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Effect of Adding Guava Epicarp Extract Flour (*Psidium guajava*) on the Physicochemical, Textural, Colour and Sensory Properties of Frankfurter Sausages

Guava Epicarp Extract Flour in Frankfurter Sausages

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SUMMARY

Research background. The industrial transformation of tropical fruits, and in particular guava, generates a large quantity of by-products that are generally disposed of as organic waste. In said by-products a large quantity of bioactive substances is concentrated, such as carotenoids, which can be used for the partial substitution of nitrites in meat sausages without affecting their physicochemical, color and conservations characteristics. Although there are some studies in this regard, not carried out with guava residues, there is still a lack of research to verify this hypothesis. Therefore, the aim of this study was to investigate the action of the components of the guava epicarp extract on frankfurters.

Experimental approach. Three treatments were proposed (25 %, 50 % and 75 % replacement of guava epicarp flour extract), along with a control treatment without said extract. The physicochemical properties, color coordinates, and texture parameters were analyzed, and a sensory evaluation was also carried out. The treatment that presented the best results was subjected to a stability analysis over 30 days.

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Results and conclusions. The treatment with the 25 % of guava epicarp flour extract addition showed the best results, which did not affect the coloration of the sausages or the physicochemical and textural properties. Likewise, during the stability analysis over time, the parameters related to fat oxidation were not affected, and the final products obtained a final residual nitrite load of (23.65±0.16) mg/kg, lower than the maximum allowed (150 mg/kg).

Novelty and scientific contribution. The partial substitution of the nitrites in Frankfurt sausages by the carotenoids obtained from the guava epicarp, in a concentration not exceeding 25 %, is shown as viable alternative for the reduction of said nitrites, which does not affect the coloration or their useful life times. The above can be seen as a new alternative for the reduction of nitrites in the meat industry, which favors its development as it is a substance of natural origin.

Key words: carotenoids, guava epicarp, nitrites, Frankfurt sausages, fat oxidation

INTRODUCTION

The production of tropical fruits, worldwide, has been growing in recent years. According to data provided by FAO, the highest production of tropical fruits (99 %) occurs in developing countries (*1*) such as Colombia with its geographical and biological diversity and varying climates that make up different ecosystems, which guarantee a high annual production of fruits and vegetables (*2*), including the significant production of guava (*Psidium guajava*). In 2019, according to data from the Departamento Administrativo Nacional de Estadística de Colombia (*3*) 102,877 tons of guava were produced, destined for direct consumption as fresh fruit or for the elaboration of multiple products. Agro-industrial transformation generates a large amount of by-products, basically epicarp and seeds, which are generally disposed of as organic waste. However, multiple studies are found in the literature that show guava epicarp is rich in bioactive compounds such as carotenoid pigments, antioxidants substances, phenols and vitamins (*4-5*).

Antioxidants play a fundamental role in the metabolism of human beings since they prevent oxidative cell alterations resulting from the presence of free radicals, which minimizes the possibility of acquiring terminal diseases, such as cancer, Alzheimer's or diabetes, along with other neurological and degenerative disorders (*6-7*). Fruits and vegetables are rich in bioactive compounds, including antioxidants (*8*), making them necessary to the human diet. Therefore, in recent years, the trend has been to include them in the manufacture of numerous food products including foods with an animal origin (*9*). Carotenoid pigments, fat soluble compounds that are red or orange, are among the natural antioxidants found in fruits and vegetables (*10*) and fight the oxidative damage caused by free radicals, which reduces the risk of acquiring destructive diseases (*11*).

In the meat industry, the use of different chemical substances is common, including nitrites, which increase shelf-lives and/or improve sensory characteristics (basically color, taste, and smell). These nitrites also play an important role in controlling the development of certain pathogenic microorganisms such as *Clostridium botulinum*, which is why they cannot be totally eliminated in the manufacture of meat products. Despite these benefits, nitrites have been rejected by some consumers since they are associated with substances that are harmful for humans. Nitrites react with secondary and tertiary amines to for N-nitroso derivatives, which can accelerate the development of certain terminal diseases (*12*). Therefore, alternatives with a natural origin are needed for the meat industry that can preserve products without altering the sensory characteristics and without affecting the health of the final consumer.

