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Orange albedo flour as a fat replacer in beef burgers: adding value to citrus industry by-products

Farinha de albedo de laranja como substituto de gordura em hambúrgueres bovinos: agregação de valor aos subprodutos da citricultura

Harina de albedo de naranja como un sustituto de la grasa en hamburguesas bovinas: un valor agregado a los subproductos de la citricultura

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Abstract

Dietary fiber is an important component to improve the nutritional appeal of meat products, and it could be obtained from by-products of the citrus industry. Considering that orange albedo was not sufficiently addressed in meat products, the purpose of this work was to evaluate the influence of the orange albedo flour as an animal fat substitute in beef burgers. Five formulations were developed with different substitutions of pork fat by the orange albedo flour (0; 25; 50; 75; and 100%). The analyses carried out were the proximal composition of orange albedo flour and beef burgers and the cooking yield, shrinkage, pH, color, sensory acceptance, and purchase intent of the beef burgers. The results showed that the percentage of lipids was reduced by up to 70%, however, the yield parameters were negatively affected by the inclusion of the orange albedo flour: the higher the amount of flour added, lower was the water retention capacity and higher was the shrinkage rate. Concerning sensory analysis, the formulations that pork back fat was substituted by 25 and 50% of orange albedo flour were the most acceptable for all sensory attributes and purchase intention, characterizing themselves as viable alternatives both of the nutritional and sensory aspects.

Keywords: Citrus by-products; Citrus sinensis L. Osbeck, var. Pera-Rio; Dietary fiber intake; Fat reduction.

Resumo

As fibras alimentares são componentes importantes para melhorar o apelo nutricional dos produtos cárneos, podendo ser obtidas a partir de subprodutos da citricultura, dentre eles o albedo de laranja. Considerando que o albedo de laranja não foi suficientemente avaliado em produtos cárneos, o objetivo deste trabalho foi avaliar a influência da farinha de albedo de laranja como substituto da gordura animal em hambúrgueres de carne bovina. Cinco formulações foram desenvolvidas com diferentes substituições da gordura suína pela farinha de albedo de laranja (0; 25; 50; 75; e 100%). As análises realizadas foram a composição proximal da farinha de albedo de laranja e dos hambúrgueres bovinos e o rendimento de cozimento, encolhimento, pH, parâmetros de cor, aceitação sensorial e intenção de compra dos hambúrgueres bovinos. Os resultados mostraram que o percentual de lipídios foi reduzido em até 70%, porém, os parâmetros de rendimento foram afetados negativamente pela inclusão da farinha de albedo de laranja: quanto maior a quantidade de farinha adicionada, menor a capacidade de retenção de água e maior foi a taxa de encolhimento. Em relação à análise sensorial, as formulações em que a gordura suína foi substituída por 25 e 50% de farinha de albedo de laranja foram as mais aceitáveis para todos os atributos sensoriais e intenção de compra, caracterizando-se como alternativas viáveis tanto no aspecto nutricional quanto no sensorial.

Palavras-chave: Subprodutos cítricos; Citrus sinensis L. Osbeck, var. Pera-Rio; Ingestão de fibra alimentar; Redução de gordura.

Resumen

Las fibras dietéticas son componentes importantes para mejorar el atractivo nutricional de los productos cárnicos y pueden obtenerse a partir de subproductos cítricos. Considerando que el albedo de naranja no ha sido lo suficientemente estudiado en productos cárnicos, este trabajo tiene como objetivo determinar la influencia de la harina de albedo de naranja como un sustituto de la grasa animal en hamburguesas bovinas. Con el fin de cumplir este objetivo, se desarrollaron cinco formulaciones, sustituyendo grasa de cerdo por harina de albedo de naranja en diferentes porcentajes (0; 25; 50; 75; y 100%). Fueron analizados diferentes parámetros como: la composición proximal de la harina de albedo de naranja y de las hamburguesas de carne, el rendimiento de cocción, la reducción del diámetro, pH, color, aceptación sensorial e intención de compra de las hamburguesas. Los resultados revelaron que el porcentaje de lípidos se redujo hasta en un 70%. Sin embargo, los parámetros de rendimiento se vieron afectados negativamente por la adición de la harina de albedo de naranja mostrando que, a mayor cantidad de harina agregada, existe una menor capacidad de retención de agua y una mayor reducción del diámetro. Los resultados del análisis sensorial mostraron que las formulaciones en las que se sustituyó la grasa porcina por 25 y 50% de la harina de albedo de naranja, fueron las más aceptadas para todos los atributos sensoriales e intención de compra, lo cual muestra que estas pueden funcionar como alternativas viables tanto en el aspecto nutricional como en el sensorial.

