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Preparation of chicken nuggets breaded with tropical fruit peel flours: physicochemical and sensory evaluation

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Abstract

This research aimed to evaluate the influence of tropical fruit peel flours on the breading and quality of chicken nuggets. The treatments consisted of nuggets breaded with four different flour formulations: breadcrumbs, pineapple, bacuri, and peach palm peel. The nuggets were subjected to moisture analysis, fixed mineral residue, lipids, proteins, carbohydrates, caloric value, total carotenoids, instrumental color, and sensory analysis. The breaded nugget with peach palm flour had higher lipid, protein, and carotenoid content, which were 11.21%, 17.73%, and 7.60 mg/100g, respectively. The color of the products differed, as the lightness of the nuggets breaded with breadcrumbs and peach palm peel was higher with 58.46 and 54.89. Principal component analysis showed that the most accepted nuggets formulations were those with peach palm peel flour and breadcrumbs. Pineapple, bacuri, and peach palm fruit peel flours are rich sources of carotenoids. Therefore, its use as meat breading can increase the nutritional value of chicken nuggets. Fruit peel flours can be used to prepare healthier and more nutritious meat-based products, while reducing the generation of agro-industrial residues.

Keywords: fruit residue; meat products; nutritional enrichment.

Practical Application: Fruit peels can be used as a nutritional enrichment for nuggets.

1 Introduction

According to the Food and Agriculture Organization of the United Nations (Food and Agriculture Organization of the United Nations, 2019), around 14% of food production is discarded as waste, which are sources of nutrients and have high added value, in the environment (Durán-Aranguren et al., 2021). In order to minimize waste, fruit residues such as peels can be used in the preparation of flours aiming to improve the nutritional, sensory, and technological properties of food products (Resende & Franca, 2019).

In addition, the rapid urbanization and industrialization has demanded from the market easy-to-prepare and convenient food such as chicken nuggets (Verma et al., 2013; Schuch et al., 2019), considering that consumers who have a busy routine choose to consume pre-prepared products such as *fast foods* instead of meals that require longer preparation time (Teo & Yan, 2021). In this context, the enrichment of processed meats with nutritious ingredients is an innovation in the food industry, in response to the demand for health-beneficial and easy-to-prepare products (Shan et al., 2017).

An increasing number of studies using plant-based products has been found in nuggets such as pitaya peel (Madane et al., 2020), citrus residues (Faiz et al., 2020), green banana flours and soybean peel (Kumar et al., 2013), okara, and rice bran (Echeverria et al., 2022), chia flour (Barros et al., 2018), pitaya peel (Biswas et al., 2022). These studies found a positive effect on the nutritional quality of chicken nuggets. However, the pineapple, bacuri, and peach palm peel flours have not yet been used in the preparation of nuggets, despite the nutritional potential shown by these products in several studies (Soares, 2010; Li et al., 2014; Matos et al., 2019).

Therefore, this study aimed to evaluate the effect of pineapple, bacuri and peach palm flours on the breading process and physical, chemical, microbiological, and sensory properties of chicken nuggets.

2 Material and methods

2.1 Research ethics committee

The project was approved by the Ethics Committee for Research with humans under the CAAE 07077818.9.0000.

2.2 Preparation of fruit peel flours

The fruit used in the preparation of the flours were selected for their appearance, absence of injuries, and maturation. After the selection, the pineapples, bacuris, and peach palms were transported to the laboratory where they were sanitized at 100 ppm with sodium hypochlorite for ten minutes and rinsed in tap water. The pineapples were peeled, the bacuris cut, and

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the skins subjected to heat treatment by immersion in water at 100 °C for 90 minutes to remove the resin (Carvalho et al., 2008). The peach palms were cooked at 120 °C for 20 minutes and peeled. At the end of the process, 3.78 kg, 8.35 kg, and 1.42 kg of pineapple, bacuri and peach palm were obtained, respectively.