The use of plant material in the meat industry as a source of functional compounds has been reported in numerous studied: the use of tomato pomace extract mixed with coriander essential oil (*13*); the use of celery powder, purple sweet potato powder, red gardenia powder, and paprika and blueberry (*14*); the application of powered parsley extract in mortadella type sausage (*15*); and the application of melon grain flour to beef sausages (*16*). However, the literature does not contain studies on the use of bioactive compounds obtained from guava epicarp and their application in meat products in order to reduce nitrite levels. Consequently, a new line of research related to the use and agro-industrial valuation of guava residues and their bioactive compound applications in the meat industry is needed. Therefore, the objective of the present study was to evaluate lipid extract from guava epicarp as an alternative to reduce the content of nitrites in Frankfurt sausages and to evaluate stability over time.

MATERIALS AND METHODS

Sausage elaboration

This experiment was developed in the laboratories of Tecnología de Carnes y Tecnología de Frutas y Hortalizas of the Universidad Nacional de Colombia – Palmira. The raw Materials were purchased in the regional market in the city of Palmira, Valle del Cauca, Colombia and at a specialized meat supermarket in the same city. The guava residues (fruits in maturity degree 5) included epicarp, seeds and some mesocarp; fruits with visible mechanical damage or with abnormal coloration were eliminated. The fruits were disinfected in a hypochlorite solution at 150 ppm for 20 min and subsequently washed with drinking water. Finally, an EGARVAC SCP Basic B (Vacarises, Barcelona, Spain) was used to pack the material in vacuum sealed polyethylene bags that were frozen at (-30±2) °C for 24 h.

Initially, the extract was prepared according to the ultrasound extract methodology (*17*), in which the material was subjected to lyophilization at vacuum pressure of 12 Pa and a condenser temperature of -80 “C for 24 h using an 18 L Labcomco, Kansas City MI, USA tray. The dry material was ground with an IKA M-20s3 mincer, Wilmington DE, USA with a 3 mm diameter, and sieved a Rotap (M® PS-35, series 1329, Bogotá, Colombia) for 15 min until obtaining a flour with particles of 0.074 mm. Then, to carry out the extraction of carotenoids, sunflower oil was used as an extractor reagent, with the following operating conditions: ultrasound equipment power 240 W, extraction time 40 min, process temperature 60 °C and flour/oil ratio 0.0256 g/4ml, in the Ultrasonic Branson 1510 equipment (Branson Ultrasonics Corp., Danbury CN, USA) obtaining a concentration of β-carotene of 47.40 mg/100g of extract. This ultrasound-assisted extraction technique allows a yield of 36.00 % higher yield compared to the conventional maceration method.

The sausages were made with pork backfat. For the elaboration of the sausages, the formulation (Table 1) and the procedural development were taken from Pinzón-Zárate *et al*. (*10*) and according to the Colombian Technical Standard NTC 1325 (*18*). Three treatments (three samples were taken for each treatment) were used with different concentrations of guava epicarp flour extract (GEFE) and a control treatment as shown in Table 2.

Table 1

Table 2

Lean pork meat (pH 6.3) and selected backfat, free of foreign odors, were used to make the sausages. Wheat flour was used as an extender element and water was added in the form of ice to achieve the desired consistency of the final product. The inputs and additives used were those traditionally accepted by the meat industry, in order to improve the organoleptic characteristics and extend the shelf life of the final product. The maximum content of nitrites in the applied treatments was defined in accordance with the provisions of Colombian Technical Standard NTC 1325 (*18*), applied to processed meat products.

Physicochemical determination

Based on the AOAC methods (*19*), the dry matter, protein, fat, ash and carbohydrates were determined by difference from the proximal analysis, for each of the analyzed treatments, and the caloric intake was determined according to the Berthelot-Malher bomb calorimeter method cited by Fabbri *et al*. (*20*), using Parr 6300 equipment (Parr Instrument Company, Moline IL, USA). All analyses were done in triplicate.

