 by treatment). Later, these samples were processed using the paraffin embossed method (Prophet et al., 1992) using a Microm model TP120 automatic tissue processor (Microm GmbH, Waldorf Germany). The samples were stained using the hematoxylin and eosin method (Prophet et al., 1992). Subsequently, the samples were analysed using a bright-field Olympus BX41 microscope (Olympus Corporation, Tokyo, Japan).

Table 2 - Chemical proximate analysis of the different sections of jackfruit (*Artocarpus heterophyllus* Lam.)

Variable (%)	Section of jackfruit		
	Pulp	Seed	Peel
Dry matter	10.02±0.07	12.78±0.36	16.07±0.73
Ash	6.47±0.5	5.00±0.00	5.97±0.56
Crude protein	13.10±1.72	17.52±0.02	9.01±0.56
Neutral detergent fibre	39.15±1.12	57.08±2.97	67.77±0.64
Acid detergent fibre	31.41±0.33	40.06±1.30	57.16±0.27

Changes in tissues were observed, while images were captured using ImagePro ver. 6.0 software (MediaCybernetics).

To determine the composition of the broilers' carcass characteristics, the hot carcasses from the birds were weighed (carcass was considered after removing blood, feathers, viscera, head, and feet) and the cold carcasses were weighed after the chilling process (5 °C/5 min). Carcasses were divided into the breast, legs, thighs, wings, and rest of the carcass. The viscera were weighed in its entirety and separately to the heart, liver, and kidney. All measurements were carried out using a Torrey L-PCR scale (Torrey, Monterrey, NL, Mexico). From the weighing process previously described, dressing percentages for hot and cold carcasses were calculated, while chiller yield was determined from the difference between hot carcass weight and cold carcass weight.

The characteristics were evaluated after slaughtering the broilers ($n = 12$ for each treatment). Pectoralis muscle pH levels ($n = 3$ for each sample) were measured using a Hanna HI99163 pHmeter (Hanna Instruments, Cluj-Napoca, Romania). The colour of the meat ($n = 5$ for each sample) was determined using the colour space with a Minolta CM-508d colorimeter (Konica Minolta, Tokyo, Japan). This equipment was configured with a D65 illuminant, and calibrated with an aperture of 8 mm aperture, with the angle set to 10°. Then, the angle and Chroma were calculated as $h = \arctangent(b^*/a^*)$ and $C = (a^{*2} + b^{*2})^{0.5}$, respectively, following the indications described by King et al. (2023).

All pieces from each treatment of pectoralis meat were deboned, vacuum packed, and frozen until use (three months) for sensory analysis. The samples were thawed, and the meat was then ground and mixed with 1% chloride sodium. The meat (30 g) was placed on aluminium foil and cooked in a Vollrath 40795 model grill (Vollrath, Wisconsin, USA) at 205 °C for 2.30 min. A sensory analysis was performed using pectoralis meat samples ($n = 12$ for each treatment) obtained from the groups C, SY, PY and CY. An affective hedonic test was performed to determine the acceptability levels for the samples. Sixty-six consumers with an average of age of 29 years were recruited to evaluate the samples, of which 47% were female and 53% were male. Each attribute was graded using a 10 cm scale marked with words indicating weak intensity on the left and strong intensity on the right. The test was carried out in analysis sensorial laboratory booths that met international requirements as indicated in the ISO 8589 standard (ISO, 2007). Consumers were asked to assess the sensory properties of the ground and cooked broiler meat considering five attributes, which were odour, firmness, juiciness, flavour, and general acceptability. Furthermore, the colour of the raw meat was determined using three variants (white, red, and yellowness) as indicated in Table 3. A set of four broiler meat samples for each treatment was presented to consumers together with water and a cracker to cleanse the palate between the sample tasting. Samples were presented randomly to the consumers to avoid first-order carryover effects (MacFie et al., 1989).

Table 3 - Descriptors with scale (0 to 10) used to evaluate raw and cooked broiler

Attribute	Descriptor
	Cooked broilers meat
Odour	0 = slight odour, 10 = strong odour
Firmness	0 = extremely soft, 10 = extremely hard
Juiciness	0 = extremely dry, 10 = extremely juicy
Flavour	0 = extremely unacceptable, 10 = extremely acceptable
General acceptability	0 = extremely unacceptable, 10 = extremely acceptable
	Raw broilers meat
Red	0 = slight, 10 = intense
Yellow	0 = slight, 10 = intense

This study was carried out using a completely random design, with data analysed by ANOVA using a generally linear model for carcass traits, meat characteristics, and sensory analysis according to the following model:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

A mixed model was used to analyse feed intake, daily weight gain, weekly weight, and feed conversion ratio according to the following model:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \alpha_i * \beta_j + \alpha_i(\beta_j) + \varepsilon_{ij},$$

in which Y_{ij} = response variable; μ = population media general; α_i = experimental diets; β_j = weeks; $\alpha_i * \beta_j$ = interaction between experimental diets and weeks; $\alpha_i(\beta_j)$ = rabbit in each cage as a random effect; ε_{ij} = experimental error.