Fruit peels were dehydrated in a forced air circulation oven: the pineapple at 65 °C for 17 hours (Damasceno et al., 2016); the bacuri at 60 °C for 12 hours (Vasconcelos et al., 2018), and the peach palm at 60 °C for 4.5 hours (Martínez-Girón et al., 2017). After drying, they were crushed in an industrial blender and standardized in a 0.25 mm sieve to obtain the flours identified as F2: pineapple peel flour (0.62 kg), F3: bacuri peel flour (0.82 kg) and F4: peach palm peel flour (0.47 kg). After the dehydration process, the yields were 20.39%; 8.41%; 30.89%, respectively for F2, F3, and F4.

2.3 Preparation of chicken nuggets

For nuggets processing, skinless and boneless chicken upper legs were weighed, crushed in a food processor and added with fine flaked oats (2.70%), sodium chloride (2.25%), dehydrated onion (1.98%) and dehydrated garlic (1.17%), to obtain a homogeneous meat mass. Then, the dough was molded into nuggets and subjected to breading in three steps. At first, the pre-breading was carried out with the fruit peel flours. After that, the nugget was dipped in the coating liquid (fresh albumen). Subsequently, they were breaded with the prepared flours. Four formulations of bread nuggets with the respective flour were developed: N1: breadcrumbs (control), N2: pineapple peel, N3: bacuri peel, and N4: peach palm peel.

2.4 Physicochemical analysis of chicken flours and nuggets

The analyses of moisture, fixed mineral residue, proteins, and lipids were carried out according to Association of Official Agricultural Chemists (2005). Carbohydrates were determined by difference, subtracting the sum of other nutrients from 100%. The caloric value was determined in accordance with the standards required by current legislation, through the Collegiate Board Resolution No. 360, of December 23, 2003 (Brasil, 2003a).

The extraction of total carotenoids was performed in the flours and nuggets, according to the methodology adapted from Talcott & Howard (1999) with absorption readings performed in a spectrophotometer at 450 nm. The instrumental color analysis was performed with a portable colorimeter CR – 410 MINOLTA model, with a 45 lb slope angle and D65 illuminant. The identified parameters were: L* (Lightness), the coordinate a* which varies from red (+a*) to green (-a*), and the coordinate b* from yellow (+b*) to blue (-b*).

2.5 Sensory analysis of chicken nuggets

The microbiological quality of nuggets was determined by analyzing *Salmonella* sp., *Staphylococcus* coagulase-positive and Coliforms thermotolerant at 45 °C according to the Compendium of Methods for the Microbiological Examination of Foods (Salfinger & Tortorello, 2015). Subsequently, the products were fried in soybean oil by immersion at 180 °C for 35 seconds (Dill et al., 2009) and analyzed by 106 untrained judges, who received 4 samples (N1, N2, N3, and N4) in coded plastic cups, along with mineral water for cleaning the palate during testing. Sensory analysis was performed in individual cabins under controlled environmental conditions, at a temperature of around 23 °C.

The evaluation form consisted of a hedonic scale anchored by the extremes "I extremely dislike it" (1) and "I extremely like it" (9) and the sensory attributes were: color, taste, texture, aroma, and global impression, according to Dutcosky (2013). Acceptability indices were determined by the average of the grades of each sensory attribute divided by the maximum grade and multiplied by 100% (Lima et al., 2021).

2.6 Statistical analysis

The results were subjected to the analysis of variance (ANOVA). The means were compared by the tukey, at a 5% significance level, using the ExpDes.pt package of the RStudio software (version 4.0.2). The acceptance scores were evaluated by the internal preference map technique, where they were organized in a matrix of products (rows) and judges (columns), and subjected to Principal Components Analysis - PCA. The unsupervised PCA method is used for exploratory multivariate analysis of large amounts of data. This statistical tool decreases the dimensionality of the data, resulting in linear combinations of the original independent variables (Teixeira et al., 2020). This method was performed to assess the distributions of the samples according to the acceptance of the judges and verify the formation of groups within the sample set. The procedure was performed for each sensory attribute separately (color, taste, texture, aroma, and general impression), and five preference maps were obtained. The acceptance results were expressed in dispersion graphs of the formulations and correlation of the data of each judge with the first and second main components.

