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Green banana biomass: Physicochemical and functional properties and its potential as a fat replacer in a chicken mortadella

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ABSTRACT

The potential of green banana biomass (GBB) as a natural ingredient and its impact as a fat replacer in chicken mortadella on sensory perception were investigated. The GBB was assessed for physicochemical characterization, antioxidant capacity and antimicrobial activity. Five chicken mortadella formulations were developed with fat replacement of 25, 50, 75 and 100% by GBB. Microbiological stability of the formulations was assessed, and the sensory profiling was evaluated by Preferred Attribute Elicitation (PAE). The dietary fiber, resistant starch, total phenolic compounds and antioxidant capacity in GBB were 3.99%, 4.16%, 518.39 mg GAE/100 g (GAE: Gallic acid equivalent) of dry sample, 5307.62 μmol of trolox equivalent (TE)/100 g of dry sample and 3583.12 μmol of trolox equivalent (TE)/100 g of dry sample, respectively. GBB contained potassium (1121 mg/100 g), phosphorus (183.6 mg/100 g), magnesium (77.4 mg/100 g), copper (0.53 mg/100 g) and iron (7.21 mg/100 g). The microbial counts in the formulations after 90 days of chill storage were within the safe limit. The results concluded that GBB showed desirable functional and technological proprieties to be used in chicken mortadella without affecting the characteristic flavor of these products. Besides, PAE proved to be a potential method to characterize chicken mortadella.

1. Introduction

Poultry meat is among the animal source foods most widely eaten at global level and the consumption and processing of poultry meat have increased rapidly in past decades (FAO, 2019), primarily due to their convenience, variety, lower price, low levels of fat and faces few religious and cultural barriers, as compared to that of beef and pork (Chmiel, Roszko, Adamczak, Florowski, & Pietrzak, 2019). Among the poultry products, the mortadella is appreciated by all social classes, with high popularity in the lunch meat market, it is attractive due to its low cost, pleasant flavor, and characteristic aroma (Júnior et al., 2019). However, due to the high lipids content, the high consumption of this product is associated with obesity, and an increased risk of cardiovascular diseases and cancer (Fernández-López et al., 2020).

Consumers' preference for healthier meat products with a nutritional or functional claim, such as lower content of fats, sodium and nitrite, fatty acids improvement and addition of functional ingredients are continually increasing all over the world (Zhang, Xiao, Samaraweera, Lee, & Ahn, 2010). However, reducing the fat content in the preparation of this type of product can affect the flavor and texture characteristics, leading to a decrease in consumer acceptance (Saldaña et al., 2018).

The reformulation of meat products with simultaneous replacement of compounds considered harmful to health by natural and functional ingredients is a potential alternative for the improvement of their nutritional characteristics and aligns with a growing demand from consumers, increasingly aware of their food (Hung, de Kok, & Verbeke, 2016). Thus, ingredients derived from fruits and vegetables as fat substitutes in mortadella products have been investigated (Alves et al., 2016; Auriema et al., 2019; Pires, dos Santos, Barros, & Trindade, 2019; Santos et al., 2020).

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The green banana biomass (GBB) is a product from banana processing, being obtained by cooking the green bananas (maturation stages 1 and 2), according to the maturation scale of Von Loesecke (1950). The green banana pulp does not present flavor or aroma when cooked, and can be employed as a technological ingredient in different food preparations (Ranieri & Delani, 2014), besides its nutritional contribution (Izidoro, Scheer, Sierakowski, & Haminiuk, 2008). Despite this, there are scarce studies related to GBB application as a fat replacer of meat products (Alves et al., 2016; Bastos et al., 2014; Dinon, Devitte, Canan, Kalschne, & Colla, 2014) Additionally, there are no reports of the partial/total fat replacement by GBB in chicken mortadella.

Therefore, this study aimed to evaluate the physicochemical, technological, and functional characteristics of the GBB, as well as its effectiveness as a fat replacer in chicken mortadella through its impacts on microbiological and sensory properties.

2. Material and methods

2.1. Raw material characterization

The green bananas (*Musa* spp., AAAB, var. Prata BRS Platina) were obtained at Embrapa Agrobiology, Seropédica, RJ, Brazil (geographic coordinates: 220 48′00″ south latitude and 430 41′00″ west longitude), through the integrated system of agroecological production (SIPA) with organic management and harvested in maturation stage 1 (peel full green), according to the maturation scale of Von Loesecke (1950).

The bananas' ripeness degree was determined by total soluble solids (TSS) content, titratable acidity (TA), and pH. For TSS, a refractometer (Instrutherm, RT-280) was used according to the method described by Yap, Fernando, Brennan, Jayasena, and Coorey (2017), and the results were presented in Brix degree (°Brix). The TA was quantified by titration with NaOH 0.1 N and the results were expressed in g of malic acid/g of the sample, as described by method 13.6.2 by IAL (1985). The pH was determined using a digital pH meter (MS - Tecnopon, RS 232), according to the Association of Official Analytical Chemists, AOAC (AOAC, 2019a).

2.2. Green banana biomass (GBB) processing

GBB was processed according to Dinon et al. (2014) and Riquete et al. (2019) methodologies, with modifications. The unpeeled green bananas were washed with running water, placed in a pressure cooker at a proportion of 1.800 g of green bananas for 1.750 ml of water, and subjected to cooking (1.8 Pa, 120 °C) for 15 min. Then the peels were removed, and the pulps milled in a grinder (BECKER go®, SC, Brazil), using a stainless-steel plate of 5 mm holes.

2.3. Macronutrients characterization (proximate chemical composition)

The chemical composition of the GBB was determined according to the AOAC methods (AOAC, 2019b; AOAC, 2019c; AOAC, 2019d; AOAC, 2019e): moisture by the oven method (Solab - SL 100) at 105 °C; ashes by using the muffle (Solab - SL 102) at 550 °C; total proteins by the micro-Kjeldahl method using a nitrogen conversion factor of 6.25, and total lipids by the Soxhlet method. Although the nitrogen conversion factor in vegetable origin products ranged from 5.30 to 6.31, the value used was based on previous studies using green banana and fruit derivatives (Costa, Alencar, Rullo, & Taralo, 2017; Damasceno et al., 2016; Peris-Felipo, Benavent-Gil, & Hernández-Apaolaza, 2020; Salih et al., 2017).

The total carbohydrate content was obtained by subtracting the moisture, protein, lipid, and ash values from 100. The total dietary fiber was quantified according to the enzymatic-gravimetric method (AOAC, 1995, p. 474), and the resistant starch according to the method of Ovando-Martinez, Sáyago-Ayerdi, Agama-Acevedo, Goñi, and Bello-Pérez (2009), with modifications.

2.4. Mineral profile

The mineral content was determined according to the USEPA 3052 method, using concentrated HNO_3^- in digestion procedure. Phosphorus (P) was determined by colorimetry, potassium (K) by flame emission photometry, and the other elements (Ca, Mg, Fe, Mn, Al, Cu, Ni, Co, Cr, Zn, Ba, Pb, and Cd) by flame atomic emission spectrometry (Varian 606, model OPTIMA 3000).

The contents of carbon and total nitrogen were determined by the dry combustion in the elemental analyzer (LECO Corporation, model TruSpec CHN).

2.5. Ascorbic acid content

The ascorbic acid was determined following the method described by Strohecker and Henning (1967, p. 428). One gram of GBB was added in 50 ml of oxalic acid (0.5%) and shaken in a shaker table (Orbital SL 180) at 2500 rpm for 30 min. After, 10 ml of the solution was added to an Erlenmeyer flask with 40 ml of distilled water. Then, the samples were titrated with 2,6-dichloro-phenol indophenol solution (DCPIP). The concentration of ascorbic acid was expressed in mg. 100 g^{-1} of sample.