The pH and water holding capacity (WHC) were determined according to the methodology proposed by Dzudie *et al.* (21), For the pH, a digital Metter Toledo MP 230, Swiss, was used and, for the WHC, a sample of 0.5 g was taken from each sausage, placed on a grade 1 filter paper and subjected to pressure with a 1 kg plexiglass plate for 20 min. The surface area of the pressed sausage and the extracted liquid were defined using ImageJ (ImageJ®11, USA) (*22*), and the WHC was calculated according to the following equations:

$$Released\ water\ (\%) = \frac{A1-A2}{\omega}\ .61.1\ .100 \qquad /1/$$

$$CRA\ (\%) = 100-(\%)\ released\ water \qquad /2/$$

where A_1 is the total surface area, A_2 is the area of the pressed sausage and ω is the total moisture of the sausage sample.

The stability of the emulsion was determined according to Choe *et al*. (*23*). 6 g of meat emulsion were placed in 16 ml Falcon tubes that were previously weighed and heated to 75±1 °C for 30 min and centrifuged at 3600 rpm for five min. The stability of the emulsion was calculated as follows:

$$Ee\ (\%) = \frac{\omega 1}{\omega 2} x\ 100 \qquad /3/$$

where Ee id the stability of the emulsion (%), ω1 is the weight (g) of the emulsion mass in the Falcon tube after drainage of the lipid layer and ω2 is the weight (g) of the meat emulsion mass in the tube before heating.

The water activity of the different sausages was determined according to the AOAC methodology (*24*) with the help of an AquaLab 4te hygrometer, USA.

Texture profile analysis

A Universal Shimadzu Tester EZTestEZ-S texturometer, Tokyo, Japan, was Used according to the methodology proposed by Savadkoohi *et al*. (*25*). A 15 mm thick slice of each of the analyzed sausages was placed in the two axial parallel plates and compressed at 50 % at a speed of 5 mm/min (three technical replications were tested for each sample). The hardness, cohesiveness, elasticity, chewiness, adhesiveness and gumminess were measured.

CIE$_{L*a*b*}$ color coordinate determination

The color coordinates were measured according to the methodology proposed by Ordóñez-Santos *et al*. (*26*). A Minolta Meter CR-100, Tokyo, Japan, colorimeter was used. A D65 illuminant (8 mm diameter measurement area) and a 10° observer were used as reference (equipment calibrated with a white ceramic plate with reference values Y = 89.5, x = 0.3176 and y = 0.3340). From each sausage, three cylindrical samples 5 cm in length were taken, from which a longitudinal incision was made to determine the internal color. The luminosity (*L**) and the coordinates (*a**) and (*b**) were measured, and, based on these parameters, the chromaticity or saturation index (*C**), the tonality (*h* °) and the total difference of color were determined, respectively, as follows:

$$C° = (a*^2 + b*^2)^{1/2} \quad /4/$$

$$h° = \arctan\frac{b^*}{a^*} \quad /5/$$

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2} \quad /6/$$

Sensory evaluation of the sausages

The sensory parameters smell, color, flavor, texture and acceptability were evaluated with a panel made up of 50 semi-trained evaluators of both sexes and aged between 17 and 65 years. The panel was made on day zero of storage, and for the evaluation, the sausages were chopped into pieces 1.5 cm long and fried in sunflower vegetable oil. A survey was applied with a seven-point unstructured hedonic scale, whose amplitude ranged from 1 – I dislike it very much, to 7 – I like it very much (*27*).

Stability analysis of the sausages

The sausage treatment that showed the best results in terms of physicochemical, texture profile, color and sensory parameters was taken, and its stability was analyzed over time. The proximate analysis and color coordinates were determined at 0, 10, 20 and 30 days of storage under refrigeration (6±2 °C) and vacuum packing. Likewise, the residual nitrite content was analyzed according to the methodology proposed by Zahran and Kassem (*28*), along with the oxidation of fats at 0, 15 and 30 days of storage. The analysis of the oxidation of fats was based on the determination of reactive substances to 2-thiobarbituric acid – TBARS, substances formed as a secondary product of lipid peroxidation. Including malondialdehyde (MDA), the quantification of the p-anisidine value according to AOCS Cd 18-90 (*29*) and the peroxide index according to AOCS Cd 8-53 (30).

