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Effect of adding *Theobroma grandiflorum* and *Hylocereus polyrhizus* pulps on the nutritional value and sensory characteristics of bread

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Abstract

This research aimed to evaluate the influence of adding cupuassu (*Theobroma grandiflorum*) and pitaya (*Hylocereus polyrhizus*) pulps on the physicochemical and sensory properties of milk bread. We prepared four formulations: control (no fruit added), and three formulations where milk was partially replaced for different proportions of pulps. The following percentages were used: cupuassu pulp (32.37 to 41.61%), pitaya pulp (4.62 to 13.87%), and milk (5.60 to 31.52%). The nutritional composition, instrumental color analysis, and acceptability of the bread were assessed. The addition of fruit pulp into the bread reduced up to 41.44% the lipid content, 40.20% of proteins, and 10.27% of caloric value. The colorimetric analysis showed that the increase in pitaya pulp and decrease in cupuassu pulp reduced the lightness (L^*) and the coordinate b^*, and increased the coordinate a^*. The principal components analysis showed that the most accepted bread formulations were those with 18.14% and 20.74% cupuassu pulp, and 7.78% and 5.18% pitaya pulp. Thus, cupuassu and pitaya pulp can be added into bread formulations as alternative to add nutritional value and contribute to the innovation of bakery products.

Keywords: bakery products; nutritional quality; sensory analysis.

Practical Application: Cupuassu and pitaya pulps can act on nutritional enrichment of bread.

1 Introduction

Bread is an important part of the daily diet, since it carries complex sugars, as well as being essential to provide energy (Olagunju et al., 2021). The development of food with functional claims of positive impact on consumer health is a trend in the food industry. The primary sources of ingredients used to obtain functional bakery products are: cereals, legumes, fruits and vegetables, probiotics and prebiotics (Mitelut et al., 2021; Reque & Brandelli, 2021). Thus, fruits can be used to enrich bakery products as they are a source of antioxidants, prebiotic fibers, and polyphenols (Fernandez & Marette, 2017; Bolha et al., 2020), as well as minerals and vitamins that benefit the body functioning and disease prevention.

Cupuassu (*Theobroma grandiflorum* Schum) is considered one of the most appreciated fruit by the Amazonian market and presents high economic, nutritional, and sensory potential (Barros et al., 2016). The pulp presents a yellowish-white color with intense flavor thanks to volatile compounds such as esters, providing good acceptability by local communities and international markets (Pereira et al., 2018; Costa et al., 2019). Moreover, the pulp contains antioxidant polyphenols, such as flavones, flavan-3-ols, and proanthocyanidins, which are important antioxidants associated with health (Yang et al., 2003; Pugliese et al., 2013).

Pitaya is a fruit present in tropical and subtropical regions, known for its exotic appearance, pleasant taste, high nutritional value (Fan et al., 2018; Hu et al., 2019), and also the antioxidant content (Hua et al., 2018), which act as inhibitors of oxidative processes in human metabolism and in the protection and conservation of food (Cömert & Gökmen, 2018). Pitaya can be classified according to peel and pulp appearances in the following species: *Hylocereus polyrhizus* (red pulp/red peel), *Hylocereus undatus* (white pulp/red peel), and *Hylocereus megalanthus* (white pulp/yellow peel) (Bellec et al., 2006; Jiang et al., 2021).

Thus, the addition of fruit pulp can contribute to the nutritional and sensory characteristics of bread. Moreover, they are little used in the nutritional enrichment of bakery products, which can provide another product option that meets the consumer demands for food products with beneficial effects on the body, benefiting the health and well-being. Therefore, this research aimed to study the nutritional and sensory properties of milk bread made with different proportions of cupuassu and pitaya pulps.

2 Material and methods

2.1 Material

Cupuassu (1.0 kg) and pitaya (0.5 kg) were obtained in Castanhal, Pará, Brazil (1°17'31.3"S 47°55'25.4"W). The fruits

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were collected in January 2019 and transported to the State University of Pará (Castanhal, Pará, Brazil). They were sanitized with sodium hypochlorite (100 mg L^{-1} for 5 min), pulped, frozen at -18 °C, and stored until the products were prepared.

2.2 Bread making

We prepared three formulations where the milk was partially replaced for different quantities of cupuassu and pitaya pulps, and the control (no fruit added) as shown in Table 1.