Differences between the averages were evaluated using the lsmeans option to compare treatments or treatments $\times$ weeks. All data were analysed using SAS version 9.0.

3. Results

There was not interaction between time and treatments for feed intake, weight gain and weekly weight ($P > 0.05$; Table 4). However, feed intake during the first week was similar among the treatments ($P > 0.05$) fluctuating between 13.6 and 14.6 g d⁻¹ (Table 4). Nevertheless, groups were different on fifth and sixth weeks ($P < 0.05$), with groups C and CY consuming less food. Daily weight gain was different

Table 4 - Means of daily feed intake, daily weight gain, and weekly weight to determine the productive performance of broilers fed jackfruit (*Artocarpus heterophyllus* Lam.)

Variable	Weeks	Treatments ¹				SEM	P-value		
		C	SY	PY	CY		Treatment	Weeks	Treatment $\times$ Weeks
Feed intake (g)	1	14.15d	13.84f	14.05e	13.62e	6.14	0.00	0.00	0.19
	2	29.98d	33.35e	31.77d	29.96d	6.68			
	3	67.95c	67.98d	69.92c	65.00c	6.87			
	4	99.48b	106.63c	104.16b	97.19b	6.87			
	5	126.30aBC	148.85bA	139.32aAB	119.09aC	6.87			
	6	131.12aC	172.18aA	150.40aB	134.00aBC	6.87			
	SEM	6.74	6.74	6.74	6.62				
Daily weight gain (g)	1	9.20e	15.68c	16.47d	15.07d	4.02	0.54	0.00	0.68
	2	15.71d	14.79c	15.65c	16.11c	4.38			
	3	34.81c	27.19c	30.49c	31.45c	4.50			
	4	49.61bc	44.74b	45.98b	47.90b	4.67			
	5	70.15abA	61.67aB	64.18bB	75.82abA	4.50			
	6	79.84a	74.31a	74.65a	68.20a	4.50			
	SEM	4.42	4.42	4.50	4.45				
Feed conversion ratio	1	1.55cA	0.89cB	0.85cB	0.91cB	0.13	0.00	0.00	0.02
	2	1.84bc	2.17bc	1.96c	1.87bc	0.13			
	3	1.99bB	2.52aA	2.30aA	2.09aA	0.15			
	4	2.05abB	2.48bA	2.28bA	2.16bcB	0.16			
	5	1.83aB	2.50abA	2.18aB	1.57bB	0.15			
	6	1.65aB	2.35abA	2.03abB	2.24bA	0.15			
	SEM	0.14	0.14	0.14	0.14				

SEM - standard error of the mean.

¹ C - control; SY - 5% jackfruit seed; PY - 5% jackfruit pulp; CY - 1% jackfruit peel.

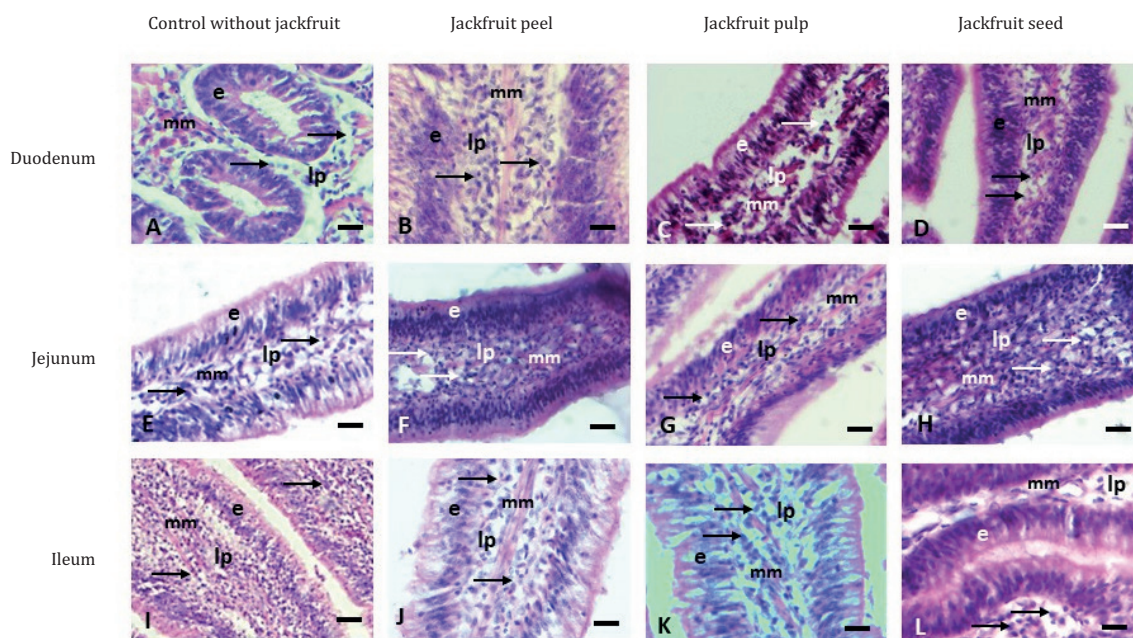
Means within each column followed by different lowercase letters differ at $P < 0.05$.