2.6. Preparation of the GBB extract for determination of total phenolic compounds (TPC), antioxidant capacity (based on the evaluation of DPPH scavenging activity and ferric reducing antioxidant potential) and antimicrobial activity

The GBB extract was obtained according to Ovando-Martinez et al. (2009), with modifications. One gram of sample was added to a tube with 50 ml of acetone solution (70%) and shaken in a shaker table (Orbital SL 180) at 2500 rpm for 60 min. The solution was centrifuged at 3000 rpm for 15 min. The supernatant was collected, and the extraction repeated one more time. The supernatants of the two extractions were combined in a volumetric flask of 100 ml and filled with distilled water.

2.7. Total phenolic compounds (TPC)

The TPC was determined following the method described by Swain and Hillis (1959). One ml of the extract and 1 ml of Folin-Ciocalteu reagent 0.25 N were added to 10 ml of distilled water. After 3 min, 1.5 ml of Na_2CO_3 at 10% was added and the solution was kept at room temperature (25 ± 1 °C) for 2 h in the dark. Then, the measurement was carried out in a spectrophotometer (Spectrophotometer Model NOVA 2000 UV, São Paulo, Brazil) at 725 nm and the result was expressed in mg GAE/100 g (GAE: Gallic acid equivalent) of dry sample.

2.8. Antioxidant capacity by the methods of ferric reducing power (FRAP) and free radical scavenging (DPPH)

The antioxidant capacity was evaluated by FRAP (method based on the reduction of iron ions) according to the method proposed by Thaipong, Boonprakob, Crosby, Cisneros-Zevallos, and Byrne (2006). The extract (90 μL) was diluted in distilled water (270 μL) and reacted with 2.7 ml of FRAP reagent. The solution was shaken and kept in water bath (37 °C) for 30 min. The absorbance was measured by a spectrophotometer (Model NOVA 2000 UV, São Paulo, Brazil) at 595 nm, and the result expressed in μmol of trolox equivalent per 100 g of dry sample (μmol TE/100 g).

The antioxidant capacity by DPPH (method based on the sequestration of the stable free radical 1,1-diphenyl-2-picrylhydrazyl) was determined according to the method of Rufino et al. (2010), with modifications. The GBB extract (150 μL) was mixed with 2.85 ml of DPPH* (60 μmol/L) and shaken in a vortex for 30 s. Then, the solution rested for 1 h in the dark and the measurement was carried out by spectrophotometry at 515 nm (spectrophotometer Model NOVA 2000 UV, São Paulo, Brazil), with the result expressed as μmol of trolox

equivalent per 100 g of dry sample (μmol TE/100 g).

2.9. Antimicrobial activity

The antimicrobial activity was determined according to the method of diffusion in agar described by Bauer, Kirby, Sherris, and Turck (1966). The tests were carried out using *Salmonella typhimurium* and *Staphylococcus aureus* strains. The inoculum of each microorganism was obtained after activation for three successive transferences in BHI (brain heart infusion) broth, incubation at 35 °C for 20 h, and subsequent superficial inoculation on BHI agar. The colonies were suspended until reaching 1 × 10^8 UFC/ml, corresponding to the turbidity 5 in the MacFarland scale. It was carried out to obtain a work suspension containing approximately 1 × 10^6 UFC/ml according to the *Clinical and Laboratory Standards Institute* (CLSI, 2003). Aliquots of 0.1 ml of this suspension were spread using Drigalsky handle, on Petri dishes containing 20 ml of MH (Mueller Hinton) agar. Two wells were made using a sterile 6 mm hole punch, which were filled with 50 μL of GBB extract and control (containing acetone 70%). Ampicillin discs for Gram-positive and Gentamicin discs for Gram-negative bacteria were added as well. The plates rested until complete absorption of the extract by the agar. Then, they were incubated for 24 h at 36 °C. The inhibition zones' diameter was measured in mm (including the 6 well diameter).

2.10. Water retention capacity (WRC) and oil retention capacity (ORC)

The WRC and ORC of the GBB were carried out according to the method of Salih et al. (2017). In a tube containing 25 ml of distilled water or soy oil, 1 g of the sample was added and kept in water bath at 80 °C for 1 h. The tubes were centrifuged at 3000 x rpm for 20 min. The supernatant was discarded, and the residue was weighed. The WRC and ORC were calculated as g of water or oil/g of sample, as described in equation (1).

$$WRC \ or \ ORC = \left(\frac{(final \ \ weight - initial \ \ weight)}{initial \ \ weight}\right) \quad (1)$$

2.11. Chicken mortadella preparation

The chicken breast meat, skin and mechanically separated chicken meat (MSCM) were provided by Reginaves Indústria e Comércio de Aves Ltda (RICA) (Rio de Janeiro, RJ, Brazil) and the additives [cure salt (nitrite/nitrate), sodium erythorbate, carrageenan, soy isolated protein, condiment for mortadella, flavor enhancement, sugar, cassava starch, and sodium polyphosphate] were provided by IBRAC additives and condiments (Rio Claro, SP, Brazil).

Mortadella samples were prepared in the meat processing plant at the Department of Food Technology at the Federal Rural University of Rio de Janeiro (DTA/UFRRJ). Five different formulations of chicken mortadella were processed, and two replicates were made for each formulation, totaling ten experimental units. The formulations were: Control (FC) without fat reduction, and those with fat replacement by GBB at 25% (F1), 50% (F2), 75% (F3) and 100% (F4). For the preparation of the product mass, the cold (0 °C) chicken breasts (21.57%) were initially minced in the grinder. Then, the mass was taken to the cutter along with ice cubes (15%) and MSCM (30%), where everything was finely comminuted.

After homogenization of the mass, the chicken skin (FC-23%, F1-17.25%, F2-11.5%, F3-5.75% and F4-0%) and salt were added, and subsequently, comminuted for 30 s. Then, the GBB (FC-0%, F1-5.5%, F2-11.5%, F3-17.25% and F4-23%), cure salt (nitrite/nitrate) (0.13%), sodium erythorbate (0.30%), carrageenan (1.0%), isolated soy protein (4.0%), mortadella condiment (0.30%), flavor enhancer (0.40%), sugar (0.20%), cassava starch (3.5%), and sodium polyphosphate (0.30%) were mixed with the mass. Afterward, the mass was stuffed in a 90 mm caliber artificial casing made of polyamide, with portions of 400 g.

The mortadella cooking was carried out in a water bath, according to the following program: 45 °C/30 min, 55 °C/30 min, 65 °C/30 min, 75 °C/30 min and 85 °C until the internal temperature of the center of the mass reached 72 °C. After cooking, they were submerged in cold water and stored at 4 °C until analysis.

2.12. Microbiological analysis of the chicken mortadella samples

To evaluate the effect of the green banana biomass addition on the microbiological quality of the chicken mortadella samples, analyses were carried out after 1, 15, 30, 45, 75 and 90 days of cold storage (4 °C) for *Salmonella* sp., *Staphylococcus* coagulase-positive, *Clostridium* sulfite reducers, and total coliforms, as established by Brazilian legislation (Brasil, 2001).

2.13. Sensory evaluation

Sensory characterization of mortadella samples was performed using Preferred Attribute Elicitation (PAE) as described by McSweeney, Sisopha, T'ien, Rector, and Duizer (2017) and Soares et al. (2019). The participants comprised students, employees, and visitors, aged between 22 and 60 years old and were recruited through email, posters and social media and selected according to interest, availability, and consumption profile (at least once a week).