Statistical analysis

This research was based on a simple randomized design, and the study of stability over time used a randomized block design. Data is presented as mean ± standard deviation of at least three replicate measurements. All statistical analysis and the effect of the variables and their interactions were evaluated with analysis of variance (ANOVA). The difference between the means of treatments was determined with the Tukey test with a probability for significant differences of $p<0.05$. The statistical analysis was performed using SPSS v. 22.0 (*31*).

RESULTS AND DISCUSION

Physicochemical determination

Table 3 shows the results of the proximal analysis and the physicochemical properties of the three treatments; there were no significant differences ($p<0.05$), which led to the conclusion that the addition of the GEFE did not alter the chemical characteristics of the different sausages. Some studies have suggested the use of vegetable extracts to fully or partially replace nitrite and nitrate salts in sausages, without significantly affecting the characteristics of the product. The results were similar to those recorded by Riyad *et al*. (*32*), who added dry parsley, coriander and spinach powders to beef sausage. The physicochemical parameters pH, WHC, a_w and stability of the emulsion of the different treatments compared with the control sausage did not present significant differences. The pH values found in this research showed values lower than those obtained by Kim *et al*. (*33*) (pH 6.29 on average) in sausage with Konjac gel (*Amorphophallus konjac*) and powder from different vegetables. However, Serdaroğlou and Ōzsümer (34) found pH values (pH 5.93 on average) similar to those of this study in sausages with soy protein, whey powder and wheat gluten. Chattopadhyay *et al*. (*35*) registered an average pH value of 6.55, higher than in the present study, in fish sausages with a vegetable gel, while the WHC value (WHC 91.41 % on average) was lower than in the present study. Auriema *et al*. (*36*) worked with chicken mortadella type sausages with moringa seed flour powder and observed an average pH value of 5.92, slightly higher than in this study; however, the WHC values (96.23 % on average), the stability of the emulsion (99.66 % on average) and a_w (0.974) were similar to those obtained in this study. On the other hand, Savadkoohi *et al*. (25) worked with sausages with tomato bagasse and obtained values similar to those in this study (pH 5.48, WHC 88.22 %). Finally, Rosero-Chasoy *et al*. (*37*) registered a pH value of 6.04 for sausages with yacon peel flour, higher than in the present study, and a value of 96.8 % for the stability of the emulsion, similar to that obtained in the present study. The high variability in physicochemical parameters is attributed to the marked differences in the chemical composition of the different vegetables added to the meat products.

Table 3

Determination of the texture profile and CIE$_{L*a*b*}$ color coordinates

The results are shown in Table 3. The elasticity and gumminess parameters presented statistical differences, while for the other parameters, no impact was observed on the texture of the sausages. The different sizes of the fat particles, especially those with a larger diameter, led to a reduction in the adhesion between proteins and cellulose and the proteins and fat globules in the meat emulsion, which influenced the texture of the sausages (*38*).

When comparing the values with those found by Saldaña *et al*. (*39*), who worked with low-fat mortadella type sausages, lower values were found in the present study for hardness (16.24/N), elasticity (0.86/mm) and chewiness (11.49/N/mm), In other research developed by Ozaki *et al*. (*40*) using sausages with two concentrations of a mixture of radish powder and chitosan, higher values were found than in this study, except for adhesiveness. Finally, the results shown by Savadkoohi *et al*. (*25*) were lower for hardness (27.95/N), while for elasticity (3.49/mm), adhesiveness (0.22/N/mm), cohesiveness (0.41/N) and chewiness (40.05/N/mm) higher values were found than in this study in sausages with tomato bagasse. The differences in the texture parameters shown in the different studies are probably attributed to the variety in the composition of the sausages and particularly to the characteristics and quantity of the fats and the quantity of water and hydrocolloids used in their preparation.