Means within each row followed by different uppercase letters differ at $P < 0.05$.

among the groups ($P<0.05$) only during the fifth week of growth, with the C and CY presenting the highest weight gains (Table 4).

Feed conversion ratio (FCR) has shown an interaction between treatment and time ($P<0.05$; Table 4). Subsequently, the FCR was different ($P<0.05$) among treatments, the highest values for FCR were obtained in the control and PY groups in the first week. However, after six weeks to fed with different jackfruit sections, these groups have the lowest FCR values (Table 4).

There was no evidence of morphological changes to indicate pathological effects among the treatments (Figure 1). However, the small intestine analysis of the three sections analysed (duodenum, jejunum, and ileum) from all of the animals sampled (treatments and control) had moderate lymphocyte infiltration in the lamina propria and a slight presence at the epithelial level (Figure 1). In addition, no changes or pathological alterations were observed in the organs' structure, while the presence of protozoa or bacteria was not detected (Figure 1).



A-D: Duodenum without treatment, and treatments with peel, pulp and seed of jackfruit. E-H: Jejunum without treatment, and treatments with peel, pulp and seed of jackfruit. I-L: Ileum without treatment, and treatments with peel, pulp and seed of jackfruit. e: simple columnar epithelium with goblet cells, lp: lamina propria, mm: muscularis mucosae. Arrows indicate lymphocytic infiltration in the lp. Bars = 20 μ m.

Figure 1 - Small intestine of broilers fed jackfruit using different components of the fruit (*Artocarpus heterophyllus* Lam).

Evaluation of the main cuts shows differences among the treatments ($P<0.05$) in lower-value cuts (Table 5). The respective weights of the liver and heart were different ($P<0.05$), and the animals from groups PY and CY groups had the smallest organs compared to the control group. The others body components and carcass yields were similar ($P<0.05$) among all groups. The lower-value cuts (head, neck, back and rump) were lower in CY treatment (Table 5).

Table 5 - Means of carcass characteristics of jackfruit-fed broilers (*Artocarpus heterophyllus* Lam.)

Variable (%)	Treatments ¹				SEM	P-value
	C	SY	PY	CY		
Carcass and visceral yields ²						
Hot carcass yield	64.95	67.10	65.83	65.18	1.06	0.41
Cold carcass yield	66.8	68.9	67.99	67.13	1.39	0.67
Feathers	8.87	8.17	8.83	8.87	0.41	0.52
Viscera	11.61	12.19	11.98	12.00	0.52	0.86
Liver	2.63a	2.36ab	2.30b	2.11b	0.10	0.01
Heart	0.84a	0.71b	0.75ab	0.81ab	0.03	0.05
Gizzard	1.37	1.25	1.32	1.25	0.08	0.75
Chiller yield ³	102.90	102.65	103.40	103.04	1.41	0.98
Carcass trait ⁴						
Legs	12.29	12.02	11.81	11.69	0.22	0.29
Thighs	13.65	13.90	14.37	14.6	0.38	0.32
Breast	33.82	34.72	34.64	35.30	0.72	0.57
Wings	10.21	10.12	10.49	10.31	0.19	0.58
Neck	5.55a	5.84a	4.75b	4.89b	0.19	0.00
Back	8.68	8.76	7.80	8.26	0.23	0.02
Rump	7.49a	7.38a	7.69a	6.37b	0.31	0.03
Head	3.23a	2.75b	2.85b	2.87b	0.11	0.02
Feet	4.75	4.46	4.91	4.93	0.17	0.20

SEM - standard error of the mean.

¹ C - control; SY - 5% jackfruit seed; PY - 5% jackfruit pulp; CY - 1% jackfruit peel.² Calculated based on live weight.³ Calculated based on hot carcass weight.⁴ Calculated based on cold carcass weight.

Means within a row followed by different lowercase letters differ at P<0.05.

The L* value in the meat was higher (P<0.05) in the C and CY groups (Table 6). Since Hue values were higher (P<0.05) in CY group without differences among the animals feed with jackfruit sections (P>0.05; Table 6). While redness values on skin were higher in control and SY groups, although yellowness values were higher in treatments feed with jackfruit sections. Likewise, the hue and chroma for the skin were higher in the SY, PY, and CY groups (Table 6).

Table 6 - Means for meat and skin colour from broilers fed jackfruit (*Artocarpus heterophyllus* Lam.)

	Variable	Treatments ¹				SEM	P-value
		C	SY	PY	CY		
Meat	L*	57.17a	53.59b	54.92b	58.40a	0.51	0.00
	a*	0.34	0.77	0.22	0.45	0.16	0.10
	b*	13.42	13.76	13.68	15.02	0.49	0.13
	Chroma	13.51	13.81	13.78	15.09	0.49	0.14
	Hue	85.08b	86.22ab	86.32ab	87.50a	0.46	0.00
	pH	6.49ab	6.42c	6.45bc	6.52a	0.01	0.00
Skin	L*	62.59	63.67	63.77	63.51	0.40	0.1618
	a*	5.20a	4.69a	3.62b	3.86b	0.30	0.0015
	b*	20.58b	23.68a	25.16a	24.76a	0.45	<0.0001
	Chroma	21.45b	24.25a	25.47a	25.10a	0.47	<0.0001
	Hue	68.90b	75.22a	82.01a	81.29a	2.65	0.0021

SEM - standard error of the mean.