The total number of panelists who agreed to participate in the PAE was 27 people (65% female), randomly divided into two homogeneous groups in two distinct sessions. The sample size used was based on previous studies (Muggah & McSweeney, 2017; Popoola, Bruce, McMullen, & Wisme, 2019) and in line with the recommendations of McSweeney et al. (2017). The first session (PAE1) comprised 14 panelists, while the second (PAE2) was composed of 13 panelists. There were no significant differences between the age and sex distribution between the groups.

Initially, panelists received 30 g of each sample at once, identified with 3-digit random numbers, and served at 15 °C in white plastic dishes. Water and cream crackers were served to clean the palate between testing samples. Firstly, they were asked to describe the attributes that they liked and disliked the most, and then participants were asked to think and nominate all the sensory descriptors that differed between the samples. In a round table discussion moderated by the responsible researcher, the elicited descriptors were listed on a board so that the participants could see them. The participants were asked to group the descriptors according to their similarity (for example: spice flavor, spicy, and seasoning were grouped in spicy).

Next, 9-point intensity scales were created for each mentioned descriptor, being the anchors defined by the panelists (for example: not salty and extremely salty), considering the attribute intensity. In addition, participants were informed that if the scale did not include all the attributes considered important by them, they could add a new scale (Grygorczyk, Lesschaeve, Corredig, & Duizer, 2013). Participants were also asked to order the attributes according to their preference in the form, and a tie was allowed between attributes that they had perceived as equally important. After a short break, panelists received the forms that were previously designed by themselves, and chicken mortadella samples were presented monadically to run the sensory test.

Tests were carried out at the sensory analysis laboratory and each session lasted approximately 90 min. For this study, the approval was obtained from the ethics committee (CAAE: 16784119.0.0000.5285) of the Federal University of the State of Rio de Janeiro (UNIRIO), Brazil.

2.14. Data analysis

All the analyses on green banana biomass were performed in triplicate and the results were expressed as average ± standard deviation. Data of the PAE method were submitted to Generalized Procrustes Analysis (GPA) (Dijkterhuis, 1995) through a matrix of 5 rows

(mortadellas samples) and 150 columns for PAE1 and 180 columns for PAE2 (attributes x consumers). The comparison of similarity in sample characterization between the PAE sessions (PAE1 x PAE2) was performed using Multiple Factor Analysis (MFA) (Pagès, 2004) through a matrix of 5 rows (mortadella samples) and two groups of columns (GPA coordinates of the samples corresponding to data from the PAE1 and PAE2), and the RV coefficient (Santos et al., 2013). All the analyses were done using the statistical software XLSTAT (version 2018.2).

3. Results and discussion

3.1. Green banana analysis

TA, TSS content and the pH of the green banana were 0.18 (±0.00) g of malic acid/g of sample, 4 (±0.00) °Brix and 5.48 (±0.04), respectively. Similar values were found by Youryon and Supapvanich (2017) (TSS = 3.6 °Brix, TA = 0.10 g of malic acid/g of sample) and Izidoro et al. (2008) (TSS = 5.2 °Brix, TA = 0.15 g of malic acid/g of sample and pH = 5.2), in studies using green banana at maturation stage 1.

3.2. GBB characterization

3.2.1. GBB chemical composition

The proximate chemical composition of the GBB is presented in Table 1. Fat, ash, protein, and carbohydrate content of GBB were 0.40, 0.65, 0.84, and 19.59, respectively. Similar results were found for GBB characterization (Costa et al., 2017; Dinon et al., 2014).

The GBB presented resistant starch and the dietary fiber content of 3.99% and 4.16%, respectively, which according to FAO (2013), may be considered a "source of fiber" food once it has a content of fibers above the minimum of 3 g of fibers/100 g of food. Resistant starch and dietary fiber present similar functional characteristics since both are non-digestible by the small intestine and are fermented in the large intestine. These characteristics confer physiological benefits such as reduction of glycemic response, short-chain fatty acid production, which contributes to colon health, among other nutritional benefits (Ranieri & Delani, 2014). Thus, the addition of GBB in frequently consumed foods, such as meat products, may help improve the daily fiber intake.

3.2.2. GBB mineral composition

Macro and micro mineral content of GBB are shown in Table 2. Among the macro minerals, the carbon content was the highest (37,900 mg/100 g), followed by potassium (1121 mg/100 g), nitrogen, phosphorus, magnesium, calcium, and sodium (752, 183.6, 77.40, 78 and 76.70 mg/100 g, respectively).

The potassium concentration represents 23.85% of the Recommended Daily Intake (RDI) for adults (31–50 years old) (Table 2), according to the Institute of Medicine (IOM) (IOM, 2005). The phosphorus represents 18.4% of the RDI, the magnesium 24.2% of the RDI for women, and 18.4% for men, and the calcium and sodium represent 10% of the RDI (Table 2) (IOM, 1997).

Regarding the micro minerals, the iron content was the highest (7.21 mg/100 g), representing 40% of the RDI for women and 93.8% for men, followed by manganese (2.32 mg/100 g), copper (0.53 mg/100 g), zinc (0.49 mg/100 g), nickel (0.09 mg/100 g), cobalt (0.06 mg/100 g) and cadmium (0.03 mg/100 g). The manganese concentrations were higher than the RDI for women (28%) and 100% of the RDI for men; Whereas the copper content represents 58.9% of the RDI for both gender; while zinc contents represent less than 10% of the RDI (Table 2) (IOM, 2001; IOM, 2005).

According to the Food and Drug Administration (FDA) (FDA, 2016), to be considered a "good source", a nutrient must have a content between 10 and 19% of the RDI, whereas to be an "excellent source", it must contain at least 20% of the RDI. As such, the GBB may be considered as an excellent source of potassium, phosphorus, magnesium, copper, and iron. Based on these results, the application of GBB in foods can contribute to the enrichment of minerals.

Table 1
Proximate chemical composition of the green banana biomass (GBB).

Parameters	Experimental Value*
Moisture (%)	78.58 ± 0.20
Lipid (%)	0.40 ± 0.03
Proteins (%)	0.94 ± 0.04
Ash (%)	0.65 ± 0.04
Total Carbohydrates (%)**	19.43 ± 0.47
Resistant Starch (%)	3.99 ± 0.04
Dietary Fiber (%)	4.16 ± 0.20

* Mean ± standard derivation (n = 3).
** Obtained by difference.

Table 2
Composition of macro and micro mineral and Recommended Daily Intake (RDI) of essential minerals (IOM, 1997, 2001 and 2005).

	GBB Contents (mg.100 g^{-1})	RDI (mg.dia^{-1}) W*– M**
Macrominerals		
Na	76.70 ± 23.50	1500
K	1121 ± 37.00	4700
Ca	78 ± 4.90	1000
Mg	77.4 ± 6.40	320–420
P	183.6 ± 1.10	700
N	752 ± 29.50	Nd***
C	37,900 ± 843.00	Nd***
Microminerals		
Fe	7.21 ± 0.29	18–8
Cu	0.53 ± 0.03	0.9
Mn	2.32 ± 0.30	1.8–2.3
Zn	0.49 ± 0.02	8–11
Ni	0.09 ± 0.03	Nd***
Co	0.06 ± 0.01	Nd***
Cd	0.03 ± 0.00	Nd***

* W: women from 35 to 50 years old.
** M: men from 35 to 50 years old.
*** Nd: not declared.

