Nativa, Sinop, v. 13, n. 3, p. 368-378, 2025.
Pesquisas Agrárias e Ambientais
DOI: https://doi.org/10.31413/nat.v13i3.19462
ISSN: 2318-7670

Use of peach palm flour in the formulation of a papaya paste

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Submitted: 04/08/2025; Accepted: 07/04/2025; Published: 08/04/2025.

ABSTRACT: The incorporation of functional ingredients into processed foods represents a promising strategy to enhance their nutritional and sensory profiles. This study evaluated the effect of adding peach palm (*Bactris gasipaes* Kunth) flour on the physicochemical, functional, microbiological, and sensory characteristics of a papaya (*Carica papaya* L.) paste. Four formulations were developed with increasing concentrations of peach palm flour (10, 20, 30, and 40% w/w). The 10% formulation showed the highest sensory acceptance, with mean scores of 6.78 for color, 6.67 for odor, 6.89 for flavor, and 6.78 for texture (7-point hedonic scale). This formulation also showed a significant increase in protein content (from 0.3% to 2.2%) and fat content (from 0.1% to 1.6%), along with a reduction in carbohydrate content (from 72.6% to 69.8%), compared to the control, without compromising sensory perception. The product remained microbiologically stable (<1.0 log CFU/g for aerobic mesophilic bacteria and molds/yeasts) for 45 days at 15–20 °C. A total of 87% of consumers reported that they would consume the product “always” or “often”, confirming its acceptability. These findings support the use of peach palm flour as a value-adding ingredient in tropical fruit-based functional products.
Keywords: *Bactris gasipaes* Kunth; *Carica papaya* L.; functional snacks; nutritional improvement; tropical fruit products.

Utilização de farinha de pupunha na formulação de pasta de mamão

RESUMO: A incorporação de ingredientes funcionais em alimentos processados representa uma estratégia promissora para aprimorar seus perfis nutricional e sensorial. Este estudo avaliou o efeito da adição de farinha de pupunha (*Bactris gasipaes* Kunth) nas características físico-químicas, funcionais, microbiológicas e sensoriais de uma pasta de mamão (*Carica papaya* L.). Quatro formulações foram desenvolvidas com concentrações crescentes de farinha de pupunha (10, 20, 30 e 40% m/m). A formulação com 10% apresentou a maior aceitação sensorial, com médias de 6,78 para cor, 6,67 para odor, 6,89 para sabor e 6,78 para textura (escala hedônica de 7 pontos). Essa formulação também apresentou aumento significativo no teor de proteínas (de 0,3% para 2,2%) e lipídios (de 0,1% para 1,6%), além de uma redução nos carboidratos (de 72,6% para 69,8%) em relação ao controle, sem comprometer a percepção sensorial. O produto manteve-se microbiologicamente estável (<1,0 log UFC/g para microrganismos mesófilos aeróbios e bolores/leveduras) durante 45 dias de armazenamento a 15–20 °C. No total, 87% dos consumidores afirmaram que consumiriam o produto “sempre” ou “frequentemente”, confirmando sua aceitação. Esses resultados sustentam o uso da farinha de pupunha como ingrediente de valor agregado em produtos funcionais à base de frutas tropicais.
Palavras-chave: *Bactris gasipaes* Kunth; *Carica papaya* L.; lanches funcionais; melhoria nutricional; produtos de frutas tropicais.

1. INTRODUCTION

The development of innovative, value-added food products using natural ingredients is gaining importance globally, driven by consumer preference for healthy and sustainable diets. Among Latin America's tropical resources, papaya (*Carica papaya* L.) and peach palm (*Bactris gasipaes*) stand out for their nutritional and functional properties. Papaya is recognized for its abundant antioxidants, vitamin C, and digestive enzymes, while peach palm is an excellent source of carbohydrates, proteins, and carotenoids (LUZARDO-OCAMPO et al., 2022). However, the transformation of these fruits into functional and consumer-friendly foods, such as snacks or innovative ingredients, remains limited.