¹ C - control; SY - 5% jackfruit seeds; PY - 5% jackfruit pulp; CY - 1% jackfruit peel.

Means followed by different letters among rows differ at P<0.05.

The intensity of the odour attribute had the lowest values ($P < 0.05$) in the CY group (Table 7). The C, SY and PY groups recorded the lowest hardness parameters and the highest juiciness values ($P < 0.05$; Table 7). Furthermore, the C and SY groups showed the highest intensity in terms of redness, while the highest intensity for yellowness was recorded in the CY group ($P < 0.05$). Finally, for flavour and general acceptability, all treatments were similar ($P < 0.05$; Table 7).

Table 7 - Mean for the sensory analysis of meatballs made from broilers fed jackfruit (*Artocarpus heterophyllus* Lam.)

Attribute	Treatments ¹				SEM	P-value
	C	SY	PY	CY		
Odour	3.91ab	3.96a	3.97a	3.12b	0.29	0.12
Hardness	4.01b	3.45b	4.03b	5.66a	0.24	0.00
Juiciness	5.31a	5.67a	5.32a	3.64b	0.24	0.00
Flavour	6.21	6.31	6.08	6.17	0.25	0.93
General acceptability	6.35	6.61	6.39	6.49	0.24	0.88
Redness intensity	7.03a	6.98a	5.73 b	1.57c	0.22	0.00
Yellowness intensity	1.89c	1.83c	2.74 b	7.14a	0.21	0.00

SEM - standard error of the mean.

¹ C - control; SY - 5% jackfruit seed; PY - 5% jackfruit pulp; CY - 1% jackfruit peel.

Means followed by different letters among rows differ at $P < 0.05$.

4. Discussion

Body weight gain is influenced by feed intake, and positive changes in feed intake influence the feed conversion ratio, which in turn predicts carcass composition (Martinez et al., 2022). Some non-conventional ingredients or additives obtained from agro-industrial by-products can be used in poultry feeding, including different jackfruit sections. The results of this study indicate the observed effect on feed intake may be related to the components present in jackfruit. The control and PY treatments had the best FCR because feed intake was lower while body weight gain was greater. Therefore, feeding jackfruit sections, such as pulp and seed, had a detrimental effect on feed intake. Previous studies have observed that jackfruit pulp or seed decreased body weight. Agiang et al. (2017) fed rats with different quantities of jackfruit pulp and found that body weight decreased due to the presence of antinutritional factors such as oxalates and phytate, which can affect the bioavailability of nutrients. In a related study, Kadem Bemmo et al. (2023) described the presence of antinutritional compounds in jackfruit pulp and boiled seeds, such as condensed tannin, hydrolysed tannin, oxalate, phytate, and saponin. However, the use of 10% toasted jackfruit seed in the diet of west African dwarf bucks contributed to an increase in body weight gain (Eyoh et al., 2021). This could be attributed to the toasting process, which contributes to reducing antinutritional compounds, such as phytate, oxalate, and tannin (Eyoh, 2020).

As indicated above, the jackfruit has antinutritional factors that can influence feed intake, which consequently affects body weight during animal growth. However, the group fed with jackfruit peel showed lower feed intake but higher body weight gain and a similar FCR to the control group. Therefore, jackfruit peel can be used in poultry diets because it contains phenolic compounds can improve growth. Jackfruit contains 14 different phenolic compounds that contribute to its antioxidant properties and phenolic compounds which are found in the whole fruit (Maradesha et al., 2022), as well as in the seeds, pulp (Kamdem Bemmo et al., 2023) and peel (Zhang et al., 2017). These phenolic compounds, such as gallic and tannic acids, may contribute to improved growth in broilers fed jackfruit peel. Patel et al. (2016) evaluated *Emblia officinalis* fruits fed to broilers and indicated that gallic and tannic acids could have anabolic and antioxidant effects that contribute to growth performance. It is possible that jackfruit increases broiler growth, as the final body weight in this study was higher than that reported by Odukwe et al. (2017) who added jackfruit seeds at different inclusion levels to broiler diets. The

nutrients and phenolic compounds in jackfruit may be important contributors to the development and growth of broilers, although these compounds are affected by climate, geographical area, processing and extraction methods (Erinle and Adewole, 2022).

In another study, jackfruit peel was used to feed red tilapia fish, resulting in an increased growth rate and weight gain (Sulaiman et al., 2022). In addition, Zhang et al. (2017) found that jackfruit peel contains higher levels of phenolic compounds than the pulp or the seed, and it is possible that these types of compounds promote growth in both fish and livestock (Sulaiman et al., 2022). Although jackfruit peel is a by-product, it has a high nutritional value and energy content; therefore, it can potentially be used in broiler diets (Sugiharto, 2023). However, Eburuaja et al. (2019) evaluated roasted jackfruit seeds in broiler diets and reported a higher feed conversion ratio, recommending the inclusion of 5% roasted seeds to increase the percentage of carcass dressing.