3.2.3. Ascorbic acid, total phenolic compounds content and antioxidant capacity (FRAP and DPPH)

The GBB presented an ascorbic acid content of 42.98 mg/100 g of sample whereas the GBB extract presented a total phenolic content of 518.39 mg GAE/100 g of dry sample and the FRAP and DPPH values were of 5307.62 μmol TE/100 g and 3583.12 μmol TE/100 g of dry sample, respectively (Table 3). The phenolic compounds and the ascorbic acid are related to several health benefits such as antioxidant, anti-inflammatory, antimicrobial and anticarcinogenic activities (Rodrigues et al., 2020; Varvara et al., 2016). The antioxidant capacity present in the GBB extract may be attributed to both the phenolic compounds and the ascorbic acid content, but the phenolic compounds seem to contribute more to the total antioxidant capacity of the food (Guimarães et al., 2019). The phenolic compounds can remove free radicals by donation of hydrogen atoms, and the ascorbic acid can chelate metals, removing reactive oxygen species, as well as regenerate phenolic antioxidants (Brewer, 2011).

Table 3
Ascorbic acid (AA), total phenolic compounds (TPC) and antioxidant capacity by the methods of ferric reducing power (FRAP) and free radical scavenging (DPPH) of GBB.

AA* (mg/100 g)	TPC* (mg GAE/100 g)[a]	FRAP* (μmol TE/100 g)[b]	DPPH* (μmol TE/100 g)[b]
42.98 ± 0.10	518.39 ± 9.92	5307.62 ± 39.40	3583.12 ± 166.68[b]

* Data are mean ± standard deviation (n = 3).
[a] Results were expressed as mg of gallic acid equivalent (GAE)/100 g.
[b] Results were expressed as μmols trolox equivalent (TE)/100 g.

In meat processing industries, the use of synthetic antioxidants to reduce or inhibit the lipid oxidation of food is common, being an important factor to be considered in determining the shelf life of the products (Oswell, Thippareddi, & Pegg, 2018). However, the consumers' demand for natural ingredients led industries to seek alternative natural antioxidants (Nikmaram et al., 2018). Thus, GBB can emerge as an opportunity for the food industry due to the presence of antioxidant compounds, requiring studies related to the oxidative stability of meat products added with GBB. Additionally, it should be taken into account that despite the presence of high content of antioxidant compounds, the concomitant presence of dietary fibers, which interact with the polyphenols, may reduce their bioaccessibility and antioxidant activity (Guimarães et al., 2020; Tomas et al., 2018).

Previous studies have evaluated the functional potential of the green banana pulp flour and found lower phenolic compounds content (16.54; 32.9; 373.88 and 91.24 mg EAG/100 g of dry sample) than the GBB (Campuzano, Rosell, & Cornejo, 2018; Castelo-Branco et al., 2017; Fatemeh, Saifullah, Abbas, & Azhar, 2012). During the green banana drying process, the phenolic compounds may be gradually oxidized by polyphenol oxidase enzymes, which reduce their concentration (Pico et al., 2019). Therefore, the green banana processing to produce GBB may be beneficial to preserve the phenolic compounds in compared to the flour.

3.2.4. Antimicrobial activity

The antimicrobial properties of GBB are shown in Fig. 1. At the concentration of 0.01 g/ml, the GBB extract exhibited an inhibition halo of 10.5 mm for *S*, *typhimurium* and of 11.5 mm for *S*, *aureus*, which may be considered effective at this concentration, but less effective than the standard antimicrobials evaluated. It is suggested that in the studied concentration, the antimicrobial compounds present in the extract are at very low levels and that an increase in the concentration may bring more positive and promising results.

The antimicrobial effect of GBB is probably related to the phenolic compounds, which cause protein precipitation and affect bacterial peptidoglycan (Chabuck, Al-Charrakh, Hindi, & Hindi, 2013). It was also observed that the GBB extract showed a greater inhibition zone for Gram-positive bacteria (*S*, *aureus*) compared to Gram-negative bacteria (*S*, *typhimurium*). Some studies reported that this difference may be due to the morphological constitution of the bacteria, once Gram-negative bacteria have an outer membrane constituted of lipoprotein and lipopolysaccharide, which is selectively permeable, making them less susceptible to the extracts than Gram-positive bacteria (Chan, Lim, & Omar, 2007).

Some studies found antimicrobial activity in banana peel (Audu et al., 2015; Chabuck et al., 2013; Ibrahim, 2015; Mordi et al., 2016), green banana (Fagbemi, Ugoji, Adenipekun, & Adelowotan, 2009) and ripe banana (Kusuma, Soraya, Indah, & Resmi, 2017). Therefore, further studies evaluating different concentrations of GBB extract and their use to inhibit different microorganisms are suggested.

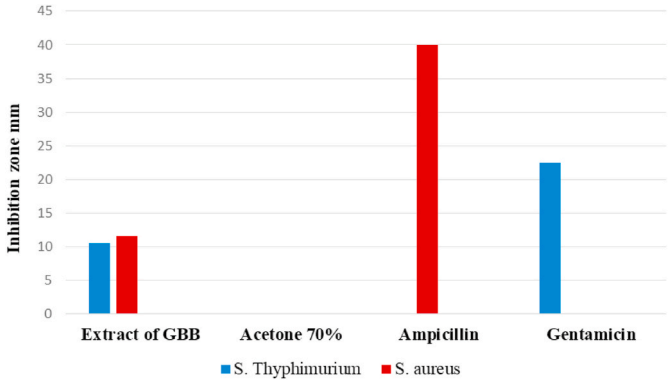

Fig. 1. Inhibition zone (mm) of GBB extracts, acetone 70% and antibiotics against pathogenic microorganisms.

3.2.5. Water retention capacity (WRC) and oil retention capacity (ORC)

WRC and ORC presented values of 2.04 g/g and 1.41 g/g, respectively, and represent the ability to immobilize water and oil during food processing and storage, and are parameters of great importance in improving the stability, texture, flavor and performance of food products, especially in emulsified meat products (Kamruzzaman, Makino, & Oshita, 2016; Pérez-Andrés, Álvarez, Cullen & Tiwar, 2019). Thus, GBB can significantly contribute to the technological properties of emulsified meat products.

Similarly, according to Bastos et al. (2014), the fat replacement of hamburgers by green banana-based substitutes showed higher WRC compared to other substitutes such as oatmeal and apple peel flour.

3.3. Microbiological analysis of the chicken mortadella samples

After 90 days of cold storage (4 °C), all the formulations presented microbiological counts (*Salmonella* spp., *Staphylococcus* coagulase-positive, *Clostridium* sulfite reducers, and total coliforms) allowed by Brazilian standard for mortadella (Brasil, 2001). Meat products are highly perishable, and the reformulation of these products implies guaranteeing the microbiological quality during processing and shelf life. In this regard, the replacement of chicken skin by GBB in mortadella did not affect the microbiological quality during 90 days of storage, being in accordance with the commercial expiration date of the mortadella found in the Brazilian market, which varies from 60 to 90 days.

3.4. Sensory evaluation

The sensory terms of chicken mortadellas described by PAE1 session were pink color and fibrous aspect, chicken mortadella and spicy aroma, chicken mortadella, salty, pungent and spicy residual flavor, fibrous and firm. Meanwhile, PAE2 session described the greatest amount of sensory descriptors, being pink color, homogeneous and bright, smoked, chicken mortadella and spicy aroma, spicy, salty, smoked, pungent, chicken mortadella and fat flavor, chewability, juicy and firm. The similar attributes among the sessions were pink color, chicken mortadella aroma, spicy aroma, salty taste, pungent flavor, and firmness.