Peach palm flour is a functional ingredient that can enhance the nutritional profile of processed products, providing dietary fiber and bioactive compounds that enrich their functional value (SOARES et al., 2022). This study proposes the creation of a fruit snack made from papaya and peach palm flour, combining the beneficial properties of both ingredients in a food that responds to trends toward healthy and sustainable consumption. The proposal is justified by the need to diversify the use of underutilized tropical fruits and reduce postharvest losses by producing products with greater stability and added value.

Several investigations have highlighted the potential of papaya to develop functional foods thanks to its richness in antioxidant compounds and vitamins (SANTANA et al., 2019; SHARMA et al., 2022). In addition, the peach palm, characterized by its high content of carbohydrates, healthy lipids, and carotenoids, offers promising applications in fortified foods and processed products. Previous research has explored the production of peach palm flour as a functional ingredient for snacks and baked goods, highlighting its versatility and ability to improve the nutritional properties of various products (TORRES-VARGAS et al., 2021; GONZÁLEZ-JARAMILLO et al., 2022). However, its use in traditional products, such as fruit snacks, has not yet been sufficiently investigated, leaving a gap that this research aims to address.

From a technical and regulatory perspective, fortification, supplementation, and enrichment are distinct concepts defined by entities such as the *Codex Alimentarius* and *Agência Nacional de Vigilância Sanitária* (ANVISA) of Brazil. Fortification involves the deliberate addition of essential nutrients to prevent population-level deficiencies (OLSON et al., 2021). In contrast, supplementation refers to the intake of concentrated nutrients, typically in the form of pills or capsules (*Codex Alimentarius*, 2009; ANVISA, 2020). Enrichment, in the strict sense, refers to the process of restoring nutrients that are lost during food processing. In this study, the incorporation of *B. gasipaes* flour does not fit these regulatory definitions, as it involves a whole-food ingredient that naturally enhances the product's nutritional profile. Therefore, including peach palm flour should be described as a nutritional improvement using functional ingredients, without invoking regulatory terms like fortification or enrichment.

This fruit snack, known in various regions as fruit paste or fruit cream, is a traditional Latin American food that combines attractive sensory characteristics, such as a soft texture and sweet flavor, with a long shelf life. This research aimed to develop a papaya snack enriched with peach palm flour, thereby contributing to the diversification of tropical crop use and promoting their market value. For these reasons, this research contributes to the development of functional foods that meet the demands of contemporary consumers and promote sustainability in the food sector.

2. MATERIALS AND METHODS

2.1. Selection and processing of the peach palm

The peach palm fruits (*Bactris gasipaes* var. *gasipaes*) were collected in the eastern region of Ecuador, specifically in Puyo, Pastaza province. This variety is characterized by larger fruits, higher starch content, and lower lipid content compared to wild *Bactris gasipaes* var. *chichagui* (CLEMENT et al., 2017). Fruit selection was conducted to ensure the absence of visible defects, uniform ripeness, and consistent dimensions.

Before obtaining the flour, the fresh fruits were washed with running water and disinfected using a sodium hypochlorite solution at a concentration of 1.0 mL L^{-1}. They were blanched and rapidly cooled in an ice-water bath for 5 seconds. After this treatment, the fruits were allowed to cool to room temperature, peeled, deseeded, and quartered.

2.2. Dehydration and grinding

For preparing the flours, the pre-cut fruits were dehydrated in a forced-air circulation oven (model MA035, Marconi, Piracicaba, Brazil) at a constant temperature of 50 °C for 24 hours. Moisture loss was assessed at the beginning and throughout the drying process. Samples were taken from different areas of the tray, and the material was occasionally mixed to ensure uniform moisture content. This was determined by indirect gravimetry using a thermobalance (Sartorius, model MA-40, Germany) at 105 °C until a constant mass was reached (SAMANIEGO et al., 2024).

The dehydrated material was ground in a hammer mill to obtain fine flour (PIRES et al., 2019). The flours were packaged in bags and vacuum-sealed (Tecnotrip EV086154, Spain). They were then stored in a cool, dry place away from direct sunlight until use.