3 Results and discussion

3.1 Physicochemical characteristics of the flours

The chemical variables differed ($p < 0.05$) among the flours (Table 1). Moisture is within the parameters recommended by Brasil (2005), which sets a maximum value of 15% and varied among the samples due to the different moisture content of the fruits used in this study. The low moisture content allows for a longer food shelf life, as it reduces chemical and biochemical reactions and minimizes the proliferation of unwanted microorganisms (Ferreira et al., 2015).

The fixed mineral residue varied ($p < 0.05$) due to the different concentrations of minerals present in the fruit peels. The same result was confirmed by Basto et al. (2016) who observed a higher value of fixed mineral residue in the peel compared to the peach palm pulp. Thus, pineapple peel and bacuri have calcium, iron, sodium, magnesium, zinc, and potassium in their composition (Gondim et al., 2005; Soares, 2010). On the other hand, the mineral profile of peach palm peel has not yet been elucidated. According to our findings in the present study and those available in the literature, the complete utilization of the peel, seeds, and fruit leaves results in the intake of minerals that are essential for the maintenance of human health (Gondim et al., 2005).

The lipid content of peach palm peel flour was higher ($p < 0.05$) because this fruit is oleaginous. Nonetheless, these lipids

Table 1. Physicochemical characteristics of breadcrumbs in chicken nuggets.

Parameter	F1	F2	F3	F4	P-value
Moisture (%)	3.06 ± 0.18[c]	5.17 ± 0.01[b]	5.07 ± 0.05[b]	6.39 ± 0.10[a]	<0.001
Fixed mineral residue (%)	3.93 ± 0.02[a]	3.87 ± 0.03[a]	2.17 ± 0.02[c]	2.61 ± 0.02[b]	<0.001
Lipids (%)	2.16 ± 0.01[b]	1.32 ± 0.21[b]	3.50 ± 0.02[b]	20.68 ± 0.02[a]	<0.001
Proteins (%)	6.59 ± 0.32[a]	4.04 ± 0.01[b]	1.60 ± 0.41[c]	6.11 ± 0.16[a]	<0.001
Carbohydrates (%)	84.26 ± 0.52[c]	85.6 ± 1.15[b]	87.66 ± 0.35[a]	64.21 ± 2.65[d]	<0.001
Calories (kcal/100 g)	382.45[b]	370.17[c]	387.87[b]	467.31[a]	<0.001
Carotenoids (mg/100 g)	1.33 ± 0.88[d]	10.67 ± 0.75[c]	19.77 ± 0.54[b]	35.81 ± 0.05[a]	<0.001
Lightness (L^*)	54.74 ± 0.56[a]	45.64 ± 0.71[c]	49.01 ± 0.86[b]	48.19 ± 0.47[bc]	<0.001
Redness/greenness (a^*)	3.58 ± 0.05[c]	3.56 ± 0.19[c]	7.30 ± 0.34[b]	15.22 ± 0.26[a]	<0.001
Yellowness/blueness (b^*)	12.07 ± 0.84[c]	25.27 ± 0.30[b]	27.14 ± 0.74[b]	59.75 ± 0.67[a]	<0.001

Means and standard deviation within rows followed by different letters differ significantly at p < 0.05 by tukey test. F1: breadcrumbs (control), F2: pineapple peel flour, F3: bacuri peel flour, and F4: peach palm peel flour.

are beneficial to health, as they are composed of unsaturated fatty acids (Bezerra & Silva, 2016; Neri-Numa et al., 2018). The protein content of F2, F3, and F4 differed ($p < 0.05$), and the peach palm flour showed a higher protein content of 6.11%. According to the Collegiate Board Resolution No. 54, November 12 (Brasil, 2012), food products with at least 6% protein are classified as a protein food. Therefore, peach palm flour may be an alternative source for enriching meat products.