According to Fig. 2a, it was observed that the first dimension D1 (40.44%) was more related to the texture, color, salty taste, and mortadella flavor attributes, while the second dimension D2 (27.48%) was associated mainly to the mortadella aroma and pungent flavor. For PAE2 session (Fig. 2b), the D1 (40.02%) was associated mainly to the texture, fat flavor and mortadella flavor attributes, while the D2 (33.39%) was represented mainly by the appearance (bright and color), mortadella aroma and flavor (smoked, spicy and pungent) attributes.

In PAE1 session, sample FC was characterized mainly by the attributes of pink color and spicy aroma. Meanwhile, sample F1 presented fibrous appearance and fibrous and firm texture. Sample F2 presented higher association to chicken mortadella aroma, residual spicy flavor, salty taste, and chicken mortadella flavor, while in the same quadrant samples F3 and F4 were related to pungent flavor, chicken mortadella flavor, and salty taste.

In PAE2 session, sample F4 was characterized by presenting in higher intensity the attributes homogeneity, smoked aroma, spicy aroma, salty taste, pungent flavor, and spicy flavor. F1 was described mainly by firmness, juiciness, and chewability, and also by chicken mortadella aroma and pink color. Samples F2 and F3 were in the same quadrant and were related to chicken mortadella flavor, smoked flavor, pungent flavor, and spicy. Meanwhile, the control sample (FC) was related mainly to the attributes bright and fat flavor. In both sessions, sample F2 (50% fat replacement by GBB) was attributed to the highest chicken mortadella flavor and F1 (25% fat replacement by GBB) was characterized as the firmest.

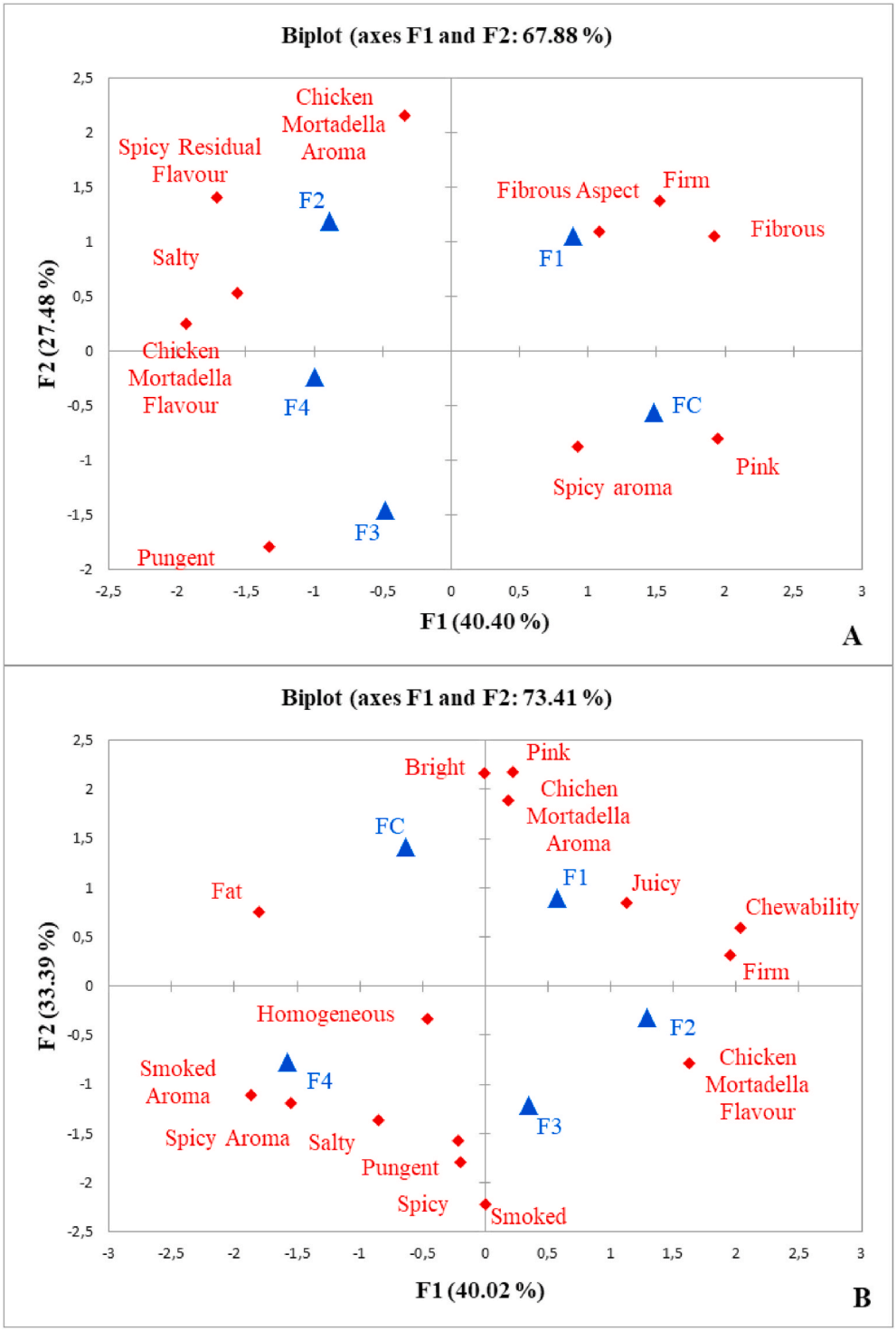

Fig. 2. Sensory attributes generated in the PAE 1 session (a) and PAE 2 session (b). The descriptive data from the PAE sessions was then combined and normalized using Generalized Procrustes Analysis.

The comparison of the results from PAE sessions can be seen in the MFA (Fig. 3). It was observed that PAE1 and PAE2 sessions presented high similarity in the positioning of the formulations FC, F1, and F2, observed by the distance from the analysis points to their centroid. Whereas the F3 and F4 formulations showed a little more distinct positioning between sessions in the sensory space, despite its constancy in samples evaluation in both sessions. This difference in results between sessions may be due to a wrong interpretation by the participants or the disagreement of some participants with the attribute definition, being an inherent limitation of the method, which does not invalidate the importance and relevance of the results found (McSweeney et al., 2017).

The RV is a correlation coefficient between two spaces, ranging from 0 (total disagreement) to 1 (perfect agreement), and in the present study, this value was of 0.6 ($p < 0.001$), showing a significant agreement between sessions. Therefore, the use of PAE method may be a potential tool for sensory characterization of reformulated products by meat products industry, without the need of using classical methods of sensory characterization, especially the ones with training steps.

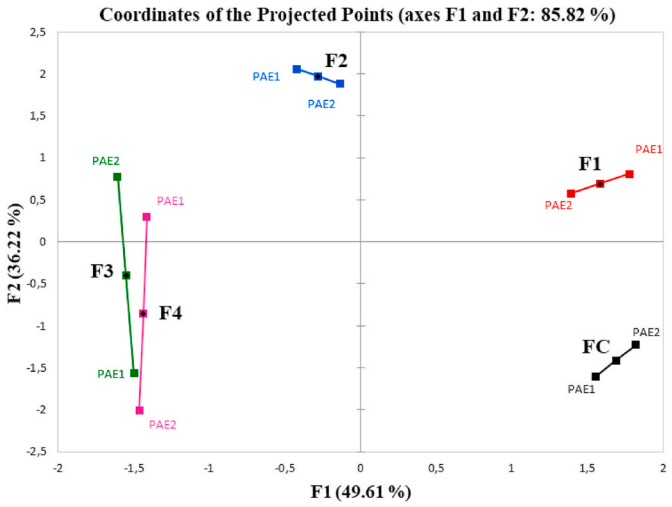

Fig. 3. Preference map generated by multiple factor analysis (MFA) from the results of PAE 1 (n = 15) e PAE 2 (n = 12).