2.3. Selection and characterization of papaya

Fresh fruits *(Carica papaya* L. var. Maradol Roja) were selected from the same plantation (Masapingue, Portoviejo, Ecuador). The fruits were chosen because they generally presented similar characteristics, including size, absence of bumps, spots, and cracks, and a uniform degree of ripeness (between stages 5 and 6), as shown in Figure 1.

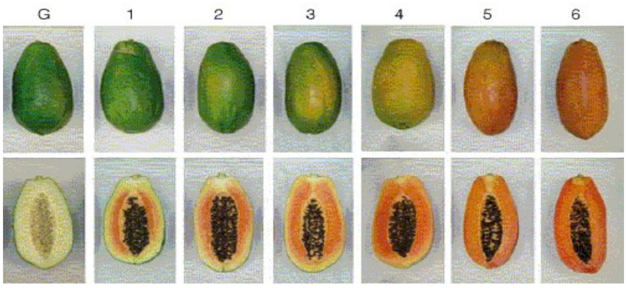

Figure 1. Visual appearance of a representative Maradol papaya fruit at each ripening stage. G: Green skin without yellow stripes; 1: Green skin with a faint yellow stripe; 2: Green skin with a well-defined yellow stripe; 3: One or more orange stripes on the skin; 4: Distinctly orange skin with some light green areas; 5: Orange skin characteristic of Maradol papaya; 6: Fruit color similar to that at stage 5, but more intense (SANTAMARÍA et al., 2009).

Figura 1. Aspecto visual de um mamão Maradol representativo em cada estágio de maturação. G: Casca verde sem listras amarelas; 1: Casca verde com uma listra amarela tênue; 2: Casca verde com uma listra amarela bem definida; 3: Uma ou mais listras laranja na casca; 4: Casca distintamente laranja com algumas áreas verde-claras; 5: Casca laranja característica do mamão Maradol; 6: Cor do fruto semelhante à do estágio 5, mas mais intensa (SANTAMARÍA et al., 2009).

Papayas were evaluated for moisture (% m/m), total proteins (% m/m), total carbohydrates (% m/m) by difference, total fats (% m/m), soluble solids (ºBrix), acidity (% m/m citric acid), maturity index, pH and penetration force (N), using standardized methods to ensure the homogeneity of the raw material.

2.4. Formulation of papaya paste with peach palm flour

2.4.1. Experimental design

The experimental design was conducted using Design-Expert version 8.0.6 (Stat-Ease Inc., Minneapolis, USA), employing a numerical optimization method via an optimal IV response surface design. This allowed the development of mathematical models describing the behavior of the response variables for each formulation, which included increasing levels of peach palm flour (10, 20, 30, and 40% m/m).

The sensory evaluation was conducted by a panel of 15 semi-trained judges, who were previously familiar with the sensory characteristics and evaluation criteria of fruit-based pastes. The assessment took place in an environment with controlled lighting, temperature (20-22 °C), and ventilation, ensuring standardized test conditions.

Each judge received coded samples of the four formulations and evaluated color, flavor, and texture using a 7-point hedonic scale, where 1 = "dislike extremely" and 7 = "like extremely". A mean score of 5.0 or higher was established as the threshold for acceptance for each attribute.

The data were analyzed using analysis of variance (ANOVA), followed by Duncan's multiple range test to identify significant differences between treatments ($p \leq 0.05$), using Statistica software version 7.0 (StatSoft Inc., Tulsa, USA).

2.4.2. Papaya paste preparation

The papaya pulp was mixed with peach palm flour in proportions of 10, 20, 30, and 40% (m/m). The mixture was cooked at 80 °C until it reached a firm, malleable texture. It was then poured hot into molds to form uniform 10-g pieces and cooled to room temperature.

The pulp was cooked in a stainless-steel pan over moderate heat and mixed with sugar in a 1:1 ratio. Citric acid and pectin were then added to this mixture, and it was cooked to approximately 70 °Brix, indicating a sufficient concentration of soluble solids to ensure consistent product quality. During cooking, which took approximately 45 minutes, constant stirring was necessary to prevent the mixture from sticking to the bottom of the pan. Once the mixture reached the desired texture, it was poured into plastic molds and allowed to cool at room temperature until solidified. Finally, the snack was stored at 15-20 °C and 60-70% relative humidity for evaluation (Figure 2).