Palabras clave: Subproductos cítricos; Citrus sinensis L. Osbeck, var. Pera-Rio; Ingesta de fibra dietética; Reducción de grasas.

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1. Introduction

The reformulation of meat products processed from a nutritional perspective is essential to meet the growing demand for products that are addressed for a healthy lifestyle. One of the focuses of the reformulation of meat products is the reduction of saturated fat due to the correlation attributed to the increase in its consumption and the increased risk of developing cardiovascular diseases (Kris-Etherton et al., 2018). The reduction of fat in meat products, however, is quite challenging, due to its effect on sensory characteristics: it contributes to texture, mouthfeel, provides a lubricating effect, and contributes to flavor (Tobin et al., 2012).

For this propose, dietary fibers can be considered suitable ingredients to replace animal fat since they could improve both the technological and nutritional aspects of the meat products. Regarding technological aspects, dietary fibers could improve water and oil retention capacity, can act as stabilizers, “body”, gelling, and emulsifiers agents (Elleuch et al., 2011) and, therefore, have been reported as fat substitutes in processed meat (Han & Bertram, 2017; Schmiele et al., 2015; Zhao et al., 2018). In the nutritional aspect, the regular consumption of dietary fibers helps to reduce cholesterol, to control blood glucose levels, to improve intestinal transit, and to stimulate the development of a beneficial microbiota (Elleuch et al., 2011; Lattimer & Haub, 2010). For adults, the recommended intake of dietary fiber is 28–36 g/day, of which 70–80% should be insoluble one, however the population does not consume an adequate intake of dietary fibers (Han & Bertram, 2017).

The use of dietary fibers from industrial by-products has been evaluated in many studies due to the low-cost of them and the sustainability issues (López-Vargas et al., 2014; Pereira et al., 2020; S. K. Sharma et al., 2016; Soncu et al., 2015). Among the vegetable by-products, it is worth highlighting those arising from the processing of citrus fruits (Luis Aleson-Carbonell et al., 2004; Fernández-Ginés et al., 2004; Sariçoban et al., 2008; Sayas-Barberá et al., 2012; Selim et al., 2019). Citrus by-products are comprised of peel (flavedo and albedo), pulp (juice vesicles), carpel membranes, and seeds (Bampidis & Robinson, 2006).

Brazil is the world's largest producer and exporter of orange juice. According to the Brazilian Association of Citrus Exporters (CitrusBR), 1.016 x 10^6 tons of orange juice were exported in 2019 against 2.67 x 10^5 tons of juice by-products. The quantity of by-products obtained from the whole fruit corresponds to 45-60% (Fernández-López et al., 2009). Thus, there is still a significant amount of by-products from the Brazilian orange industry that can be reused.

The albedo, the white, spongy and cellulosic tissue, is rich in fibers of better quality than other sources of dietary fibers (Sharma et al., 2017). According to Santana (2005), the insoluble fraction (cellulose and hemicelluloses) constitutes 78.5% of the total fibers present in the orange albedo (76.5% on a dry basis). The soluble fraction, in turn, consists mainly of pectin (Liu et al., 2006). Also, Escobedo-Avellaneda et al. (2014) showed that the orange albedo is the main source of phenolic compounds and flavanones, and it exhibited higher antioxidant activity among juice, flavedo, and comminuted orange.

Despite the technological and nutritional potential of orange albedo, few studies have evaluated its use in meat products. Among these products, the hamburger stands out due to its high-fat content and because it is a widely consumed product. From this context, the objective of this work was to evaluate the influence of the addition of orange albedo flour as a fat substitute on the physical-chemical and sensory characteristics of beef burgers.

2. Methodology

2.1. Experimental design

In this work, the orange albedo flour was elaborated and incorporated in beef burgers as pork fat substitute in different levels (25, 50, 75 e 100%) and one treatment control, totalizing five treatments. Each treatment was elaborated in three repetitions with the same ingredients and process using a completely randomized design. To evaluate the psychochemical and technological characteristics, three aleatory samples were taken of each repetition block.