On the other hand, the description of the histology findings in the three organs defined in this study was mainly related to lymphocyte infiltration of the tunica mucosa. This is to be expected as the microorganism population becomes dense during broiler production and interacts directly with the host when the feed is ingested (Pan and Yu, 2014). There was no evidence to suggest that supplementing broiler feed with jackfruit had a negative effect on the morphology of the small intestine. As stated by Colombino et al. (2020), phenolic compounds found in fruits have a positive effect on intestinal morphology. Furthermore, no major pathological changes were observed in the structural integrity of the organs studied, and no differences were observed compared with the control group. According to these results, the supplementation of different jackfruit components to broiler feed in the quantities used in this research does not cause harm to the architectural tissue of the small intestine. Perin et al. (2023) concluded that bioactive compounds can have a positive influence on the morphophysiological characteristics of the small intestine. Furthermore, Colombino et al. (2020) reported no significant changes in the three segments of the small intestine after supplementing broilers with fruit waste.

The use of agro-industrial by-products feed animals does not affect the carcass yield. There are many studies indicating that the use of fruit by-products, such as apple, cherry, and strawberry (Sosnówka-Czajka et al., 2023), sea buckthorn (Ma et al., 2015), carob (Mahmoudi et al., 2022), bocaiuva (Perin et al., 2023), and okra fruit (Ashour et al., 2020) does not affect carcass yield when included at low levels in broiler diets.

Meat colour is an important characteristic in consumer acceptance of meat (Adeyemi and Sazili, 2014), and the perception of meat colour results from the interaction between the light source and the human eye or the colorimeter used (King et al., 2023). The differences found in meat and skin colour could be due to the natural pigment content in jackfruit such as carotenoids (Sosnówka-Czajka et al., 2023), which are responsible for yellow and red pigmentation and can be found in the fruit. Jackfruit also contains carotenoids such as lutein and β -carotene (Faria et al., 2009).

The pH is the result of the transformation of glycogen into lactic acid during the conversion of muscle to meat (Adeyemi and Sazili, 2014; Ashour et al., 2020; Matarneh et al., 2023). The results indicate that the C and CY groups had a higher pH compared to the SY and PY groups. However, the pH values found in this study were higher than those in other studies, which consider that a normal pH ranges between 5.7 and 5.9. Any values which are lower or higher than this range are associated with meat defects (Perin et al. 2023; Hammemi et al., 2024).

Meat consumption depends on sensory attributes which are influenced by antemortem and postmortem factors (Adeyemi and Sazili, 2014). Ashour et al. (2020) indicates that meat pH is one the main factors with regard to meat quality including colour, juiciness, and hardness. Samutsri et al. (2023) developed a sensory analysis with chicken meatballs added with immature jackfruit and found similar attributes for flavour, taste, and general preference.

5. Conclusions

The use of jackfruit peel at 1% of the diet as a new fiber-rich ingredient has been improved productive performance in broilers without affecting carcass yield, small intestine histology, or the general

acceptability of the meat. These findings support the potential application of jackfruit peel as an alternative ingredient broiler diets, contributing to safer and more environmentally sustainable feed practices while enhancing the suitability of broiler meat for human consumption. However, the use of different jackfruit sections in broiler diets needs to be studied in greater depth, with an emphasis on identifying the bioactive compounds that may affect productive performance and meat quality.

Data availability

The entire dataset supporting the results of this study is available upon request to the corresponding author.

Author contributions

Conceptualization: Ortega-González, L.; Soto-Simental, S.; Ocampo-López, J. and Ayala-Martínez, M. **Data curation:** Soto-Simental, S. **Formal analysis:** Ortega-González, L. and Soto-Simental, S. **Funding acquisition:** González-Tenorio, R.; Ocampo-López, J. and Ayala-Martínez, M. **Investigation:** González-Tenorio, R.; Hernández-Domínguez, H.; Nava-Morales, G. M. and Ayala-Martínez, M. **Methodology:** Ortega-González, L.; Soto-Simental, S.; González-Tenorio, R.; Ocampo-López, J.; Hernández-Domínguez, H.; Nava-Morales, G. M. and Ayala-Martínez, M. **Project administration:** Ayala-Martínez, M. **Resources:** Soto-Simental, S.; González-Tenorio, R.; Ocampo-López, J.; Hernández-Domínguez, H. and Ayala-Martínez, M. **Software:** Soto-Simental, S. **Supervision:** Soto-Simental, S.; Ocampo-López, J.; Hernández-Domínguez, H.; Nava-Morales, G. M. and Ayala-Martínez, M. **Validation:** Soto-Simental, S.; Hernández-Domínguez, H.; Nava-Morales, G. M. and Ayala-Martínez, M. **Visualization:** González-Tenorio, R. **Writing – original draft:** Ortega-González, L. and Ayala-Martínez, M. **Writing – review & editing:** Soto-Simental, S.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The authors express their gratitude to the Secretaria de Ciencia, Humanidades, Tecnología e Innovación from Mexican government for grant number 1002987 assigned to Ortega-González, L. Furthermore, the authors would like to express their gratitude to Christopher Shackley for English language editing the manuscript.