Carbohydrate content showed a difference ($p < 0.05$) among the flours. The higher values were obtained for F3 and F2, due to the fact that these flours have greater amounts of sugar and fiber. Fibers are important nutrients for health, and technological functions such as gelling and thickening of food (O'Shea et al., 2012).

The calories of the peach palm peel flour differed ($p < 0.05$) due to the higher lipid content of 20.68 kcal/100 g. This value is similar to that found by Rojas-Garbanzo et al. (2012), which was 405.88 kcal/100 g.

The total carotenoid content of pineapple, bacuri, and peach palm influenced ($p < 0.05$) the color intensity of the flours, which resulted in higher values compared to breadcrumbs. Such results are attributed to the natural pigments in the peel flours. The most common fruit residues include bagasse, peel, and seeds. These are rich in bioactive compounds such as carotenoids.

Thus, the bioactive compounds may also have interfered with the color variables, since differences ($p < 0.05$) were obtained for lightness, coordinate a* and b* of the flours. The lightness value of the breadcrumbs differed, since the fruit residue flours had a darker tone due to the natural pigments and the degree of maturation of each fruit. The bacuri and peach palm peel flours differed from the others in terms of the coordinate a* (red/green), since they tended to have a red color, with higher value for the peach palm peel flour. The coordinate b* (yellow/blue) differed between F1 and F4. We identified that the peach palm peel flour had greater intensity for yellow shades, followed by F2 and F3.

3.2 Physicochemical characteristics of nuggets

The parameters assessed showed a difference ($p < 0.05$), except for moisture (Table 2). The difference between the fixed mineral residue is due to the proportion of this component in the flours used in the breading, which influenced the product composition. Similar results (2.11 to 3.29%) were found by Echeverria et al. (2022) in nugget formulations added with okara and rice bran.

The lipid content of peach palm flour of 20.68% was higher than the others, and contributed to the highest value of lipids in N4. Restrepo et al. (2016) reported that peach palm has a lipid profile with 62.43% of unsaturated fatty acids such as oleic, linoleic, and linolenic acid that contribute to disease prevention.

The protein content in N1 and N4 showed a difference ($p < 0.05$) and were higher due to the protein composition of the flours used in the breading process. These values were similar to the means observed by Jayanthi et al. (2017), who obtained a protein content of 17.45% in chicken nuggets added with guava powder. All nuggets are within the standards recommended by Brasil (2001), which establishes a minimum value of 10% of protein in breaded products.

The carbohydrates content in N2 and N3 differed ($p < 0.05$) from the other products due to the nutritional fiber composition of the flours. Pineapple processing generates by-products with high dietary fiber content that have technological functions such as water retention capacity, viscosity enhancement or gel formation, in addition to acting as prebiotic substances (Campos et al., 2020). According to Valença et al. (2008), bacuri peel flour is also rich in fiber and can be an alternative for enriching food products.

The caloric value of N4 differed from N3 ($p < 0.05$), due to the higher lipid and protein content of peach palm flour. Albuquerque et al. (2016), when checking the nutritional tables of commercial nuggets packaging, the authors found caloric values ranging from 204 to 261 kcal/100 g, which are higher than that obtained in this study. High-calorie diets composed of saturated lipids and simple sugars can lead to the emergence of non-communicable chronic diseases. Thus, encouraging the consumption of less caloric meat products and with ingredients with nutritional properties has been the focus in the discussion about healthy eating (Allan et al., 2019; López-Lluch & Navas, 2020).

The carotenoid content in the nuggets differed among the treatments ($p < 0.05$). The N4 treatment showed the higher content due to the higher level of this compound in F4, which

Table 2. Physicochemical composition of breaded nuggets with breadcrumbs and fruit peel flours.