2.2. Orange albedo flour production

The orange albedo was obtained from oranges (Citrus sinensis L. Osbeck, var. Pera-Rio) at the commercial maturation stage. The oranges were washed and sanitized in sodium hypochlorite solution (200 ppm) for 15 minutes. The fruits were peeled and the albedo was separated from the fruit. After separation, the albedo was dried in trays with forced air circulation (PD-25, Polidryer, Viçosa, MG, Brazil) at a temperature of 60 °C for approximately 8 hours. The orange albedo flour was obtained by grinding the dehydrated albedo in an industrial blender (Vitalex, LQI-04, São Paulo, Brazil) and, after, sifted for granulometric uniformity. The flour was kept at room temperature in glass jars lined with aluminum foil until the use.

2.3. Beef burgers elaboration

Five beef burger formulations were prepared, in triplicate, with different levels of pork back fat and orange albedo flour (Table 1). The ground beef (*Quadriceps femoris*, 0 to 1 °C), water (4 ºC), and sodium chloride were mixed for 2 minutes in a mixer (Arno, Deluxe SX84, Brazil). Then, the textured soy protein, properly hydrated (one part of protein for three parts of water, and the water was discounted from the total formulation), monosodium glutamate, and condiments were incorporated. The pork back fat and the orange albedo flour were added, following by homogenization for 5 minutes. The formulations were freezing (-1ºC), for an hour. Portions of 45 g were weighed, wrapped in polyethylene plastic, and molded (90 cm of diameter) using a manual burger modeler (Lucre, SP, Brazil). The burger samples were stored at -40 °C until use. The beef burgers were melting at 4 ºC for 12 hours, before cooking on an electric grill (Fun Kitchen, SS 36P, China) at 150ºC for 15 min (7 min on one side and 8 min on the other side). The final internal temperature was 71ºC.

Table 1. Beef burger formulations (g/100g)

Ingredients	Formulations				
	FC	F1-25	F2-50	F3-75	F4-100
Beef meat	78	78	78	78	78
Pork back fat	8.7	6.5	4.3	2.2	0
Orange albedo flour	0	2.2	4.3	6.5	8.7
Sodium chloride	1.7	1.7	1.7	1.7	1.7
Texturized soy protein	2.6	2.6	2.6	2.6	2.6
Water	8.7	8.7	8.7	8.7	8.7

Condiments (g/100g): Powder garlic (0.1); black pepper (0.05); powder onion (0.1). Monosodium glutamate (0.1). Source: The authors.

2.4. Proximate composition and pH

The soluble, insoluble, and total dietary fibers of the orange albedo flour and the proximate composition (moisture, lipids, protein, and ash contents) of the orange albedo flour and the raw beef burgers were determined according to the methodology described by the Association of Official Analytical Chemists (AOAC, 2005). The dietary fibers content in the beef burger samples was estimated considering the orange albedo flour level added in each formulation. The pH analysis was performed using a pH meter W3B (BEL *Engineering*, Monza, Italy) by dipping a pH electrode into homogenates obtained with a ratio of 1:10 w/v of raw burger samples/distilled water and 1:20 w/v of orange albedo flour/distilled water.

2.5. Cooking parameters

The cooking yield and shrinkage were evaluated according to Berry (1992). The cooking yield was determined by the difference between the weight of the samples before and after cooking and expressed in percentage. The shrinkage of burgers was quantified with the aid of a 0.02 mm/0.001'' grade caliper according to Equation 1.

$$\%\ CY = \left(\frac{D_1 - D_2}{D_1}\right) x\ 100 \qquad \text{Equation 1}$$

Where: D1 and D2 are the diameters (cm) of the raw and cooked sample, respectively.

2.6. Water holding capacity

A water holding capacity (WHC) was determined according to the methodology described by Bastos et al. (2014), and calculated according to the following Equation 2:

$$\%WHC = \left(1 - \frac{A - D}{U}\right) x\ 100 \qquad \text{Equation 2}$$

Where: A = weight of the sample before centrifugation (g); D = weight of the sample after centrifugation (g); U = initial moisture content of the sample (g).

2.7. Color parameters

The color was measured using a CR 400 spectrophotometer (Konica Minolta, Japan), operating with D65 illuminant and CIELab color system: where L * ranges from 0 (black) to 100 (white), a* varies from green (-) to red (+), and b * varies from blue (-) to yellow (+). The whiteness (W) was determined with the formula proposed by Lohman & Hartel (1994) as follows: $100 – [(100 – L^*)2 + a^*2 + b^*2]^{½}$.