References

- Adan, A. A.; Ojwang, R. A.; Muge, E. K.; Mwanza, B. K. and Nyaboga E. N. 2020. Phytochemical composition and essential mineral profile, antioxidant and antimicrobial potential of unutilized parts of jackfruit. *Food Research* 4:1125-1134.
- Adeyemi, K. D. and Sazili, A. Q. 2014. Efficacy of carcass electrical stimulation in meat quality enhancement: A review. *Asian-Australasian Journal of Animal Science* 27:447-456. <https://doi.org/10.5713/ajas.2013.13463>
- Agiang, M. A.; Dongo, B. S.; Williams, I. O. and Utu-Baku, A. B. 2017. Assessment of the haematological indices of albino rats fed diets supplemented with jackfruit bulb, seed or a blend of bulb and seed. *International Journal of Biology and Chemical Sciences* 11:397-407. <https://doi.org/10.4314/ijbcs.v11i1.31>
- Antonisamy, A. J.; Marimuthu, S.; Malayandi, S.; Rajendran, K.; Lin, Y. C.; Andaluri, G.; Lee, S. L. and Ponnusamy, V. K. 2023. Sustainable approaches on industrial food wastes to value-added products—A review on extraction methods, characterizations, and its biomedical applications. *Environmental Research*. 217:114758. <https://doi.org/10.1016/j.envres.2022.114758>
- Ashour, E. A.; Bin-Jumah, M.; Abou Sayed-Ahmed, E. T.; Osman, A. O.; Taha, A. E.; Momenah, M. A.; Allam, A. A.; Swelum, A. A. and Abd-El-Hack, M. E. 2020. Effects of dried okra fruit (*Abelmoschus esculentus* L.) powder on growth, carcass characteristics, blood indices, and meat quality of stored broiler meat. *Poultry Science* 99:3060-3069. <https://doi.org/10.1016/j.psj.2020.03.009>