The ingredients were weighed and mixed until a homogeneous dough was obtained, kneaded manually, and allowed to rest for 30 min at room temperature of 25 °C. At the end of this period, the dough was manually molded in spherical shape (6 g) and remained at rest for 1 h at room temperature of 25 °C, and baked in an electric oven at 150 °C for 40 min. The bread was cooled for 20 min at room temperature (25 °C) and packed in polyethylene bags.

2.3 Physicochemical analysis

Moisture, ash, protein, and lipid analyses were performed for both pulps and bread, according to the Association of Official Analytical Chemists (2005), and carbohydrates were determined by difference, subtracting from 100% the sum of the other nutrients. The caloric value was assessed according to the standards required by the current legislation through the Resolution of Collegiate Board of Directors No. 360 of December 23, 2003 (Brasil, 2003).

Minolta portable colorimeter model CR - 410 was used for the instrumental color analysis of bread, with an angle inclination of 45° and illuminant D65, which corresponds to noon illumination. The analysis resulted in the following parameters: L^* (lightness) and coordinate a^*, ranging from red ($+a^*$) to green ($-a^*$), and the coordinate b^*, ranging from yellow ($+b^*$) to blue ($-b^*$).

2.4 Ethical disclosures

This study was approved by the Ethics Committee in Human Research of the State University of Pará (Protocol No. CAAE 12939019.3.0000.8607).

2.5 Sensory evaluation

The products were evaluated by 100 untrained judges, who received 4 samples (P, A, B, and C) in plastic cups encoded with random three-digit numbers, along with mineral water, and a form composed of a structured hedonic scale ranging from "I disliked extremely" (1) to "I liked extremely" (9). The participants were asked to rinse their palate before the first sample and between samples for sensory recovery. The attributes evaluated were: color, taste, texture, aroma, and overall impression according to the methodology described by Dutcosky (2013). Acceptance index was determined by the mean of the grades of each sensorial attribute divided by the maximum grade, and multiplied by 100% (Lima et al., 2021).

2.6 Statistical analysis

The data were submitted to variance analysis and the means were compared with each other by the t-test, at the level of 5% significance, using the ExpDes.pt of RStudio software (version 4.0.2). The acceptance scores were evaluated by the internal preference mapping technique, where they were organized into a matrix of products (in rows) and judges (in columns), and submitted to the principal component analysis - PCA. The unsupervised method of PCA 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 observe the distribution 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 overall 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 two principal components.

3 Results and discussion

3.1 Physicochemical analysis

The significant increase in the moisture content compared to the standard sample ($p < 0.05$) is likely related to the inner

Table 1. Bread formulations with the addition of cupuassu and pitaya pulps, and the control.

Ingredients	Percentage (%)			
	P	A	B	C
Wheat flour	52.53	52.53	52.53	52.53
Cupuassu pulp	---	18.14	20.74	23.33
Pitaya pulp	---	7.78	5.18	2.59
Sugar	8.06	8.06	8.06	8.06
Milk	31.52	5.60	5.60	5.60
Vegetable oil	3.50	3.50	3.50	3.50
Egg	3.50	3.50	3.50	3.50
Fresh yeast	0.70	0.70	0.70	0.70
Dough conditioner	0.16	0.16	0.16	0.16
Sodium chloride	0.03	0.03	0.03	0.03

Bread: P (no pulp and 31.52% milk). A (18.14% cupuassu, 7.78% pitaya, and 5.60% milk). B (20.74% cupuassu, 5.18% pitaya, and 5.60% milk). C (23.33% cupuassu, 2.59% pitaya, and 5.60% milk).

moisture content of the pulps (cupuassu: 83.55%; pitaya: 87.12%; Table 2) which replaced the milk containing 87% of moisture (Cortez et al., 2022). The physicochemical properties of bread are presented in Table 3. According to Aleixandre et al. (2021), the water content interferes with the hydration of gluten, which may affect the final consistency of the dough (texture), considering that low moisture content leads to hardness and resistance to cutting as a result of low elasticity. Therefore, the moisture of the pulp-added bread did not affect the bread texture, according to the sensory analysis, Figure 1 (C1 and C2). The formulations meet the parameters recommended by Brasil (2000), which establishes maximum moisture of 38% for bread exclusively prepared with all-purpose wheat flour or bread flour.

Ash values differed significantly ($p < 0.05$) and decreased with the addition of pulp due to the lower mineral content of cupuassu and pitaya compared to milk. Despite the reduction in mineral content, the fruits used in the formulations are sources of fiber and bioactive compounds, according to Pereira et al. (2018) and Lima et al. (2020).