2.8. Sensory analysis

The sensory analysis was approved by the Ethics in Research Committee of the Federal University of Ouro Preto (UFOP), MG, Brazil (No. 881.408), and all participants signed a free and informed consent form, agreeing voluntarily to participate in the sensory tests. All tests were performed in the Sensory Analysis Laboratory of Nutrition School (UFOP) using individual cabins under white light. The acceptance test evaluated the appearance, flavor, texture, color, and overall liking of burgers using the 9-point structured hedonic scale, ranging from extremely disliked (note 1) to extremely liked (note 9) (Stone & Sidel, 2004). Purchase intention was assessed using the 5-point scale, ranging from certainly not buying (grade 1) to certainly buying (grade 5) (Stone & Sidel, 2004). The samples were randomly selected from each repetition block, coded with a three-digit number, and presented in a monadic order, following a balanced design (Wakeling & MacFie, 1995). A total of 108 untrained consumers composed of students, teachers, and staff participated in this study.

2.9. Statistical analysis

Three independent processes were performed. For each process, three samples were taken for each psychochemical analysis. The psychochemical and sensory results were expressed as the averages and standard deviation and they were analyzed by analysis of variance (one-way ANOVA) at 95% confidence level ($P < 0.05$), followed by Tukey's test ($P < 0.05$) using the software Sisvar 5.6 (Ferreira, 2014). For the sensory analysis, simultaneous evaluation of acceptance data and purchase intention was performed using a three-way internal preference map, through parallel factor analysis (PARAFAC), optimized using the

Core Consistency Diagnostic (CORCONDIA) value to choose the number of factors (Nunes et al., 2011) in SensoMaker software version 1.92 (Pinheiro et al., 2013).

3. Results and Discussion

3.1. Proximate composition and pH of the orange albedo flour and the raw beef burgers

The proximate composition and pH of the orange albedo flour and raw beef burgers can be seen in Table 2. The orange albedo flour showed a low moisture content (6.77 g/100g), it was below to the maximum moisture limit, 15 %, recommended for flours by RDC 263/2005 (Brazil, 2005). The dietary fiber was the main component (65.9 g/100g) of orange albedo flour. The insoluble fraction was 2.8 higher than the soluble one. The high proportion of insoluble dietary fiber was expected and corroborated by other works (Rapina, 2017; Santana, 2005). Orange albedo flour showed a low lipid content (0.51 g/100g), it was expected since the flavedo was removed. This result was similar to reported by Silva et al. (2013) and Rapina (2017), 0.39 % and 0.7 %, respectively. The protein content of orange albedo flour (2.73 g/100g), as expected, was low and close to reported by other studies (Ammar, 2017; Silva et al., 2013; Soriao et al., 2015). The average pH value (5.00) of the orange albedo flour determined in this study was similar to that obtained by Santana (2005) and superior to found by Coksever & Saricoban (2010) to bitter orange albedo (3.86). Some variations in the proximate composition of orange albedo flour are expected and may be related to the variety, region's climate, and harvest (Oliveira et al., 2014), as well as resulting from the process of obtaining the product.

The moisture content of beef burgers ranged from 69.05 to 71.04 g/100g. The control formulation (FC) presented higher ($P \leq 0.05$) moisture than the formulations contained orange albedo flour. Furthermore, an inverse relationship was observed between the increase in the fiber content in the formulation and the moisture content of the final product (Table 2), which could be explained by the low moisture of the orange albedo flour. Similar results were obtained with the incorporation of albedo flour in nuggets (Ammar, 2017) and passion fruit albedo flour in burgers (López-Vargas et al., 2014).

The protein content did not differ ($P > 0.05$) among treatments, whose results varied from 16.71 to 17.38 g/100g. This result was expected considering the low level of protein of the orange albedo flour. Other studies also reported that the protein content of raw burgers did not differ with the addition of dehydrated passion fruit albedo (López-Vargas et al., 2014) and dehydrated lemon albedo (Aleson-Carbonell et al., 2005). Furthermore, the protein content of beef burger formulations was in accordance with the Technical Regulation on Hamburger Identity and Quality (Brazil, 2000), which recommends a minimum of 15 % for protein level.