- Brahma, R. and Ray, S. 2024. Optimization of extraction conditions for cellulose from jackfruit peel using RSM, its characterization and comparative studies to commercial cellulose. *Measurement: Food* 13:100130. <https://doi.org/10.1016/j.meafoo.2023.100130>
- Colombino, E.; Ferrocino, I.; Biasato, I.; Cocolin, L. S.; Prieto-Botella, D.; Zduńczyk, Z.; Jankowski, J.; Milala, J.; Kosmala, M.; Fotschki, B.; Capucchio, M. T. and Juskiewicz, J. 2020. Dried fruit pomace inclusion in poultry diet: growth performance, intestinal morphology and physiology. *Journal of Animal Science and Biotechnology* 11:63. <https://doi.org/10.1186/s40104-020-00464-z>
- Eburuaja, A. S.; Onabanjo, R. S.; Onunkwu, D. N. and Ukenye, U. S. 2019. Performance of broiler chickens fed graded dietary levels of toasted jackfruit seed meal (*Artocarpus heterophyllus*). *Nigerian Journal of Animal Production* 46:171-178. <https://doi.org/10.51791/njap.v46i4.346>
- Erinle, T. J. and Adewole, D. I. 2022. Fruit pomaces — their nutrient and bioactive components, effects on growth and health of poultry species, and possible optimization techniques. *Animal Nutrition* 9:357-377. <https://doi.org/10.1016/j.aninu.2021.11.011>
- Eyoh, G. D. 2020. Effects of processing on nutrient composition of jackfruit (*Artocarpus heterophyllus*) seed meal. *International Journal of Agriculture and Rural Development* 23:5301-5306.
- Eyoh, G. D.; Ibanga, G. L.; Udo, M. D. and Offiong, E. E. 2021. Growth performance of West African Dwarf (WAD) bucks fed graded levels of toasted jackfruit seed meal. *Journal of Agriculture and Food Science* 5:90-97.
- Eyoh, G. D. and Udoh, M. D. 2020. Effects of processed jackfruit seed based diet on nutrient intake, digestibility and nutrition in West African dwarf goats. *Nigerian Journal of Animal Production* 47:204-212. <https://doi.org/10.51791/njap.v47i5.1271>
- Faria, A. F.; Rosso, V. V. and Mercadante, A. Z. 2009. Carotenoid composition of jackfruit (*Artocarpus heterophyllus*), determined by HPLC-PDA-MS/MS. *Plant Foods and Human Nutrition* 64:108-115. <https://doi.org/10.1007/s11130-009-0111-6>
- FEDNA - Fundación Española para el Desarrollo de la Nutrición Animal. 2019. Tablas FEDNA de composición y valor nutritivo para la fabricación de piensos compuestos. 4th ed. FEDNA, Madrid. Available at: <<http://www.fundacionfedna.org/>>. Accessed on: Mar. 05, 2023.
- Hammemi, C.; Askri, A.; Létourneau-Montminy, M.-P. and Alnahhas, N. 2024. Current state of breast meat quality in standard-yielding broiler strains. *Journal of Applied Poultry Research* 33:100383. <https://doi.org/10.1016/j.japr.2023.100383>
- ISO - International Organization for Standardization. ISO 8589. 2007. Sensory analysis. General guidance for the design of test rooms. ISO, Geneva, Switzerland. Available at: <<https://www.iso.org/standard/36385.html>>. Accessed on: Mar. 05, 2023.
- Kamdem Bemmo, U. L.; Bindzi, J. M.; Tayou Kamseu, P. R.; Houketchang Ndomou, S. C.; Tene Tambo, S. and Ngoufack Zambou, F. 2023. Physicochemical properties, nutritional value, and antioxidant potential of jackfruit (*Artocarpus heterophyllus*) pulp and seeds from Cameroon eastern forests. *Food Science & Nutrition* 11:4722-4734. <https://doi.org/10.1002/fsn3.3437>
- King, D. A.; Hunt, M. C.; Barbut, S.; Claus, J. R.; Cornforth, D. P.; Joseph, P.; Kim, Y. H. B.; Lindahl, G.; Mancini, R. A.; Nair, M. N.; Merck, K. J.; Milkowski, A.; Mohan, A.; Pohlman, F.; Ramanathan, R.; Raines, C. R.; Seyfert, M.; Sørheim, O.; Suman, S. P. and Weber, M. 2023. American Meat Science Association guidelines for meat color measurement. *Meat and Muscle Biology* 6:12473. <https://doi.org/10.22175/mmb.12473>
- Lazarus, B. S.; Leung, V.; Luu, R. K.; Wong, M. T.; Ruiz-Pérez, S.; Barbosa, W. T.; Bezerra, W. B. A.; Barbosa, J. D. V. and Meyers, M. A. 2023. Jackfruit: Composition, structure, and progressive collapsibility in the largest fruit on the Earth for impact resistance. *Acta Biomaterialia* 166:430-446. <https://doi.org/10.1016/j.actbio.2023.04.040>
- Ma, J. S.; Chang, W. H.; Liu, G. H.; Zhang, S.; Zheng, A. J.; Li, Y.; Xie, Q.; Liu, Z. Y. and Cai, H. Y. 2015. Effect of flavones of sea buckthorn fruits on growth performance, carcass quality, fat deposition and lipometabolism for broilers. *Poultry Science* 94:2641-2649. <https://doi.org/10.3382/ps/pev250>
- MacFie, H. J.; Bratchell, N.; Greenhoff, K. and Vallis, L. V. 1989. Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. *Journal of Sensory Studies* 4:129-148. <https://doi.org/10.1111/j.1745-459X.1989.tb00463.x>
- Mahmoudi, S.; Mahmoudi, N.; Benamirouche, K.; Estévez, M.; Abou Mustapha, M.; Bougoutaia, K. and Djoudi, N. E. H. B. 2022. Effect of feeding carob (*Ceratonia siliqua* L.) pulp powder to broiler chicken on growth performance, intestinal microbiota, carcass traits, and meat quality. *Poultry Science* 101:102186. <https://doi.org/10.1016/j.psj.2022.102186>
- Maradesha, T.; Patil, S. M.; Al-Mutairi, K. A.; Ramu, R.; Madhunapantula, S. V. and Alqadi, T. 2022. Inhibitory effect of polyphenols from the whole green jackfruit flour against α -glucosidase, α -amylase, aldose reductase and glycation at multiple stages and their interaction: inhibition kinetics and molecular simulations. *Molecules* 27:1888. <https://doi.org/10.3390/molecules27061888>
- Martinez, D. A.; Weil, J. T.; Suesuttajit, N.; Umberson, C.; Scott, A. and Coon, C. N. 2022. The relationship between performance, body composition, and processing yield in broilers: A Systematic review and meta-regression. *Animals* 12:2706. <https://doi.org/10.3390/ani12192706>