Lipid values showed significant differences ($p < 0.05$) compared to the control. We observed up to 41.44% reduction in lipid content. These lower values may be a consequence of both cupuassu and pitaya are not sources of lipids and the decreased milk content in the formulations. According to Manickavasagan & Al-Sabahi (2014), Mente et al. (2017) and Belc et al. (2019), the reduction of saturated fat content is an alternative to food reformulation, aiming to develop healthier products that could prevent cardiovascular diseases by reducing the Low Density Lipoproteins (LDL) concentration (Manickavasagan & Al-Sabahi, 2014; Mente et al., 2017; Belc et al., 2019).

Table 2. Physicochemical composition of cupuassu and pitaya pulps.

Analyzes	Cupuassu pulp	Pitaya pulp
Moisture (%)	83.55 ± 0.95	87.12 ± 0.86
Ash (%)	1.91 ± 0.01	0.53 ± 0.02
Lipids (%)	5.78 ± 0.90	5.80 ± 0.85
Protein (%)	1.94 ± 0.05	1.45 ± 0.29
Carbohydrates (%)	6.82 ± 0.59	5.10 ± 0.12
Caloric value (kcal/100 g)	87.15 ± 0.40	78.40 ± 0.64

The protein content decreased 40.20% ($p < 0.05$) in the pulp-added formulations as a result of reduction in milk content in the formulation. The addition of cupuassu and pitaya pulps reduced the bread caloric value up to 10.27%, differing significantly from the control ($p < 0.05$) which presented 356.60 kg/100 g. The caloric value of food products directly depends on the type and amount of the raw material used, and the ratio of nutrients. Therefore, the addition of pitaya and cupuassu pulp contributes to a wider offer of less caloric bakery products. According to Jiang et al. (2021), the consumption of low-calorie products may assist in the maintenance of body weight.

Due to the red-purple color of pitaya pulp, the color parameters showed a difference ($p < 0.05$) attributed to betalains. The application of betalains has been highlighted as an alternative to synthetic colorants. Furthermore, thanks to the free radical scavenging activity of these pigments, the consumption of betalains-enriched food is associated with health benefits such as antioxidant and anticancer activity (Coy-Barrera, 2020; Fernández-López et al., 2020; Madadi et al., 2020). The addition of pitaya pulp and decrease in cupuassu pulp led to reduced lightness (L^*) values and coordinate b^*, as well as the increase in the coordinate a^* compared with the standard formulation.

3.2 Internal preference map

Chemometric analyses are important since they allow the analysis of large and complex datasets while allowing the extraction of information from multivariate data (Milani et al., 2020). The PCA permits the visualization of patterns in the samples, which allowed the separation of the bread formulations according to the judges' acceptance.

Figure 1 shows the internal preference maps obtained for the acceptance data of bread formulations, in which the rhombus in the graphs represent correlations between the acceptance of a judge data and the first two principal components. According to Minim (2018), when expressing the relationship of product acceptance data, the sum of the first two principal components must surpass 70%.

For the color attribute, the first principal component explained 54.36% and the second component 25.52% of the variability of the responses, totaling 79.88% of the acceptance

Table 3. Physicochemical composition of cupuassu and pitaya breads, and the control.

Analyzes	Formulations				
	P	A	B	C	P-value
Moisture (%)	15.35 ± 0.29[d]	21.18 ± 0.19[b]	20.25 ± 0.34[c]	23.63 ± 0.16[a]	< 0.001
Ash (%)	1.13 ± 0.00[a]	0.95 ± 0.00[b]	0.95 ± 0.00[bc]	0.90 ± 0.00[c]	< 0.001
Lipids (%)	10.69 ± 0.01[a]	6.26 ± 0.00[c]	7.26 ± 0.00[b]	7.60 ± 0.00[b]	< 0.001
Protein (%)	9.90 ± 0.54[a-]	7.96 ± 0.26[b]	6.55 ± 0.26[c]	5.92 ± 0.26[c]	< 0.001
Carbohydrates (%)	62.93 ± 0.83[a]	63.66 ± 0.44[a]	64.99 ± 0.42[a]	61.94 ± 0.35[a]	0.107
Caloric value (kcal/100 g)	356.60 ± 0.47[a]	319.43 ± 0.04[d]	331.96 ± 0.49[b]	323.49 ± 0.07[c]	< 0.001
Lightness	54.74 ± 1.56[a]	27.10 ± 0.34[d]	37.16 ± 0.18[c]	39.14 ± 0.93[b]	< 0.001
Coordinate a^*	3.59 ± 0.06[d]	12.19 ± 0.20[a]	10.41 ± 0.56[b]	9.24 ± 1.04[c]	< 0.001
Coordinate b^*	12.07 ± 1.58[a]	10.30 ± 0.29[b]	9.15 ± 0.22[b]	9.04 ± 0.50[b]	< 0.001