The lipid content, as expected, differed among treatments ($p \leq 0.05$). Treatments FC and F4-100 presented higher and lower amounts of lipids (9.34 and 2.81 g/100g, respectively). Since the percentage of lipids was reduced by up to 70% ($P \leq 0.05$), formulations F2-50, F3-75, and F4-100 could be considered reduced in fat when compared to FC (control), due to the reduction of more than 25% of the lipid content (Brazil, 2012).

Table 2. Proximate composition (wet base, g/100g) and pH of the orange albedo flour and beef burger formulations.

Parameters	Orange albedo flour	Beef burger formulations				
		FC	F1-25	F2-50	F3-75	F4-100
Moisture	6.77 ± 0.17	71.04 ± 0.17 [a]	70.35 ± 0.13 [b]	69.58 ± 0.11 [c]	69.22 ± 0.05 [d]	69.05 ± 0.10 [d]
Lipids	0.51 ± 0.03	9.34 ± 0.18 [a]	7.70 ± 0.16 [b]	5.87 ± 0.20 [c]	4.02 ± 0.13 [d]	2.81 ± 0.02 [e]
Protein	2.73 ± 0.18	16.71 ± 0.36 [a]	16.58 ± 0.19 [a]	17.07 ± 0.41 [a]	17.30 ± 0.28 [a]	17.38 ± 0.32 [a]
Crude fiber*	65.87 ± 1.71	-	1.65	3.29	4.94	6.59
Soluble fiber*	17.18 ± 1.28	-	0.43	0.86	1.29	1.72
Insoluble fiber*	48.69 ± 1.10	-	1.22	2.43	3.65	4.87
Carbohydrate*	21.29	-	0.53	1.06	1.60	2.13
Ash	2.83 ± 0.35	2.59 ± 0.09 [c]	2.67 ± 0.03 [bc]	2.69 ± 0.02 [bc]	2.83 ± 0.08 [b]	3.20 ± 0.08 [a]
pH	5.00 ± 0.01	6.16 ± 0.05 [a]	5.94 ± 0.01 [b]	5.76 ± 0.01 [c]	5.58 ± 0.01 [d]	5.42 ± 0.00 [e]

* These parameters were estimated for beef burgers formulations according to values found to orange albedo flour. Means followed by the same letter on the same line do not show a significant difference (P > 0.05) by the Tukey test. Formulations FC, F1-25, F2-50, F3-75, and F4-100 substitute, respectively: 0, 25, 50, 75, and 100% of pork fat to the orange albedo flour. Source: The authors.

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The ash content of the beef burgers ranged from 2.59 to 3.20 g/100g. This variation was due to the increase of orange albedo flour level in the formulations. The beef burgers F2-50, F3-75, and F4-100 presented 3.29, 4.94, and 6.59 g/100g of dietary fibers, respectively, therefore they had claimed: "source of fibers" (3 g of fibers per 100 g; EC, 2006).

The pH values of raw beef burgers were significantly reduced ($P \leq 0.05$) with the replacement of fat by orange albedo flour, ranging from 6.16 (FC) to 5.42 (F4-100), which could be due to the pH of the orange albedo flour (pH = 5.00). Similar results were reported by other works (Aleson-Carbonell et al., 2005; López-Vargas et al., 2014; Sariçoban et al., 2008; Soncu et al., 2015).

3.2. Cooking parameters, WHC, and color of beef burgers

The physicochemical and sensory parameters of beef burgers are shown in Table 3. The technological properties, expressed by the cooking yield, shrinkage, and WHC varied among the treatments. FC and F1-25 showed the highest ($P \leq 0.05$) cooking yield and WHC, and the lowest ($P \leq 0.05$) shrinkage among treatments. These parameters were inversely proportional to the increase of orange albedo flour in the beef burgers. Although expect an increase of cooking yield and WHC with dietary fiber addition, the pH of beef burgers lowered proportionally as orange albedo flour increased (Table 2). Myofibrillar proteins are primarily responsible for water retention in meat products. However, this effect is quite dependent on the pH; the closer myofibrillar proteins are to its isoelectric points (pH 5.4 for myosin and pH 4.7 for actin, Aleson-Carbonell et al., 2004) less is their capacities to retain water. Thus, the drop of pH could be associated with the results related to the cooking parameters and WHC. Although these negative outcomes, the cooking yield of beef burgers were higher than those observed in burgers made with lemon albedo (67.8 to 73.3 %; Aleson-Carbonell et al., 2005) and passion fruit albedo (68.5 to 69.7 %; López-Vargas et al., 2014). Besides, Eldemery (2010) reported similar values of shrinkage (16.4 to 22.2 %) in beef burgers formulated with raw orange albedo, to those obtained in this work (16.2 to 22.6 %). Despite the pH decrease caused by citrus albedo in burgers are not a positive outcome, it could be advantageous for dehydrated and fermented meat products, as it helps in the loss of moisture by reducing the dehydration time (Fernández-López et al., 2004).