Parameter	N1	N2	N3	N4	P-value
Moisture (%)	62.62 ± 0.19[a]	61.51 ± 0.08[a]	63.10 ± 0.64[a]	63.64 ± 0.09[a]	0.168
Fixed mineral residue (%)	2.31 ± 0.10[a]	2.33 ± 0.18[a]	1.91 ± 0.09[b]	1.90 ± 0.05[b]	0.002
Lipids (%)	8.44 ± 0.00[b]	8.43 ± 0.00[b]	7.53 ± 0.00[b]	11.21 ± 0.01[a]	0.001
Proteins (%)	18.60 ± 0.20[a]	15.23 ± 0.94[b]	13.46 ± 0.17[b]	17.73 ± 0.13[a]	0.001
Carbohydrates (%)	8.03 ± 0.10[c]	12.50 ± 0.76[b]	14.00 ± 0.62[a]	5.52 ± 0.70[d]	0.001
Calories (kcal/100 g)	182.25[ab]	186.52[ab]	177.52[b]	193.00[a]	0.041
Carotenoids (mg/100 g)	0.20 ± 0.01[d]	0.73 ± 0.16[c]	2.10 ± 0.84[b]	7.60 ± 0.24[a]	0.001
Lightness (L^*)	58.46 ± 0.72[a]	41.96 ± 0.58[d]	47.95 ± 0.7[c]	54.89 ± 0.69[b]	<0.001
Redness/greenness (a^*)	3.23 ± 0.05[c]	2.59 ± 0.07[d]	5.63 ± 0.07[b]	14.18 ± 0.84[a]	<0.001
Yellowness/blueness (b^*)	19.63 ± 0.44[c]	23.41 ± 0.47[b]	23.64 ± 0.30[b]	48.28 ± 0.44[a]	<0.001

Means and standard deviation within rows followed by different letters differ significantly at $p < 0.05$ by tukey test. N1: breadcrumbs (control), N2: pineapple peel, N3: bacuri peel, and N4: peach palm peel.

allowed its use in food preparations as a natural and functional colorant, considering that the antioxidant and color characteristics led by carotenoids can act as an alternative to reduce the use of antioxidants and synthetic color additives in meat-based products (Bolognesi & Garcia, 2018; Khalid et al., 2019). In addition, carotenoids are the precursors in the biosynthesis of vitamin A, an essential micronutrient for immune responses, as well as in the prevention of cataracts and macular degeneration (Eggersdorfer & Wyss, 2018; Hermanns et al., 2020).

The lightness values differed ($p < 0.05$) among the treatments due to the amount of pigment in the breading flours. The N4 differed ($p < 0.05$) in a* and b* coordinates, which tended to be red and yellow. According to Martins et al. (2016), the bioactive compounds responsible for the fruit color can make the color of food products more attractive, in addition to contributing to health.

3.3 Internal preference map

The relevance of chemometric analyses is due to the easier interpreting of extensive and complex data sets by enabling the extraction of information from multivariate data (Milani et al., 2020). The PCA provides the visualization of patterns in the samples, which allows the spatial separation of the nuggets according to the acceptance of the judges.

Thus, Figure 1 shows the internal preference maps obtained for the acceptance data of nuggets formulations. The points in the graphs represent correlations between the acceptance data of a judge and the first two main components. According to Minim (2018), the sum of the first two main components should be at least 70% in order to express the relationship of a product acceptance data.

For the color attribute, the first main component elucidated 69.26% and the second component 16.90% of the responses' variability, totaling 86.16% of the variation in acceptance among formulations. The spatial separation of the samples indicates the existence of three groups, the first composed of the formulations N1 and N4, which suggests higher acceptance for these samples for the color attribute. The formulation N3 represented the second group, while the last group is composed of the nuggets breaded with pineapple peel flour. The acceptance of formulations N1 and N4 is attributed to higher lightness of the samples and higher shades of yellow and red for the formulation N4 (according to colorimetric parameters in Table 2), resulting from the carotenoid content of peach palm peel flour (Table 1).

In the taste evaluation, the first and second major components explained 83.20% of acceptance variability among formulations. The spatial separation of the samples shows the formation of three groups, one group formed by N1 and N4, and the other groups by the formulations N2 and N3. Such results indicated that the samples N1 and N4 were the most accepted. Therefore, breadcrumbs and peach palm peel flour were the most accepted for chicken nuggets breading, regarding the taste attribute. On the other hand, the bacuri and pineapple peel flours probably showed low acceptance due to the bittersweet taste provided by the acidity of bacuri, and sweetness of pineapple.