Bread: P (no pulp and 31.52% milk), A (18.14% cupuassu, 7.78% pitaya, and 5.60% milk), B (20.74% cupuassu, 5.18% pitaya, and 5.60% milk), C (23.33% cupuassu, 2.59% pitaya, and 5.60% milk). Means followed by the same letters, in the same line, did not differ from each other by the t-test ($p < 0.05$) of probability.

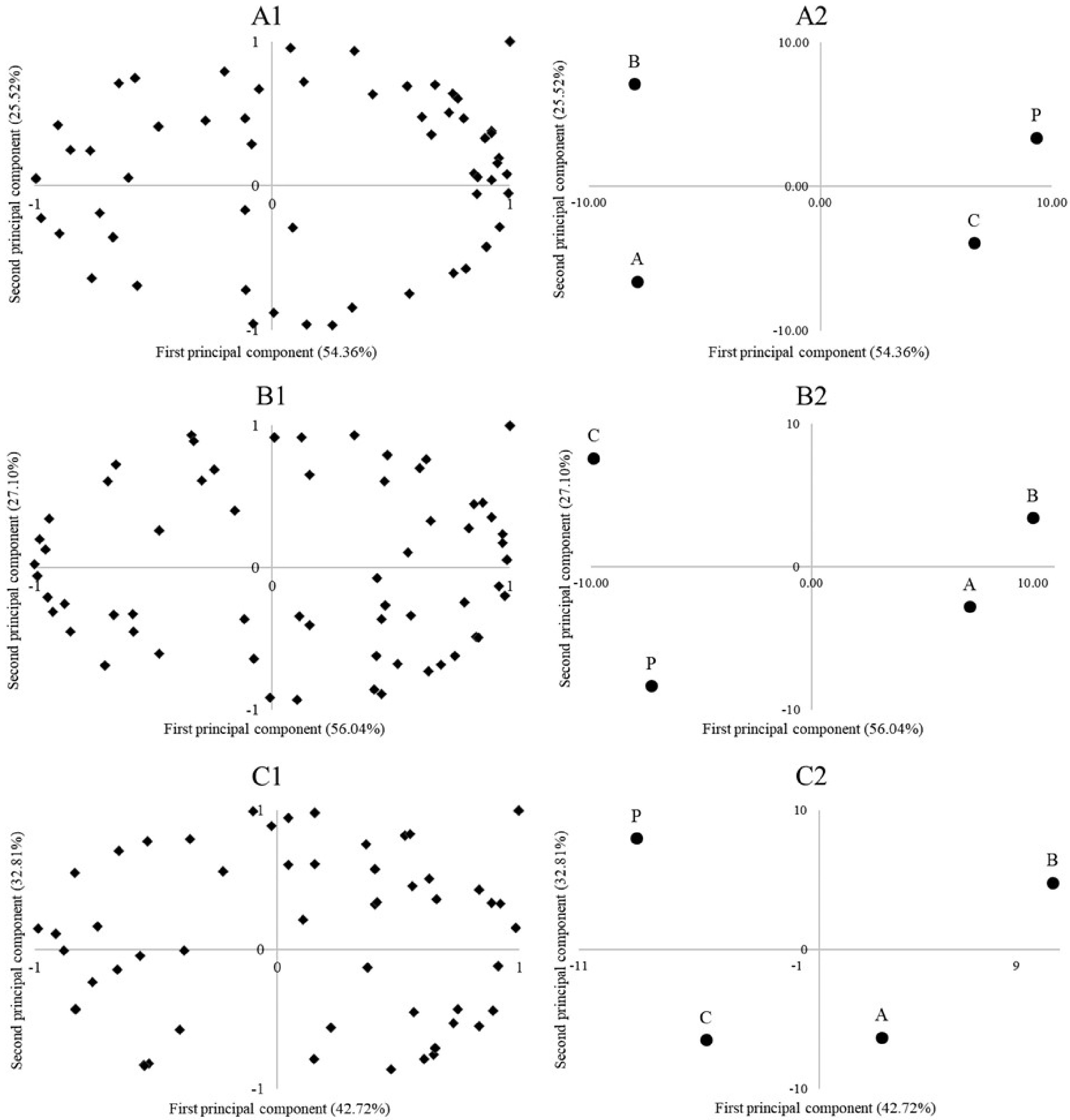

Figure 1. Graphic representation of judges and formulations for the attributes of color, taste, and texture. (♦) judges. A1 and A2: color, B1 and B2: taste, C1 and C2: texture. Bread: P (no pulp-added and 31.52% milk), A (18.14% cupuassu, 7.78% pitaya, and 5.60% milk), B (20.74% cupuassu, 5.18% pitaya, and 5.60% milk), C (23.33% cupuassu, 2.59% pitaya, and 5.60% milk).

variation between the formulations. The spatial separation of the samples indicates the existence of three groups, Figure 1A2. The first group comprises the formulations P (no pulp-added bread) and C (23.33% cupuassu and 2.59% pitaya), suggesting that the judges did not differentiate these formulations in relation to the color attribute. Formulation B with 20.74% cupuassu and 5.18% pitaya represented the second group. The last group was formed by 14% cupuassu and 7.78% of pitaya. The acceptance of the formulations P and C is attributed to the decreased pitaya pulp content, which resulted in visually attractive samples. Thus, the bread acceptance is related to higher bread Lightness (P: 54.74 e C: 39.14), as shown in Table 3.

In the evaluation of taste, the first and second principal components explain 83.14% of the acceptance variation between the formulations. The spatial separation of the samples formed three groups, Figure 1B2. A group formed by A (18.14% cupuassu and 7.78% pitaya) and B (20.74% cupuassu and 5.18% pitaya), and the others by the formulations C and P. These results indicated that samples A and B were the most accepted. Thus, the results suggest that formulations with lower concentrations of cupuassu pulp positively influenced the acceptance of bread. It is important to emphasize that the differences in bread composition (Table 3) did not interfere with taste perception, which is likely due to the untrained judges in the evaluation.