Table 3. Physicochemical and sensory parameters of the beef burgers incorporated with orange albedo flour

Parameters	Beef burger formulations				
	FC	F1-25	F2-50	F3-75	F4-100
Technological parameters					
Cooking yield (%)	82.8 ± 1.22^{a}	82.8 ± 0.93^{a}	79.6 ± 0.27^{b}	78.1 ± 0.39^{b}	75.6 ± 0.68^{c}
Shrinkage (%)	16.1 ± 0.98^{d}	16.2 ± 0.66^{d}	18.9 ± 0.63^{c}	20.7 ± 0.35^{b}	22.6 ± 0.55^{a}
WHC (%)	67.0 ± 2.28^{a}	66.1 ± 1.29^{a}	60.3 ± 0.75^{b}	58.2 ± 0.30^{bc}	55.6 ± 0.64^{c}
Color parameters					
L*	40.5 ± 0.65^{a}	39.3 ± 2.27^{a}	39.2 ± 2.84^{a}	39.2 ± 1.31^{a}	41.6 ± 2.50^{a}
a*	11.4 ± 0.43^{a}	10.5 ± 0.28^{b}	10.4 ± 0.53^{b}	10.2 ± 0.27^{bc}	9.7 ± 0.44^{c}
b*	13.2 ± 0.65^{c}	13.6 ± 0.73^{bc}	14.8 ± 1.54^{bc}	15.1 ± 0.99^{b}	16.8 ± 1.60^{a}
Whiteness	38.0 ± 0.63^{a}	36.9 ± 2.10^{a}	36.6 ± 2.78^{a}	36.5 ± 1.19^{a}	38.5 ± 2.30^{a}
Sensory parameters					
Color	7.60 ± 1.29^{ab}	7.87 ± 0.93^{a}	7.61 ± 1.16^{ab}	7.28 ± 1.37^{b}	6.60 ± 1.68^{c}
Appearance	7.47 ± 1.37^{a}	7.76 ± 1.26^{a}	7.52 ± 1.27^{a}	6.89 ± 1.56^{b}	6.07 ± 1.92^{c}
Flavor	7.53 ± 1.64^{a}	8.00 ± 1.13^{a}	7.59 ± 1.34^{a}	6.14 ± 1.89^{b}	5.33 ± 2.00^{c}
Texture	7.49 ± 1.58^{a}	7.97 ± 1.13^{a}	7.63 ± 1.21^{a}	6.50 ± 1.82^{b}	5.36 ± 2.07^{c}
Overall linking	7.54 ± 1.54^{a}	7.98 ± 0.99^{a}	7.63 ± 1.14^{a}	6.48 ± 1.69^{b}	5.59 ± 1.88^{c}

Means followed by the same letter on the same line do not show a significant difference ($P > 0.05$) by the Tukey test. Formulations FC, F1-25, F2-50, F3-75, and F4-100 substitute, respectively: 0, 25, 50, 75, and 100% of pork fat to the orange albedo flour. Source: The authors.