The first main component explains 53.80% of the variability of the data and the second 25.80%, both with 79.60% of the variation existing between samples of nuggets for texture (Figure 2). The spatial separation indicated the formation of three distinct groups. One group composed by the formulations N1 and N4, and the others composed by the samples N2 and N3. The higher concentration of the judges near the N1 and N4 samples can be explained by the higher levels of lipid and protein content of nuggets breaded with breadcrumbs and peach palm peel flour (Table 1).

Regarding the aroma, a spatial separation of three groups was observed. The highest acceptance was noted for the first group, formed by the samples N1 and N4, while N2 and N3 correspond to the second and third group. The N2 and N3 samples have a remarkable aroma attributed to the presence of pulp volatile compounds, which probably interfered with a lower acceptance of pineapple and bacuri peel flours in the nuggets Bacuri pulp has a volatile composition in terpenes and non-terpenic alcohols (Uekane et al., 2017) and in pineapple methyl butanoate, methyl 2-methylbutanoate and methyl hexanoate are predominant (Montero-Calderón et al., 2010). The formation of a group with N4 and N1 indicates that peach palm peel flour can be an alternative breading of nuggets, without

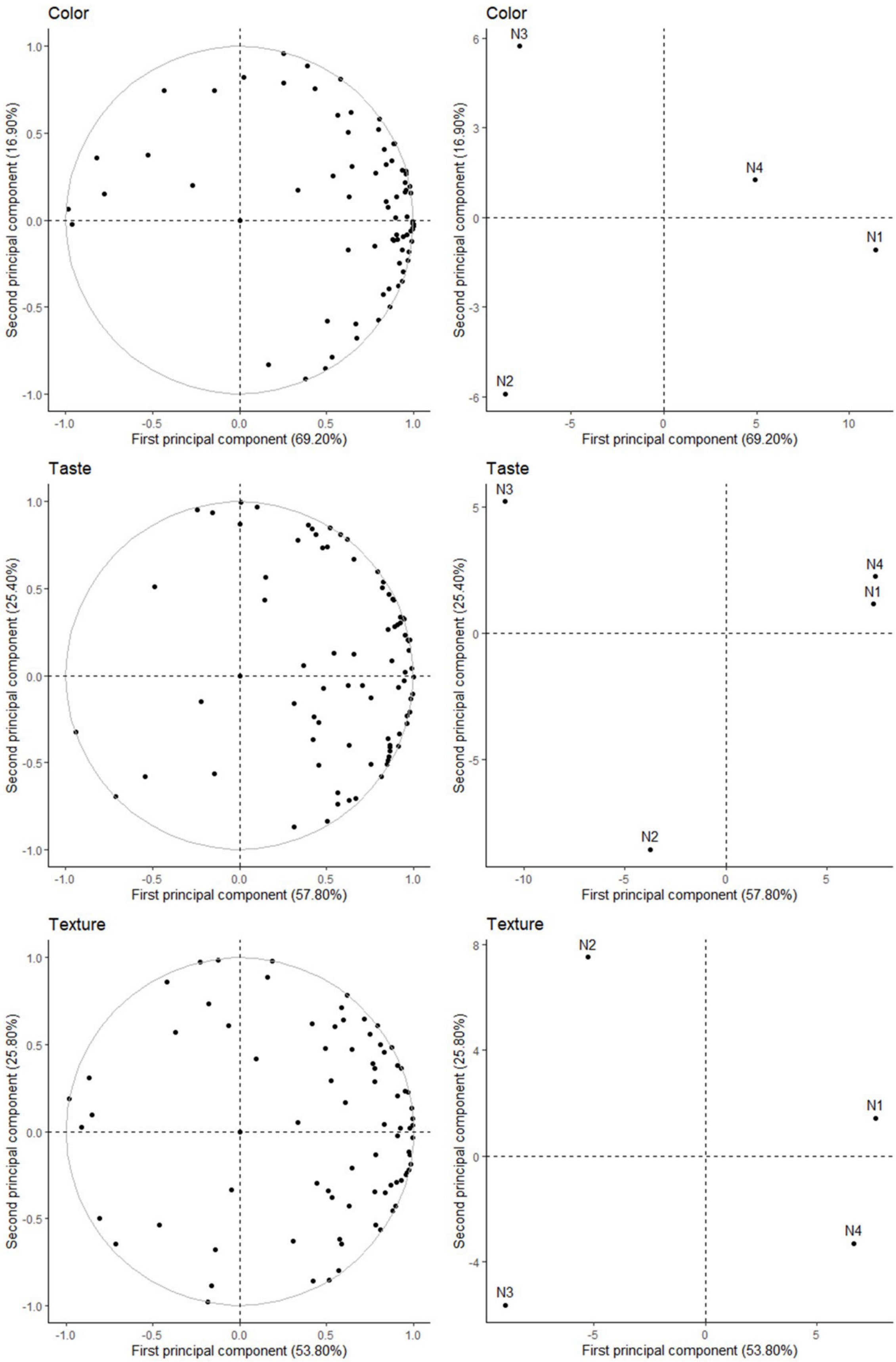

Figure 1. Graphic representation of judges and nuggets formulations for color, taste, and texture attributes (●) judges; N1: breadcrumbs (control), N2: pineapple peel, N3: bacuri peel, and N4: peach palm peel.