Regarding the texture, we observed four groups that dispersed in all, Figure 1C2, admitting that the judges did not detect a difference for this attribute among the formulations, although the significant difference in moisture content of the formulations (Table 3). This indicates that the addition of the pulp into the bread did not negatively interfere with the acceptance compared to the standard sample. The first principal component explained 42.72% of the data variability while the second component explained 32.81%, totaling 75.53% of the variation among the formulations.

The first principal component of the aroma explained 46.70% of the data variability and the second 30.61%, both with 77.31% of the variation between bread samples. When the aroma was analyzed, the spatial separation indicated the formation of three distinct groups, one group formed by formulations A and B, and the other formed by samples C and P, Figura 2D2. The higher concentration of the judges near samples A and B can be explained by the concentration of cupuassu pulp that presents an intense aroma. This intense aroma is attributed to volatile compounds in the pulp, such as ethyl butanoate, ethyl hexanoate, and linalool (Quijano & Pino, 2007).

For the overall impression, the first and second principal components explained 82.08% of the variability of the results. This attribute formed three distinct groups of judges, Figure 2E2. The first group comprises formulations A and B; the second group, formulation C; and the third group, formulation P. The results show that the highest concentration of judges is close to the formulations with the lower concentration of cupuassu, indicating this was a decisive proportion in the acceptance of bread samples.

According to the internal preference maps and acceptance index (Figure 3), the most accepted bread in most attributes (taste, aroma, and overall impression) were A and B, corresponding to those with the lowest concentrations of cupuassu pulp.