2.5. Characterization of the selected papaya paste

The treatment with the greatest sensory acceptance was characterized by its physical and chemical properties (humidity, aw, proteins, lipids, and total carbohydrates), following methods described in previous studies (AOAC, 2016).

The sensory evaluation of the snack was carried out with untrained consumers in the city of Riobamba, Ecuador. The test was conducted in a space suitable for sensory analysis, under controlled conditions of lighting, temperature, and ventilation. A total of 100 participants of both sexes, aged between 18 and 60 years, voluntarily took part in the study. Each participant was presented with a sample of the product and asked to complete a structured questionnaire, which included a five-point consumption intention scale: always, often, sometimes, rarely, and never. The data were analyzed using descriptive statistics (frequencies and percentages). Additionally, a chi-square test was used to assess the significance of differences between response categories, with a significance level of $p \leq 0.05$.

2.6. Storage study

The selected snack was packaged in plastic molds and stored at 15–20 °C at 60–70% relative humidity for 90 days of evaluation. During this period, moisture content, water activity, pH, titratable acidity, color (L*, a*, b*), texture, and microbiological counts (aerobic mesophilic microorganisms, molds, and yeasts) were determined every 15 days. The results were processed using ANOVA.

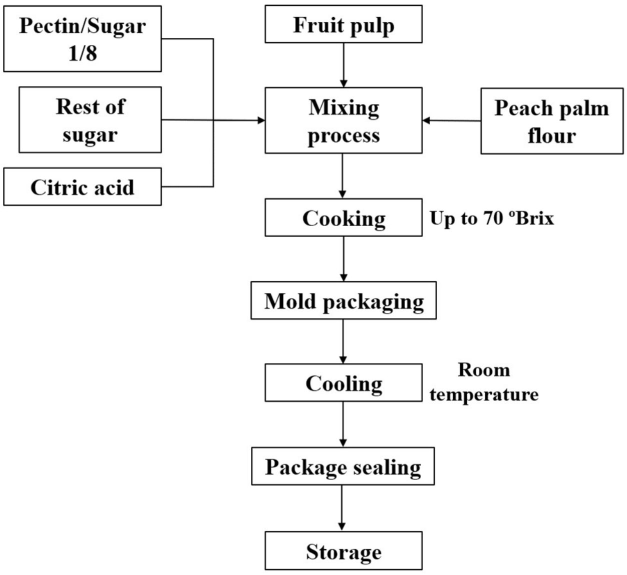

Figure 2. Technological flow for the production of papaya snacks with peach palm flour.
Figura 2. Fluxo tecnológico para produção de snacks de mamão com farinha de pupunha.

3. RESULTS

3.1. Characterization of fresh ripe papaya

Table 1 presents the physical and chemical parameters of fresh, ripe papaya, highlighting its high moisture content (88.5 ± 0.5%), which is characteristic of this fruit and contributes to its soft texture.

The total carbohydrate content (10.8 ± 0.6%) indicates a moderate energy intake, while proteins (0.5 ± 0.1%) and fats (0.21 ± 0.05%) are at low levels, which is common in tropical fruits. Regarding sensory quality, soluble solids (11.5 ± 0.8 °Brix) reflect the amount of sugars present, indicating a higher sweetness level than other studies. Furthermore, acidity (0.12 ± 0.02% citric acid) and pH (5.5 ± 0.2) indicate moderate acidity, which favors its sensory acceptance. The maturity index (96 ± 3) confirms that the fruit is in an advanced stage of ripening, which is reflected in its low firmness, evidenced by a penetration force of 8.5 ± 1.2 N.