For the color coordinates, no significant differences were detected in the *b** parameter; the other parameters had significant differences in relation to the control sausage. For the $CIE_{L^*a^*b^*}$ parameters, the most felling in the coloring of meat products are luminosity (*L**) and the red-green coordinate (*a**). In the present study, the luminosity (*L**) was directly proportional to the concentration of the GEFE added to the sausages, while the coordinate *a** had a slight downward trend, which is explained by the characteristics of the added carotenoid pigments. These results differ from those noted by Syuhairah *et al*. (*41*) for color parameters in chicken sausages with different concentrations of spinach, purple cabbage, carrot, pepper and mushrooms: the *L** coordinates and b* coordinates presented superior results, while coordinate *a** varied depending on the concentration applied, which is explained by the greater or lesser presence of natural pigments in the formulations used to prepare the sausages, which do not react completely with muscle myoglobin, preventing the correct development of oxymyoglobin, the color of sausages. The data shown by De Carvalho *et al*. (*42*), who worked with lamb sausages with different vegetables oils, showed values of *L** 69.01, *a** 8.52 and *b** 17.38, where the luminosity was lower but coordinates *a** and *b** were higher than in the present study. The high variability in the luminosity parameter (*L**) is attributed to the fact that the concentration of the pigments in the different formulations of the sausages does not have a direct impact on the luminosity but rather this parameter is basically influenced by the content of bound water and the amount of fat present in the light spaces, which leads to a decrease in the oxidation capacity of myoglobin. Variations in the *a** coordinate in the different studies may be due to the formation of a greater or lesser total amount of nitrosomyoglobin and the red pigments deoxymyoglobin and oxymyoglobin in sausages and consequently, the addition of the GEFE, which contributes certain pigments that do not promote the development of a high red-green coloration.

For the saturation index (*C**), a significant increase was not observed between the three treatments, while, from the control treatment, there was an increase of 4.35 %, 5.93 % and 3.71 %, respectively. On the contrary, the hue angle (*h* °) increased as the nitrite content decreased and the GEFE concentration increased, which can be explained by the reduction of nitrite to nitric oxide (NO) and the subsequent reaction with myoglobin, forming nitrosomyoglobin, which stabilizes during heat treatments. The values obtained in this research coincide with those shown by Pinzón-Zárate *et al*. (*10*) in sausages with chontaduro palm extract (*Bactris gasipaes*) and by Rosero-Chasoy *et al*. (*37*) in sausages with yacon peel flour.

Finally, the differences in color (ΔE) showed minimal variation in relation to the control sausage, without exceeding a value of 0.3, reported as the lowest accepted value to show significant differences, the lowest value being found in T_1 (0.83).

Sensory evaluation of the sausages

Fig. 1 shows the results of the sensory panel. Of the five attributes analyzed, texture, taste, smell and acceptance improved according to the evaluating judges when adding the GEFE at the three concentrations; only texture obtained a score similar to that of the control sausage. However, the formulation with the highest acceptability was T_1, which had higher concentrations of GEFE that led to a decrease in acceptance by the panelists.

Fig. 1

Stability analysis over time of selected sausage

The analysis showed that the sausages with better attributes and better acceptance according to their physicochemical, sensory, texture and color properties were in the T_1 treatment (25 % GEFE and 75 % nitrites), which was used for the stability analysis in storage.

The proximate analysis did not present statistically significant differences when comparing the results of day 0 with day 30 in any of the analyzed components (Table 4).

Table 4

The $CIE_{L^*a^*b^*}$ parameters did not show significant differences ($p<0.05$) for the *L** and *a** coordinates, while the *b** coordinate, the *C** saturation index, the hue angle *h* ° and the color difference in relation to the control sausage ΔE did show differences as the storage time increased (Table 4). Color is an important sensory parameter in the acceptance of food products but it also shows alterations that the product has undergone during storage. Table 4 shows a direct relationship between the storage time and the color difference, which is attributed to the isomerization of the carotenoid pigments present in the sausages. Several studies have presented results similar to those shown in this research: Ozaki *et al*. (*40*) who worked on sausages with pork and beef with a mixture of chitosan and radish powder for 60 days of storage, Souissi *et al*. (*43*) who worked with sausages made with octopus meat (*Octopus vulgaris*) with a gel for 15 days of storage and Jin *et al*. (*14*) who worked with sausages with different vegetables as partial replacement of nitrites during four weeks of storage. This increase in the color difference can be attributed to the bioactive compounds present in the added plant extracts, which promote the reaction between nitrite and myoglobin in muscle, which leads to the formation of a red nitrosylhemochrome pigment (*44*).