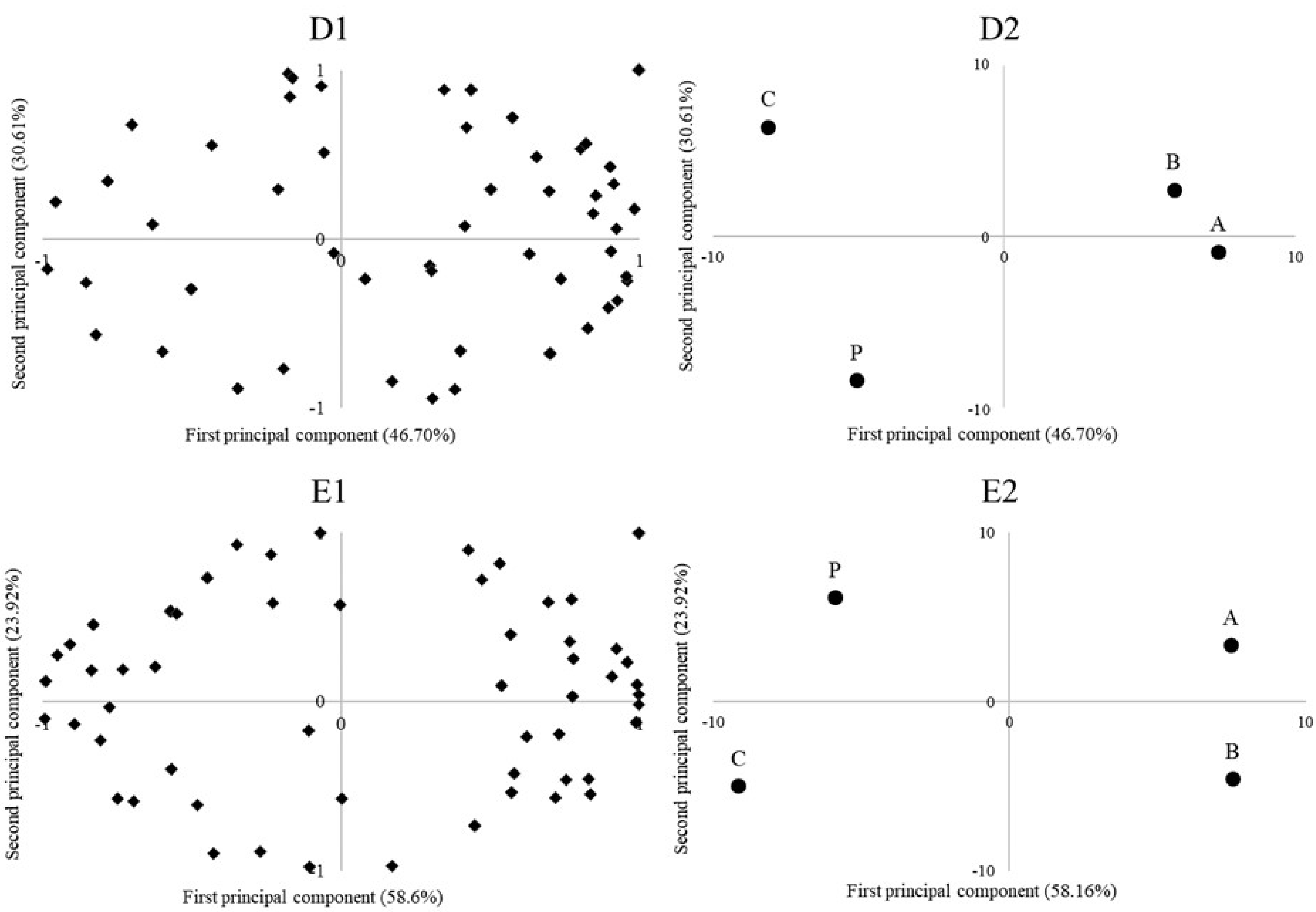

Figure 2. Graphic representation of the judges and bread formulations for the aroma and overall impression attributes. (♦) judges. D1 and D2: aroma, E1 and E2: overall impression. Bread: P (no pulp-added bread), A (bread with 18.14% cupuassu and 7.78% pitaya), B (bread with 20.74% cupuassu and 5.18% pitaya), and C (bread with 23.33% cupuassu and 2.59% pitaya).

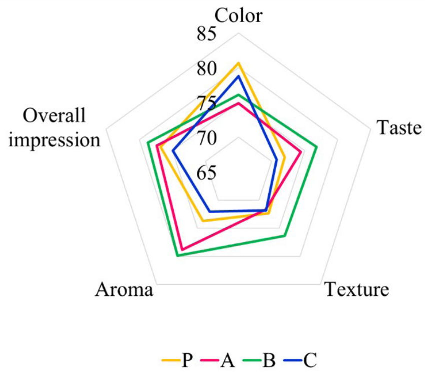

Figure 3. Acceptance index of cupuassu and pitaya breads, and the control.

4 Conclusion

Cupuassu and pitaya pulps as a replacement for milk decreased the lipid and protein content, and the caloric value in bread. Also, the lowest concentration of cupuassu in the bread led to the higher acceptance in taste, aroma, and overall impression. Therefore, this study provides useful data to support human nutrition by promoting bakery products enriched with fruit pulp.

Conflict of interest

We have no conflicts of interest to declare.

Author contributions

All authors 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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