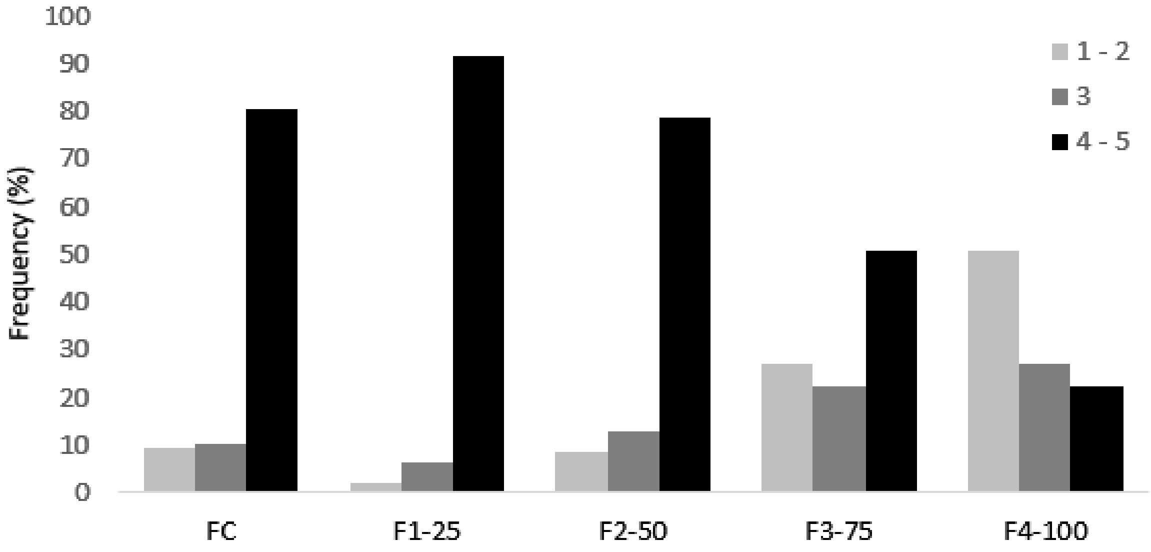
Color is one of the main attributes that influence consumers (Bastos et al., 2014), and reformulated products could be rejected when their color differs greatly from the characteristic color of the traditional products. Table 3 shows the results of the color parameters of beef burgers. It was found that the reduction of the fat percentage and the addition of the orange albedo did not influence ($P > 0.05$) the luminosity (L*) of the beef burgers. However, the increase of the orange albedo flour contributed significantly ($P \leq 0.05$) to a lower intensity of redness (a*) for all formulations and an increase in yellowness (b*) for F3-75 and F4-100 treatments compared to treatment control FC. Similar results regarding both a* and b* parameters were reported in frankfurters incorporated with shaddock albedo (Shan et al., 2014). Similarly to this work, López-Vargas et al. (2014) also did not report any difference in coordinate b* in pork burgers incorporated with up to 5 % of passion fruit albedo. Other authors showed the yellowness increased in beef burgers made with lemon albedo (Aleson-Carbonell et al., 2005), and lemon fiber (Soncu et al., 2015). The whiteness (W) value, which correlates the coordinates L*, a*, and b*, did not differ between treatments. Thus, the incorporation of orange albedo flour caused a slight difference in beef burgers' color.

3.3. Sensory analysis

The sensory acceptance of beef burgers is shown in Table 3. No significant differences were found ($P > 0.05$) for all the sensory attributes in the formulations FC, F1-25, and F2-50, which received the highest scores, ranging from 7 (I liked it moderately) to 8 (I liked it a lot). The scores for color, appearance, flavor, texture, and overall liking of beef burgers lowered when fat was replaced by 75% (F3-75) and 100% (F4-100) of orange albedo flour. The dry texture due to the cooking loss (Table 3) may have contributed to the lower scores obtained for these formulations. Besides, the high levels of orange albedo flour probably led to the perception of flavors that are not characteristic of the product, such as, fruity flavor (Aleson-Carbonell et al., 2004). Similarly, Ammar (2017) reported the all sensory parameters of nuggets formulated with up to 5 % of orange albedo did not differ from the control treatment. Other works showed negative effects regarding sensory attributes when high levels of citrus fiber were adding in the meat products (Aleson-Carbonell et al., 2005; Fernández-Ginés et al., 2004; Selim et al., 2019; Soncu et al., 2015).

The purchase intention for the beef burgers (Figure 1) corroborated the sensory acceptance analysis. Formulation F1-25 showed the highest purchase intention since 91.7% of the tasters indicated that they "would certainly buy" or "would probably buy" that product (notes 4-5). The control formulation (FC) showed 80.6% of purchase intention, followed by the formulation F2-50 with 78.7%, demonstrating that the beef burgers F1-25 and F2-50 were well accepted, and if available on the market they would be purchased by the consumers. Also, the beef burger F2-50 was the claimed "source of dietary fibers", which is important for nutritional benefits. Regarding the F3-75 and F4-100 samples, 50.9% and 26.8%, respectively, of the consumers indicated that "they certainly would not buy it" or "probably would not buy it".