According to Colombian legislation, residual nitrites in processed meat products should not exceed 150 mg/kg (*18*), which was met in the sausages analyzed in this research. The analysis of this parameter showed an important reduction during storage time (Table 5) as the result of the interaction between muscle myoglobin and nitrite transformed to NO, which results from oxidation reactions and the consumption of NO_2, causing the formation of NO and nitrosomyoglobin, i.e. the pink color of sausages. The results agree with those of Jin *et al*. (*14*) for sausages with different vegetables at different concentrations, obtaining a decrease from 27.90 mg/kg to 17.22 mg/kg during four weeks of storage and with those of Šojić *et al*. (*13*) who achieved a decrease of 24.60 mg/kg in pork sausage with coriander essential oil during fifteen weeks of storage.

Table 5

During the storage, sausage change may occur that lead to deterioration and/or rejection of the final product. These changes are mainly related to the oxidation of intramuscular fats, changes that affect the primary and secondary metabolites of fat oxidation. The data in Table 5 showed that, as the storage time increased, all measured parameters increased; however, statistically significant growth ($p<0.05$) was noted up to the first 15 days of storage, which led to the conclusion that the oxidation of fats can be decisive during this period of time.

CONCLUSIONS

In this work, sausages added with guava epicarp flour extract (GEFE) were prepared, in which the nitrite content was partially replaced. The processed sausages showed very good physicochemical and sensory parameters, in addition to the fact there were no alterations in the coloring of the final products. The stability over time was studied, which showed that, up to a period of 30 days, no alterations in quality were observed. From the foregoing, it can be concluded that the use of guava by-products, basically the epicarp, is an important alternative for agroindustrial applications in the meat industry. Replacing up to 25 % of nitrites with this extract, which is basically made up of natural carotenoid pigments, in Frankfurt sausages can help minimize the negative effects of nitrites, which have an impact on the health and well-being of consumers.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORS' CONTRIBUTION

Viviana Andrea Velasco-Arango: Formal analysis, investigation, methodology, validation. José Igor Hleap-Zapata: Conceptualization, formal analysis, funding acquisition, investigation, project administration, writing - review and editing.

Luis Eduardo Ordoñez-Santos: Conceptualization, data curation, formal analysis, methodology, validation.

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Table 1. Frankfurt sausage formulation

Ingredients	Inclusion percentage/%	
Pork meat (pH 6.3)	65	
Backfat	16	
Wheat flour	5	
Ice	10	
Inputs and additives	4	
Total	100	
Inputs and additives	**%**	***m*(meat mass)/g/kg**
Salt	0.846	7.0
Sugar	0.242	2.0
Garlic	0.459	3.8
Powdered onion	0.060	0.5
Pepper	0.060	0.5
Phosphates	0.484	4.0
Seasoning	1.208	10.0
Monosodium glutamate	0.121	1.0
Ascorbic acid	0.121	1.0
Nitrites	0.398	3,3
Total	4.000	33.1

Table 2. Percentage of nitrites and oily extract of guava epicarp for each treatment analyzed

Treatment	Nitrites		Oily extract (carotenoids)	
	%	*m(meat mass)*/g/kg	%	*m(meat mass)*/g/kg
Control	100	3.300	0	0.000
T_1	75	2.475	25	0.825
T_2	50	1.650	50	1.650
T_3	25	0.825	75	2.475

Table 3. Proximal analysis, physicochemical properties, texture profile and CIE$_{L*a*b*}$ color coordinates of the different treatments of the processed sausages