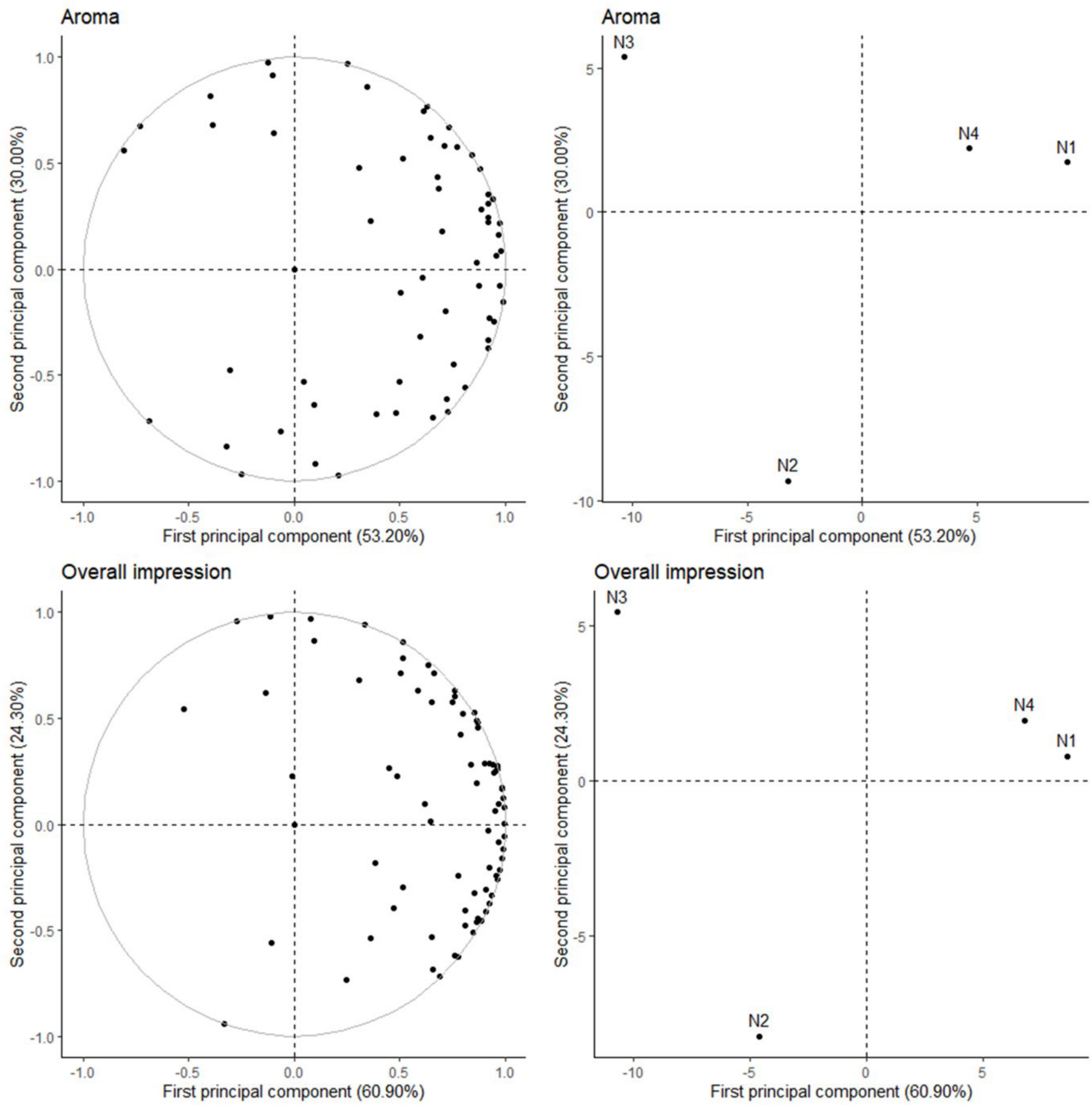

Figure 2. Graphic representation of judges and nuggets formulations for aroma and overall impression attributes. (●) judges; N1: breadcrumbs (control), N2: pineapple peel, N3: bacuri peel, and N4: peach palm peel.

aroma loss compared to the control formulation. The first main component explained 53.20% of the data variability, while the second component explained 30.0%, totaling 83.20% of the variation among formulations.

For the overall impression, the first and second major components explain 85.20% of the variability of the results. For this attribute, three distinct groups of judges were observed. The first group consists of the formulations N1 and N4. The second has the formulations N2, and the third the formulation N4. The attribute that showed greater similarity in spatial distribution compared to the global impression graph was the aroma attribute, that is, the aroma was the attribute that determined the acceptance of nuggets. According to the internal preference maps, the most accepted nuggets in all sensory attributes were N1 and N4, which can be confirmed by the acceptability index of nuggets, shown in Figure 3.