It is noteworthy that the results demonstrate a great technological potential of GBB to replace fat in chicken bologna, without negatively impacting the sensory characterization of the product. This is in line with the demands of the modern consumer who is increasingly looking for healthier products made with less fat and added with natural and functional ingredients and can be a promising alternative for the meat industry. In this sense, it is expected that this work will be the starting point for further studies on the application of this ingredient in meat products, evaluating its impact on physical-chemical quality (volatile and fatty acid profiles), for example, functional (bioaccessibility of GBB micronutrients) and hedonic parameters.

4. Conclusions

The results showed that GBB has the potential to be used as a functional ingredient, source of dietary fiber, resistant starch, minerals, and ascorbic acid. Besides that, GBB extract showed antimicrobial, antioxidant activities and may contribute to the water retention capacity and stability of the emulsion, which are required properties in emulsified meat products. In addition, PAE showed to be efficient and suitable for the sensory profiling of the chicken mortadella samples, highlighting the differences between the formulations.

For future studies, it is recommended that evaluations on the effect of GBB on physical-chemical and functional characteristics of the emulsified product be carried out, as well as its sensory acceptance and the microbiological stability with other microorganisms and for longer storage periods.

CRediT authorship contribution statement

Bruna Emygdio Auriema: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Fernando Jensen Braz Corrêa:** Methodology, Validation, Formal analysis. **Jonas de Toledo Guimarães:** Writing - original draft, Writing - review & editing. **Paula Thaís dos Santos Soares:** Writing - original draft, Writing - review & editing. **Amauri Rosenthal:** Formal analysis. **Everaldo Zonta:** Formal analysis, Writing - original draft. **Raul Castro Carriello Rosa:** Validation, Formal analysis. **Rosa Helena Luchese:** Formal analysis. **Erick Almeida Esmerino:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Supervision, Project administration. **Simone Pereira Mathias:** Conceptualization, Supervision, Project administration.

Declaration of competing interest

The authors declare no conflict of interest.

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References

Alves, L. A. A., Lorenzo, J. M., Gonçalves, C. A. A., dos Santos, B. A., Heck, R. T., Cichoski, A. J., et al. (2016). Production of healthier bologna type sausages using pork skin and green banana flour as a fat replacer. *Meat Science, 121*, 73–78. https://doi.org/10.1016/j.meatsci.2016.06.001

AOAC. (1995). Determination of fibers content. *Method 991.43, Official Methods of analysis* (16th ed.). Arlington: Association of Official Analytical Chemists.

AOAC. (2019a). *Determination of pH. Method 981.12, Official Methods of analysis* (21st ed.). Rockville, MD, USA: Association of Official Analytical Chemists.

AOAC. (2019b). Determination of moisture content. *Method 925.45. Official Methods of analysis* (21st ed.). Rockville, MD, USA: Association of Official Analytical Chemists.

AOAC. (2019c). *Determination of ash content. Method 923.03. Official Methods of Analysis* (21st ed.). Rockville, MD, USA: Association of Official Analytical Chemists.

AOAC. (2019d). Determination of protein content. *Method 960.52. Official Methods of analysis* (21st ed.). Rockville, MD, USA: Association of Official Analytical Chemists.

AOAC. (2019e). *Determination of fat content. Method 963.15, Official Methods of Analysis* (21st ed.). Rockville, MD, USA: Association of Official Analytical Chemists.

Audu, O. Y., Durodola, B. M., Mordi, R. C., Owolabi, E. F., Uzoamaka, G. C., Ayo-Ajayi, J. I., et al. (2015). Study on the potassium content of Nigerian bananas and the methanolic extraction, phytochemical and antimicrobial studies of oils from banana peels. *Covenant Journal of Physical and Life Sciences, 3*(1).

Auriema, B. E., Dinalli, V. P., Kato, T., Yamaguchi, M. M., Marchi, D. F., & Soares, A. L. (2019). Physical and chemical properties of chicken mortadella formulated with Moringa oleifera Lam. seed flour. *Food Science and Technology, 39*, 504–509. https://doi.org/10.1590/fst.25018

Bastos, S. C., Pimenta, M. E. S., Pimenta, C. J., Reis, T. A., Nunes, C. A., Pinheiro, A. C. M., … Leal, R. S. (2014). Alternative fat substitutes for beef burger: Technological and sensory characteristics. *Journal of Food Science & Technology, 51*(9), 2046–2053. https://doi.org/10.1007/s13197-013-1233-2

Bauer, A. W., Kirby, W. M. M., Sherris, J. C., & Turck, M. (1966). Antibiotic susceptibility testing by a standardized single disc method. *American Journal of Clinical Pathology, 45*(4), 493–496.

Brasil. (2001). Agência Nacional de Vigilância Sanitária, Resolução RDC nº 12 de 02/01/2001, Regulamento Técnico sobre padrões microbiológicos para alimentos, Brasília, DF: Diário Oficial da República Federativa do Brasil. Available online http://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2001/res0012_02_01_2001.html/ Accessed: 15 December 2019.

Brewer, M. S. (2011). Natural antioxidants: Sources, compounds, mechanisms of action, and potential applications. *Comprehensive Reviews in Food Science and Food Safety, 10*(4), 221–247. https://doi.org/10.1111/j.1541-4337.2011.00156.x

Campuzano, A., Rosell, C. M., & Cornejo, F. (2018). Physicochemical and nutritional characteristics of banana flour during ripening. *Food Chemistry, 256*, 11–17. https://doi.org/10.1016/j.foodchem.2018.02.113

Castelo-Branco, V. N., Guimarães, J. N., Souza, L., Guedes, M. R., Silva, P. M., Ferrão, L. L., et al. (2017). The use of green banana (Musa balbisiana) pulp and peel flour as an ingredient for tagliatelle pasta. *Brazilian Journal Of Food Technology, 20*. https://doi.org/10.1590/1981-6723.11916

Chabuck, Z. A. G., Al-Charrakh, A. H., Hindi, N. K. K., & Hindi, S. K. K. (2013). *Antimicrobial effect of aqueous banana peel extract, Iraq, 1* pp. 73–75). Research Gate: Pharmaceutical Sciences.

Chan, E. W. C., Lim, Y. Y., & Omar, M. (2007). Antioxidant and antibacterial activity of leaves of Etlingera species (Zingiberaceae) in Peninsular Malaysia. *Food Chemistry, 104*(4), 1586–1593. https://doi.org/10.1016/j.foodchem.2007.03.023

Chmiel, M., Roszko, M., Adamczak, L., Florowski, T., & Pietrzak, D. (2019). Influence of storage and packaging method on chicken breast meat chemical composition and fat oxidation. *Poultry Science, 98*(6), 2679–2690. https://doi.org/10.3382/ps/pez029

CLSI. (2003). *Clinical and Laboratory Standards Institute. Normas de Desempenho para Testes de Sensibilidade Antimicrobiana: 15° Suplemento Informativo, 25* (1) 2003. Available online http://bvsms.saude.gov.br/bvs/publicacoes/metodo_ref_testes_diluicao_modulo4.pdf/ Accessed: 22 November 2017.

Costa, L. E., Alencar, N. M. M., Rullo, B. G. S., & Taralo, L. R. (2017). Effect of green banana pulp on physicochemical and sensory properties of probiotic yoghurt. *Ciência e Tecnologia de Alimentos, 37*(3). https://doi.org/10.1590/1678-457x.01016

Damasceno, K. A., Alvarenga Gonçalves, C. A., Dos Santos Pereira, G., Lacerda Costa, L., Bastianello Campagnol, P. C., Leal De Almeida, P., et al. (2016). Development of cereal bars containing pineapple peel flour (Ananas comosus L. Merril). *Journal of Food Quality, 39*(5), 417–424. https://doi.org/10.1111/jfq.12222

Dijkterhuis, G. B. (1995). Multivariate data analysis in sensory and consumer science: An overview of developments. *Trends in Food Science & Technology, 6*, 206e211.