Parameter	Control sausage	Sausages with GEFE		
		T_1	T_2	T_3
	0 % GEFE	25 %	50 %	75 %
	Proximate analysis			
w(dry matter)/%	(31.65±0.30)[a]	(31.14±0.14)[a]	(32.13±1.24)[a]	(31.42±0.28)[a]
w(protein)/%	(61.35±0.08)[a]	(60.56±0.16)[a]	(61.35±0.08)[a]	(61.35±0.08)[a]
w(fat)/%	(18.23±0.11)[a]	(18.23±0.12)[a]	(18.23±0.11)[a]	(18.23±0.11)[a]
w(ash)/%	(7.80±0.29)[a]	(8.34±0.26)[a]	(7.80±0.39)[a]	(7.80±0.54)[a]
E/(kJ/g)	(22.6728±0.6)[a]	(22.1511±0.19)[a]	(22.6728±0.63)[a]	(22.6728±0.12)[a]
	Physicochemical properties			
pH	(5.4±0.26)[a]	(5.5±1.06)[a]	(5.4±0.83)[a]	(5.4±0.79)[a]
WHC/%	(95.84±0.56)[a]	(95.98±0.10)[a]	(96.02±0.35)[a]	(96.10±0.20)[a]
a_w	(0.96±1.38)[a]	(0.96±0.31)[a]	(0.96±0.59)[a]	(0.96±0.36)[a]
Emulsion stability/%	(98.02±0.29)[a]	(99.16±0.99)[a]	(98.82±0.32)[a]	(98.91±1.01)[a]
	Texture profile			
Hardness/N	(41.56±0.21)[a]	(40.97±0.21)[a]	(41.78±0.83)[a]	(40.64±0.14)[a]
Cohesiveness	(-0.01±0.73)[a]	(-0.01±0.91)[a]	(-0.01±0.86)[a]	(-0.01±0.26)[a]
Elasticity/mm	(0.99±1.23)[a]	(0.84±1.86)[b]	(0.88±0.51)[b]	(0.91±0.63)[a]
Chewiness/N/mm	(22.31±0.12)[a]	(23.17±0.08)[a]	(22.86±0.40)[a]	(22.45±0.24)[a]
Adhesiveness/N/mm	(-0.35±0.57)[a]	(-0.34±0.12)[a]	(-0.33±0.18)[a]	(-0.33±0.46)[a]
Gumminess/N	(9.56±0.34)[a]	(9.87±0.45)[a]	(10.16±0.56)[b]	(10.01±0.63)[b]
	CIE$_{L*a*b*}$ color coordinates			
*L** value	(75.66±0.60)[a]	(75.43±0.45)[a]	(77.45±0.39)[b]	(77.69±0.47)[b]
*a** value	(3.85±0.18)[a]	(4.51±0.20)[b]	(4.09±0.07)[b]	(3.10±0.16)[a]
*b** value	(10.06±0.25)[a]	(10.30±0.09)[a]	(10.66±0.29)[a]	(10.74±0.26)[a]
*C** value	(10.78±0.22)[a]	(11.25±0.03)[b]	(11.42±0.25)[b]	(11.18±0.28)[b]
h ° value	(69.04±1.20)[a]	(66.38±1.09)[b]	(69.00±0.84)[a]	(73.92±0.59)[c]
ΔE value	-	(0.83±0.18)	(1.91±0.42)	(2.29±0.43)

GEFE – Guava Epicarp Flour Extract

*L**: 0 = black and 100 = white; *a**: -60 = green and +60 = red; *b**: -60 = blue and +60 = yellow; *h* ° - tone angle: 90 ° = yellow, 180 ° = green and 0 ° = red; *C* - saturation index, distance from the coordinates at the origin to the determined color point.

The results are the average of three repetitions and are shown as mean ± SD (N=3)

[a-c] Different letters in the rows indicate that there is a significant effect between the samples, $p<0.05$

Table 4. Proximate analysis and CIE_{L*a*b*} color parameters for the sausages during storage

Parameter	Sausages with 25 % GEFE and 75 % nitrites			
	Day 0	Day 10	Day 20	Day 30
	Proximate analysis			
w(dry matter)/%	(31.14±0.14)[a]	(31.22±0.27)[a]	(31.17±0.31)[a]	(31.09±0.21)[a]
w(protein)/%	(60.56±0.14)[a]	(60.57±0.38)[a]	(60.56±0.31)[a]	(60.54±0.32)[a]
w(fat)/%	(18.21±0.18)[a]	(18.13±0.24)[a]	(18.06±0.31)[a]	(17.95±0.25)[a]
w(ash)/%	(8.34±0.29)[a]	(8.34±0.12)[a]	(8.33±0.23)[a]	(8.32±0.27)[a]
E/(kJ/g)	(22.1564±0.16)[a]	(22.1565±0.26)[a]	(22.1511±0.29)[a]	(22.1496±0.41)[a]
	CIE_{L*a*b*} color coordinates			
*L** value	(72.05±0.80)[a]	(72.06±0.63)[a]	(72.11±0.55)[a]	(72.50±0.19)[a]
*a** value	(9.78±0.01)[a]	(9.41±0.07)[a]	(9.81±0.16)[a]	(9.76±0.03)[a]
*b** value	(8.36±0.07)[a]	(8.71±0.17)[a]	(8.67±0.27)[a]	(9.84±0.09)[b]
*C** value	(11.86±0.05)[a]	(12.82±0.16)[a]	(13.10±0.47)[b]	(13.86±0.30)[b]
h ° value	(40.51±0.22)[a]	(42.76±0.45)[b]	(41.47±0.47)[c]	(45.22±0.30)[c]
ΔE value	-	(0.73±0.11)[a]	(0.61±0.03)[a]	(1.56±0.10)[b]