Table 1. Physical and chemical parameters of fresh ripe papaya (n = 3)
Tabela 1. Parâmetros físicos e químicos do mamão fresco maduro (n = 3)

Parameters	Mean (Standard Deviation)
Humidity (% m/m)	88.5 (0.5)
Total proteins (% m/m)	0.5 (0.1)
Total carbohydrates (% m/ m) [a]	10.8 (0.6)
Total fat (% m/m)	0.21 (0.05)
Soluble solids (ºBrix)	11.5 (0.8)
Acidity (% m/m citric acid)	0.12 (0.02)
Maturity index	96 (3)
pH	5.5 (0.2)
Penetration force (N)	8.5 (1.2)

[a] Estimated by difference.
[a] Estimado pela diferença.

3.2. Sensory evaluation of papaya paste formulations

Table 2 presents the sensory evaluation of papaya paste formulations with different proportions of peach palm flour (10, 20, 30, and 40%), considering color, odor, flavor, and texture attributes. The results show that formulations with 10% peach palm flour obtained the highest scores in all sensory attributes, with values of color (6.78 ± 0.43), odor (6.67 ± 0.44), flavor (6.89 ± 0.39) and texture (6.78 ± 0.41), indicating that they were the most sensorially accepted. These formulations exceeded the acceptance threshold in all attributes, suggesting that the moderate addition of peach palm flour does not negatively affect the sensory perception of papaya paste.

In contrast, formulations with 30% and 40% peach palm flour were the least accepted, with significantly lower scores across all attributes. In particular, samples with 40% peach palm flour had the lowest scores for color (3.56 ± 0.80), odor (3.89 ± 0.77), flavor (3.12 ± 0.83), and texture (3.45 ± 0.79), indicating clear rejection by evaluators. The negative perception could be related to changes in texture, as the higher proportion of flour may have resulted in a less appealing consistency or altered the product's organoleptic characteristics.

Formulations with 20% peach palm flour achieved intermediate acceptance values, with scores for color (5.67 ± 0.54), odor (5.45 ± 0.52), flavor (5.34 ± 0.57), and texture (5.56 ± 0.5). Although these samples exceeded the acceptance threshold, their preference level was significantly lower than that of formulations with 10%. This suggests that incorporating peach palm flour should be kept at low levels to avoid negatively affecting the sensory perception of papaya paste.

Table 2. Sensory evaluation of papaya paste formulations with peach palm flour
Tabela 2. Avaliação sensorial de formulações de pasta de mamão com farinha de pupunha

Run	Peach palm flour (%)	Color	Odor	Flavor	Texture
1	30	4.20 (0.65) e	4.45 (0.62) f	3.89 (0.75) i	4.12 (0.70) h
2	10	6.45 (0.52) b	6.34 (0.48) b	6.55 (0.50) b	6.23 (0.47) c
3	20	5.56 (0.58) c	5.45 (0.55) c	5.23 (0.61) e	5.45 (0.53) e
4	40	3.89 (0.78) f	4.12 (0.73) g	3.45 (0.81) j	3.67 (0.75) i
5	40	3.56 (0.80) f	3.89 (0.77) h	3.12 (0.83) k	3.45 (0.79) j
6	20	5.34 (0.60) c	5.23 (0.57) d	5.12 (0.62) f	5.45 (0.58) e
7	10	6.78 (0.43) a	6.67 (0.44) a	6.89 (0.39) a	6.78 (0.41) a
8	30	4.34 (0.67) d	4.45 (0.65) f	4.12 (0.72) h	4.23 (0.69) g
9	10	6.23 (0.49) b	6.45 (0.50) b	6.34 (0.48) c	6.56 (0.45) b
10	30	4.45 (0.64) d	4.56 (0.63) e	4.23 (0.70) g	4.34 (0.68) f
11	20	5.67 (0.54) c	5.45 (0.52) c	5.34 (0.57) d	5.56 (0.50) d

Mean (standard deviation); n = 15. Different letters in each column indicate significant differences for $p \leq 0.05$.
Média (desvio padrão); n = 15. Letras diferentes em cada coluna indicam diferenças significativas para $p \leq 0{,}05$.