- Matarneh, S. K.; Scheffler, T. L. and Gerrard, D. E. 2023. The conversion of muscle to meat. p.159-194. In: Lawrie's meat science. 9th ed. Toldrá, F., ed. Woodhead Publishing, Cambridge. <https://doi.org/10.1016/B978-0-323-85408-5.00010-8>
- Mashudi, M. and Nurmawati, W. 2022. Effect of fermentation on mixed rumen contents and jackfruit peel using *Aspergillus oryzae* on *in vitro* gas production and digestibility. E3S Web of Conferences 335:00048. <https://doi.org/10.1051/e3sconf/202233500048>
- Natta, S.; Pal, K.; Kumar Alam, B.; Mondal, D.; Kumar Dutta, S.; Sahana, N.; Mandal, S.; Bhowmick, N.; Das, S. S.; Mondal, P.; Pandit, G. K.; Paul, P. K. and Choudhury, A. 2023. In-depth evaluation of nutritive, chemical constituents and anti-glycemic properties of jackfruit (*Artocarpus heterophyllus* Lam) clonal accessions with flake colour diversity from Eastern Sub-Himalayan plains of India. Food Chemistry 407:135098. <https://doi.org/10.1016/j.foodchem.2022.135098>
- NOM-033-SAG/ZOO-2014. Norma Oficial Mexicana. Métodos para dar muerte a los animales domésticos y silvestres. Diario Oficial de la Federación. Available at: <<https://www.gob.mx/profepa/documentos/norma-oficial-mexicana-nom-033-sag-zoo-2014-metodos-para-dar-muerte-a-los-animales-domesticos-y-silvestres?msckid=fab04bbfd0db11ecae8a104aa8451dca>>. Accessed on: Apr. 10, 2023.
- Odukwe, C. N.; Onunkwu, D. N.; Eburuaja, A. S. and Mathias, V. N. 2017. Carcass and internal organ characteristics of broiler chickens fed soybean diets partially replaced with variable levels of raw jackfruit seed meal. Nigeria Agricultural Journal 48:190-198.
- Orayaga, K. T.; Oluremi, O. A.; Tuleun, C. D. and Carew, S. N. 2015. The feed value of composite mango (*Mangifera indica*) fruit reject meal in the finisher broiler chickens nutrition. African Journal Food Science and Technology 6:177-184. <https://doi.org/10.14303/ajfst.2015.054>
- Pan, D. and Yu, Z. 2014. Intestinal microbiome of poultry and its interaction with host and diet. Gut Microbes 5:108-119. <https://doi.org/10.4161/gmic.26945>
- Patel, A. P.; Bhagwat, S. R.; Pawar, M. M.; Prajapati, K. B.; Chauhan, H. D. and Makwana, R. B. 2016. Evaluation of *Emblia officinalis* fruit powder as a growth promoter in commercial broiler chickens. Veterinary World 9:207-210. <https://doi.org/10.14202/vetworld.2016.207-210>
- Perin, G. R.; Eyng, C.; Nunes, R. V.; Duarte, C. R. A.; Kaufmann, C.; Tesser, G. L. S.; Rohloff Júnior, N. and Savaris, V. D. L. 2023. Effect of bocaiuva pulp oil supplementation of broiler chicken diets on growth performance and quality and oxidative stability of meat. Livestock Science 275:105300. <https://doi.org/10.1016/j.livsci.2023.105300>
- Prophet, E. B.; Mills, B.; Arrington, J. B. and Sobin, L. H. 1992. Laboratory methods in histotechnology. Armed Forces Institute of Pathology, Washington, DC.
- Rostagno, H. S.; Albino, L. F. T.; Calderano, A. A.; Hannas, M. I.; Sakomura, N. K.; Perazzo, F. G.; Rocha, G. C.; Saraiva, A.; Abreu, M. L. T.; Genova, J. L. and Tavernari, F. C. 2024. Brazilian tables for poultry and swine: composition of feedstuffs and nutritional requirements. 5th ed. Suprema, Visconde do Rio Branco. <https://doi.org/10.26626/978-85-8179-212-5.2024.B001>
- Samutsri, W.; Oumaree, K. and Thimthud, S. 2023. Physicochemical characteristics and sensory preference of chicken ball with unripe jackfruit. LWT-Food Science and Technology 189:115489. <https://doi.org/10.1016/j.lwt.2023.115489>
- Sosnówka-Czajka, E.; Skomorucha, I.; Obremski, K. and Wojtacha, P. 2023. Performance and meat quality of broiler chickens fed with the addition of dried fruit pomace. Poultry Science 102:102631. <https://doi.org/10.1016/j.psj.2023.102631>
- Sugiharto, S. 2023. The effect of using fruit peel on broiler growth and health. Veterinary World 16:987-1000. <https://doi.org/10.14202/vetworld.2023.987-1000>
- Sulaiman, M. A.; Yusoff, F. M.; Kamarudin, M. S.; Amin, S. M. N. and Kawata, Y. 2022. Fruit wastes improved the growth and health of hybrid red tilapia *Oreochromis* sp. and Malaysian mahseer, *Tor tambroides* (Bleeker, 1854). Aquaculture Reports 24:101177. <https://doi.org/10.1016/j.aqrep.2022.101177>
- Wadhwa, M.; Bakshi, M. P. S. and Makkar, H. P. S. 2015. Waste to worth: fruit wastes and by-products as animal feed. CABI Reviews 10:1-26. <https://doi.org/10.1079/PAVSNNR201510031>
- Zhang, L.; Tu, Z. C.; Xie, X.; Wang, H.; Wang, H.; Wang, Z. X.; Sha, X. M. and Lu, Y. 2017. Jackfruit (*Artocarpus heterophyllus* Lam.) peel: A better source of antioxidants and α -glucosidase inhibitors than pulp, flake and seed, and phytochemical profile by HPLC-QTOF-MS/MS. Food Chemistry 234:303-313. <https://doi.org/10.1016/j.foodchem.2017.05.003>