GEFE – Guava Epicarp Flour Extract

*L**: 0 = black and 100 = white; *a**: -60 = green and +60 = red; *b**: -60 = blue and +60 = yellow; *h* ° - tone angle: 90 ° = yellow, 180 ° = green and 0 ° = red; *C* - saturation index, distance from the coordinates at the origin to the determined color point.

The results are the average of three repetitions and are shown as mean ± SD (N=3)

[a-c] Different letters in the rows indicate that there is a significant effect between the samples, $p<0.05$.

Table 5. Results of the analysis of residual nitrite and lipid oxidation for the sausages analyzed during the storage time.

Analysis	Sausages with 25 % GEFE and 75 % nitrites		
	Day 0	Day 15	Day 30
w(residual nitrite)/mg/kg	(42.15±0.35)[a]	(31.29±0.23)[b]	(23.65±0.16)[c]
Peroxide index/mmol/kg	(8.17±0.16)[a]	(11.62±0.84)[b]	(13.52±0.75)[b]
P-anisidine value/µmol/µg	(20.09±0.32)[a]	(23.90±0.41)[b]	(26.03±0.12)[b]
w(total volatile bases)/mg N_2/100g	(14.93±0.71)[a]	(15.25±0.37)[b]	(16.11±0.40)[b]
TBARS/mg MDA/kg	(0.41±0.04)[a]	(0.43±0.09)[b]	(0.46±0.07)[b]

GEFE – Guava Epicarp Flour Extract

The results are the average of three repetitions and are shown as mean ± SD (N=3)

[a-c] Different letters in the rows indicate that there is a significant difference between the samples, $p<0.05$.

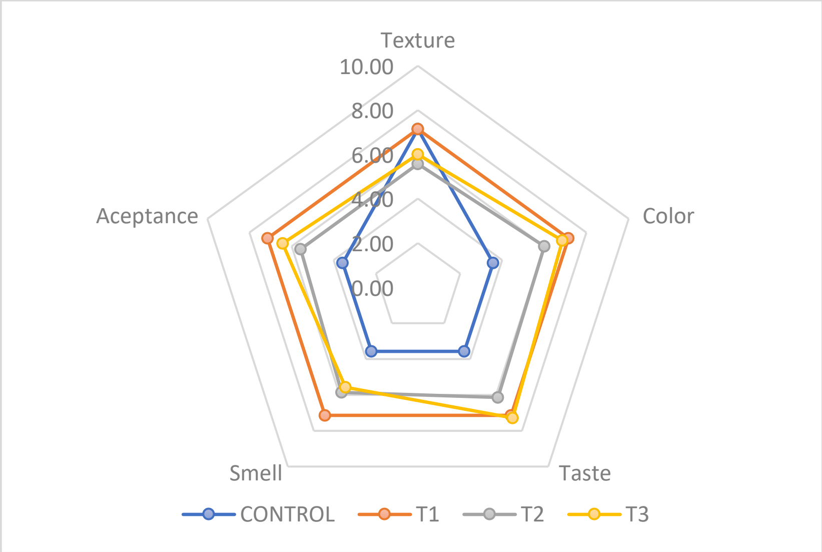

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Fig. 1. Sensory attributes of sausages with Guava Epicarp Flour Extract (GEFE). Control – 0 % GEFE, T_1 – 25 % GEFE, T_2 – 50 % GEFE, T_3 – 75 % GEFE. Quality scale: 7 – I like it very much, 6 – I like much, 5 – I like moderately, 4 – Neither like or dislike, 5 – I dislike moderately, 6 – I dislike much, 7 – I dislike very much