Dinon, S., Devitte, S., Canan, C., Kalschne, D. L., & Colla, E. (2014). Mortadela tipo Bologna com reduzido teor de lipídios pela adição de biomassa de banana verde, pectina, carragena e farinha de linhaça. *RECEN-Revista Ciências Exatas e Naturais, 16*(2), 229–246. https://revistas.unicentro.br/index.php/RECEN/article/view/2949.

Fagbemi, J. F., Ugoji, E., Adenipekun, T., & Adelowotan, O. (2009). Evaluation of the antimicrobial properties of unripe banana (Musa sapientum L.), lemon grass (Cymbopogoncitratus S.) and turmeric (Curcuma longa L.) on pathogens. *African Journal Of Biotechnology, 8*(7). https://doi.org/10.5897/AJB09.224

FAO. (2013). *Food and Agriculture Organization of the United Nations. Codex guidelines on nutrition and health claims*. Available online http://www.fao.org/ag/humannutrition/32444-09f5545b8abe9a0c3baf01a4502ac36e4.pdf/ Accessed: 15 December 2019.

FAO. (2019). *Food and Agriculture Organization of the United Nations. Meat market review*. Available online http://www.fao.org/3/ca3880en/ca3880en.pdf/ Accessed: 06 November 2020.

Fatemeh, S. R., Saifullah, R., Abbas, F. M. A., & Azhar, M. E. (2012). Total phenolics, flavonoids and antioxidant activity of banana pulp and peel flours: Influence of variety and stage of ripeness. *International Food Research Journal, 19*(3), 1041.

FDA. (2016). *Food and drug administration. Food labeling: Nutrient content claims; Alpha-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid Omega-3 fatty acids. Guidance for industry small entity compliance guide*. U.S. Department of Health and Human Services.

Fernández-López, J., Lucas-González, R., Viuda-Martos, M., Sayas-Barberá, E., Ballester-Sánchez, J., Haros, C. M., … Pérez-Álvarez, J. A. (2020). Chemical and technological properties of bologna-type sausages with added black quinoa wet-milling coproducts as binder replacer. *Food Chemistry, 310*, 125936. https://doi.org/10.1016/j.foodchem.2019.125936

Grygorczyk, A., Lesschaeve, I., Corredig, M., & Duizer, L. (2013). Extraction of consumer texture preferences for yogurt: Comparison of the preferred attribute elicitation method to conventional profiling. *Food Quality And Preference, 27*(2), 215–222. https://doi.org/10.1016/j.foodqual.2012.02.017

Guimarães, J. T., Silva, E. K., Arruda, H. S., Freitas, M. Q., Pastore, G. M., Meireles, M. A. A., et al. (2020). How does the degree of inulin polymerization affect the bioaccessibility of bioactive compounds from soursop whey beverage during in vitro gastrointestinal digestion? *Food Hydrocolloids, 101*, 105511. https://doi.org/10.1016/j.foodhyd.2019.105511

Guimarães, J. T., Silva, E. K., Ranadheera, C. S., Moraes, J., Raices, R. S. L., Silva, M. C., et al. (2019). Effect of high-intensity ultrasound on the nutritional profile and volatile compounds of a prebiotic soursop whey beverage. *Ultrasonics Sonochemistry, 55*, 157–164. https://doi.org/10.1016/j.ultsonch.2019.02.025

Hung, Y., de Kok, T. M., & Verbeke, W. (2016). Consumer attitude and purchase intention towards processed meat products with natural compounds and a reduced level of nitrite. *Meat Science, 121*, 119–126. https://doi.org/10.1016/j.meatsci.2016.06.002

IAL. (1985). *Instituto Adolfo lutz. Normas Analíticas do instituto Adolfo lutz, 1* p. 533). IAL: São Paulo.

Ibrahim, H. M. (2015). Green synthesis and characterization of silver nanoparticles using banana peel extract and their antimicrobial activity against representative microorganisms. *Journal of Radiation Research and Applied Sciences, 8*(3), 265–275. https://doi.org/10.1016/j.jrras.2015.01.007

IOM. (1997). *Institute of Medicine. Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride. Food and Nutrition Board*. Washington, DC: The National Academy Press. National Academy of Sciences.

IOM. (2001). *Institute of Medicine. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Food and Nutrition Board*. Washington, DC: The National Academies Press. National Academy of Sciences.

IOM. (2005). *Institute of Medicine. Dietary reference intakes for water, potassium, sodium, chloride, and sulfate. Food and Nutrition Board*. Washington, DC: The National Academy Press. National Academy of Sciences.

Izidoro, D. R., Scheer, A. P., Sierakowski, M. R., & Haminiuk, C. W. (2008). Influence of green banana pulp on the rheological behaviour and chemical characteristics of emulsions (mayonnaises). *LWT-Food Science and Technology, 41*(6), 1018–1028. https://doi.org/10.1016/j.lwt.2007.07.009

Júnior, M. M., de Oliveira, T. P., Gonçalves, O. H., Leimann, F. V., Marques, L. L. M., Fuchs, R. H. B., … Droval, A. A. (2019). Substitution of synthetic antioxidant by curcumin microcrystals in mortadella formulations. *Food Chemistry, 300*, 125231. https://doi.org/10.1016/j.foodchem.2019.125231

Kamruzzaman, M., Makino, Y., & Oshita, S. (2016). Hyperspectral imaging for real-time monitoring of water holding capacity in red meat. *LWT-Food Science and Technology, 66*, 685–691. https://doi.org/10.1016/j.lwt.2015.11.021

Kusuma, S. A. F., Soraya, R. M., Indah, F., & Resmi, M. (2017). Study on the antibacterial activity of fruit extracts of Klutuk Banana (Musa balbisianacolla) against Shigelladysenteriae ATCC 13313. *Asian Journal Of Pharmaceutical And Clinical Research, 10*(7), 220–223. https://doi.org/10.22159/ajpcr.2017.v10i7.18561

McSweeney, M. B., Sisopha, A., T'ien, C., Rector, M., & Duizer, L. M. (2017). Comparing preferred attribute elicitation to trained panelists' evaluations using a novel food product. *Journal of Sensory Studies, 32*, Article e12300. https://doi.org/10.1111/joss.12300

Mordi, R. C., Fadiaro, A. E., Owoeye, T. F., Olanrewaju, I. O., Uzoamaka, G. C., & Olorunshola, S. J. (2016). Identification by GC-MS of the components of oils of banana peels extract, phytochemical and antimicrobial analyses. *Research Journal Of Phytochemistry, 10*(1), 39–44. http://eprints.covenantuniversity.edu.ng/id/eprint/5643.

Muggah, E. M., & McSweeney, M. B. (2017). Using preferred attribute elicitation to determine how males and females evaluate beer. *Journal Of Food Science, 82*(8), 1916–1923. https://doi.org/10.1111/1750-3841.13799

Nikmaram, N., Budaraju, S., Barba, F. J., Lorenzo, J. M., Cox, R. B., Mallikarjunan, K., et al. (2018). Application of plant extracts to improve the shelf-life, nutritional and health-related properties of ready-to-eat meat products. *Meat Science, 145*, 245–255. https://doi.org/10.1016/j.meatsci.2018.06.031

Oswell, N. J., Thippareddi, H., & Pegg, R. B. (2018). Practical use of natural antioxidants in meat products in the US: A review. *Meat Science, 145*, 469–479. https://doi.org/10.1016/j.meatsci.2018.07.020

Ovando-Martinez, M., Sáyago-Ayerdi, S., Agama-Acevedo, E., Goñi, I., & Bello-Pérez, L. A. (2009). Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. *Food Chemistry, 113*(1), 121–126. https://doi.org/10.1016/j.foodchem.2008.07.035

Pagès, J. (2004). Multiple factor Analysis: Main features and application to sensory data. *Revista Colombiana de Estadística, 27*(1), 1–26 [Internet].