Figure 1. Frequency histogram of the purchase intention (1 - I certainly would not buy and 5 - I would certainly buy) of beef burgers.



Source: The authors.

The analysis of parallel factors (PARAFAC) showed homogeneity in acceptance among the participants (Figure 2) since the evaluation of the two factors allows representing graphically the individual opinion of each consumer. The distribution of the vectors (Figure 2), which represent consumers, demonstrated that the samples F1-25 (2.2% of orange albedo flour) and F2-50 (4.3% of orange albedo flour) were the most accepted for all sensory attributes and purchase intention, followed by F3-75 (6.5% orange albedo flour). On the other hand, samples FC (0% of orange albedo flour) and F4-100 (8.7% of orange albedo flour) were the least accepted. These results corroborate those obtained by the mean test, in which samples F2 and F3 had the highest averages and F5 the lowest acceptance averages (Table 3). Thus, it was observed that the addition of orange albedo flour up to 4.3% led to positive results in all sensory parameters of the beef burgers.

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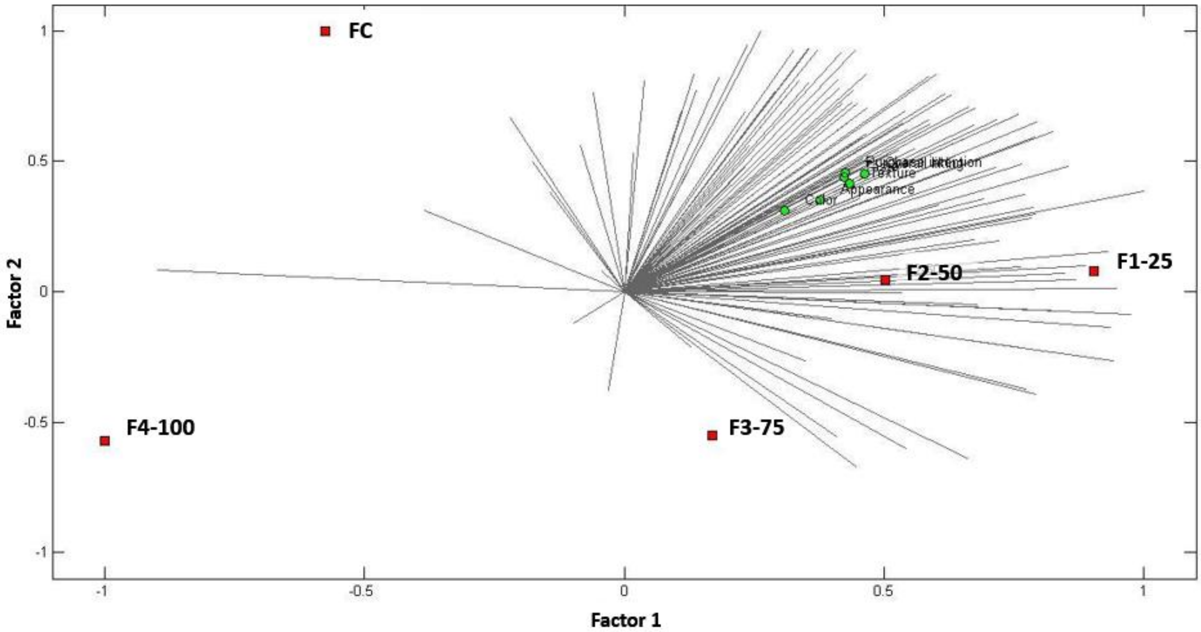
Figure 2. Three-way internal preference map for sensory acceptance parameters, and purchase intention of the beef burger formulations.



Source: The authors.

4. Final Considerations

The use of orange albedo flour as a fat substitute reduced the saturated fat and improved the dietary fibers content in beef burgers. And, its incorporation was viable up to 4.3 % with any difference from control treatment regarding the sensory acceptance and purchase intention. However, only in the formulation with 25 % of fat substitution (2.2 % of orange albedo) the cooking yield, water holding capacity, and shrinkage did not differ from the control treatment.

Considering these results, further studies should be conducted to indicate strategies that 1) minimize the pH lowering caused by the incorporation of orange albedo flour in the beef burgers, which could improve the cooking yield, texture, and sensory properties, and 2) evaluate the oxidation in the beef burgers adding with orange albedo flour that is rich in polyphenols content, which might retard the oxidation process.

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