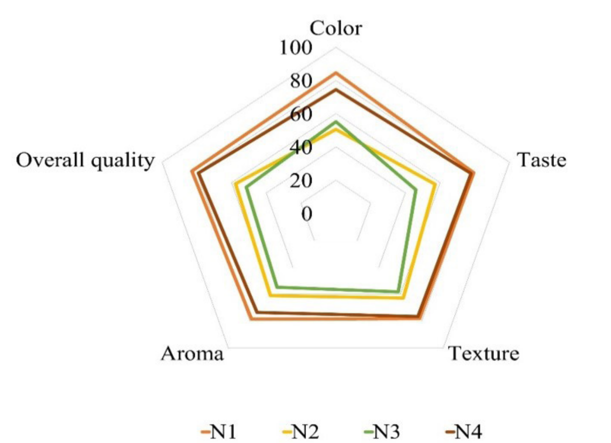

Figure 3. Acceptability parameters of chicken nuggets breaded with breadcrumbs and tropical fruit peels. N1: breadcrumbs (control), N2: pineapple peel, N3: bacuri peel, and N4: peach palm peel.

4 Conclusion

Pineapple, bacuri, and peach palm peel flours are an alternative source of total carotenoids, and may be used in the breading of chicken nuggets as a replacement of breadcrumbs, and also adding nutritional and sensory value to the product. Also, the application of fruit peels in the production of flour contributes to the reduction of waste generated after its processing and in the production of healthier meat-based products.

Conflict of interest

The authors have no conflicts of interest to declare.

Author contributions

All authors have contributed equally to the conception and writing of the manuscript. All authors critically reviewed the manuscript and approved the final version.

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