Pérez-Andrés, J. M., Álvarez, C., Cullen, P. J., & Tiwari, B. K. (2019). Effect of cold plasma on the techno-functional properties of animal protein food ingredients. *Innovative Food Science & Emerging Technologies, 58*, 102205. https://doi.org/10.1016/j.ifset.2019.102205

Peris-Felipo, F. J., Benavent-Gil, Y., & Hernández-Apaolaza, L. (2020). Silicon beneficial effects on yield, fruit quality and shelf-life of strawberries grown in different culture substrates under different iron status. *Plant Physiology And Biochemistry, 152*, 23–31. https://doi.org/10.1016/j.plaphy.2020.04.026

Pico, J., Xu, K., Guo, M., Mohamedshah, Z., Ferruzzi, M. G., & Martinez, M. M. (2019). Manufacturing the ultimate green banana flour: Impact of drying and extrusion on phenolic profile and starch bioaccessibility. *Food Chemistry, 297*, 124990. https://doi.org/10.1016/j.foodchem.2019.124990

Pires, M. A., dos Santos, I. R., Barros, J. C., & Trindade, M. A. (2019). Effect of replacing pork backfat with Echium oil on technological and sensory characteristics of bologna sausages with reduced sodium content. *LWT-Food Science and Technology, 109*, 47–54. https://doi.org/10.1016/j.lwt.2019.04.009

Popoola, I. O., Bruce, H. L., McMullen, L. M., & Wismer, W. V. (2019). Consumer sensory comparisons among beef, horse, elk, and Bison using preferred attributes elicitation and check-all-that-apply methods. *Journal of Food Science, 84*(10), 3009–3017. https://doi.org/10.1111/1750-3841.14780

Ranieri, L. M., & Delani, T. C. D. O. (2014). Banana verde (musa spp): Obtenção da biomassa e ações fisiológicas do amido resistente. *Revista UNINGÁ Review, 20*(3). http://34.233.57.254/index.php/uningareviews/article/view/1602.

Riquette, R. F. R., Ginani, V. C., dos Santos Leandro, E., de Alencar, E. R., Maldonade, I. R., de Aguiar, L. A., … Zandonadi, R. P. (2019). Do production and storage affect the quality of green banana biomass? *LWT-Food Science and Technology, 111*, 190–203. https://doi.org/10.1016/j.lwt.2019.04.094

Rodrigues, A. S., Kubota, E. H., da Silva, C. G., dos Santos Alves, J., Hautrive, T. P., Rodrigues, G. S., et al. (2020). Banana inflorescences: A cheap raw material with great potential to be used as a natural antioxidant in meat products. *Meat Science, 161*, 107991. https://doi.org/10.1016/j.meatsci.2019.107991

Rufino, M. S. M., Alves, R. E., de Brito, E. S., Pérez-Jiménez, J., Saura-Calixto, F., & Mancini-Filho, J. (2010). Bioactive compounds and antioxidant capacities of 18 non-traditional tropical fruits from Brazil. *Food Chemistry, 121*(4), 996–1002. https://doi.org/10.1016/j.foodchem.2010.01.037

Saldaña, E., de Oliveira Garcia, A., Selani, M. M., Haguiwara, M. M., de Almeida, M. A., Siche, R., et al. (2018). A sensometric approach to the development of mortadella with healthier fats. *Meat Science, 137*, 176–190. https://doi.org/10.1016/j.meatsci.2017.11.027

Salih, Z. A., Siddeeg, A., Taha, R. T., Bushra, M., Ammar, A. F., & Ali, A. O. (2017). Physicochemical and functional properties of pulp and peel flour of dried green and ripe banana (cavendish). *International Journal of Research in Agricultural Sciences, 4*(6), 2348–3997. http://repo.uofg.edu.sd/handle/123456789/2000.

Santos, M., Ozaki, M. M., Ribeiro, W. O., de Souza Paglarini, C., Vidal, V. A. S., Campagnol, P. C. B., et al. (2020). Emulsion gels based on pork skin and dietary fibers as animal fat replacers in meat emulsions: An adding value strategy to byproducts. *LWT-Food Science and Technology, 120*, 108895. https://doi.org/10.1016/j.lwt.2019.108895

Santos, B. A., Pollonio, M. A. R., Cruz, A. G., Messias, V. C., Monteiro, R. A., Oliveira, T. L. C., et al. (2013). Ultra-flash profile and projective mapping for describing sensory attributes of prebiotic mortadellas. *Food Research International, 54*(2), 1705–1711. https://doi.org/10.1016/j.foodres.2013.09.022

Soares, E. K., Silva, R., da Silva, W. P., Kuriya, S. P., Maçaira, P. M., Cyrino Oliveira, F. L., … Esmerino, E. A. (2019). An intra-cultural investigation in Brazil using Coalho cheese and preferred attribute elicitation. *Journal Of Sensory Studies, 35*(1), e12543. https://doi.org/10.1111/joss.12543

Strohecker, R., & Henning, H. M. (1967). *Análisis de vitaminas, métodos comprovados*. Madrid: Paz Montalvo.

Swain, T., & Hillis, W. E. (1959). The phenolic constituents of Prunusdomestica. I. The quantitative analysis of phenolic constituents. *Journal Of the Science Of Food And Agriculture, 10*(1), 63–68. https://doi.org/10.1002/jsfa.2740100110

Thaipong, K., Boonprakob, U., Crosby, K., Cisneros-Zevallos, L., & Byrne, D. H. (2006). Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. *Journal of Food Composition and Analysis, 19*(6–7), 669–675. https://doi.org/10.1016/j.jfca.2006.01.003

Tomas, M., Beekwilder, J., Hall, R. D., Diez Simon, C., Sagdic, O., & Capanoglu, E. (2018). Effect of dietary fiber (inulin) addition on phenolics and in vitro bioaccessibility of tomato sauce. *Food Research International, 106*, 129–135. https://doi.org/10.1016/j.foodres.2017.12.050

Varvara, M., Bozzo, G., Celano, G., Disanto, C., Pagliarone, C. N., & Celano, G. V. (2016). The use of ascorbic acid as a food additive: Technical-legal issues. *Italian Journal of Food Safety, 5*(1). https://doi.org/10.4081/ijfs.2016.4313

Von Loesecke, H. (1950). *Bananas* (2nd ed.). New York: Inter Science.

Yap, M., Fernando, W. M., Brennan, C. S., Jayasena, V., & Coorey, R. (2017). The effects of banana ripeness on quality indices for puree production. *LWT Food Science and Technology, 80*, 10–18. https://doi.org/10.1016/j.lwt.2017.01.073

Youryon, P., & Supapvanich, S. (2017). Physicochemical quality and antioxidant changes in 'LebMueNang'banana fruit during ripening. *Agriculture and Natural Resources, 51* (1), 47–52. https://doi.org/10.1016/j.anres.2015.12.004

Zhang, W., Xiao, S., Samaraweera, H., Lee, E. J., & Ahn, D. U. (2010). Improving functional value of meat products. *Meat Science, 86*(1), 15–31. https://doi.org/10.1016/j.meatsci.2010.04.018