Table 3 presents the analysis of variance and the significance of the coefficients for each model, based on the sensory attributes evaluated in papaya pastes with peach palm flour. The F and p values indicate the statistical significance of the models, while the R^2 and adjusted R^2 coefficients reflect the explanatory power of the models. The results indicate that the peach palm flour factor (A) has a highly significant effect ($p < 0.0001$) on all sensory attributes, confirming its influence on the perception of color, odor, flavor, and texture. Furthermore, the models present R^2 values greater than 0.96, suggesting that they explain a high percentage of the variability observed in the data. In particular, the model for the odor attribute yields the highest coefficient of determination ($R^2 = 0.9865$), indicating that the amount of peach palm flour has the most significant influence on this attribute in the formulation.

Table 3. Analysis of variance for the models for the sensory attributes of papaya pastes with peach palm flour
Tabela 3. Análise de variância para os modelos de atributos sensoriais de pastas de mamão com farinha de pupunha

Source	Color		Odor		Flavor		Texture	
	F value	p-value	F value	p-value	F value	p-value	F value	p-value
Model	223.5847	< 0.0001	293.8564	< 0.0001	218.3028	< 0.0001	311.9082	< 0.0001
A	223.5847	< 0.0001	533.9968	< 0.0001	408.7128	< 0.0001	311.9082	< 0.0001
A^2	-	-	16.1988	0.0038	5.7678	0.0431	-	-
Lack of fit	2.0667	0.1971	0.2948	0.6040	0.070187	0.7987	2.9323	0.1188

A: peach palm flour (%).
A: farinha de pupunha (%).

A relevant aspect of these results is the inclusion of the quadratic term (A^2) in the odor ($F = 16.1988$, $p = 0.0038$) and flavor ($F = 5.7678$, $p = 0.0431$) models, which suggests that the relationship between peach palm flour concentration and these attributes is not strictly linear. This implies an inflection point at which increasing peach palm flour stops improving these attributes and possibly begins to negatively affect the sensory perception of the product. The lack-of-fit analysis revealed no significant differences for any evaluated attributes ($p > 0.05$), confirming that the fitted models accurately describe the relationship between peach palm flour and sensory attributes without the need for additional terms.

The percentage of peach palm flour is a determining factor in the sensory quality of papaya snacks. The high explanatory power of the models suggests that slight variations in this ingredient can generate perceptible changes in the evaluated attributes. These findings underscore the importance of determining the optimal level of peach palm flour inclusion to strike a balance between the product's nutritional benefits and sensory acceptability. The obtained models (Eq. 1-4) describe the influence of the peach palm flour percentage (A) on the sensory attributes of color, odor, flavor, and texture of papaya pastes. In general, the analysis of the models suggests that the addition of peach palm flour negatively impacts the sensory attributes of papaya paste as its concentration increases. However, the odor and flavor models present quadratic terms, suggesting an optimal point at which the perception of these attributes could improve. In contrast, color and texture show a progressive deterioration with no signs of recovery. The regression models obtained to predict the influence of the percentage of peach palm flour (A) on the sensory attributes of papaya paste are presented in Table 4.

Table 4. Regression models and statistical indicators for sensory attributes of papaya pastes with peach palm flour
Tabela 4. Modelos de regressão e indicadores estatísticos para atributos sensoriais de pastas de mamão com farinha de pupunha

Regression model	R^2	Adjusted R^2	Std. error	Coefficient A (±SE)	Coefficient A^2 (±SE)	95% CI A	95% CI A^2
Color= 5.002065217 - 1.447282609 A	0.9613	0.9570	0.23	-1.45 ± 0.097	—	[-1.67, -1.23]	—
Odor= 4.892682927 - 1.252317073 A + 0.350853659 A^2	0.9866	0.9832	0.13	-1.25 ± 0.054	0.35 ± 0.087	[-1.38, -1.13]	[0.15, 0.55]
Flavor= 4.619695122 - 1.662804878 A + 0.317743902 A^2	0.9820	0.9775	0.19	-1.66 ± 0.082	0.32 ± 0.13	[-1.85, -1.47]	[0.013, 0.62]
Texture= 4.935652174 - 1.547826087 A	0.9720	0.9688	0.21	-1.55 ± 0.088	—	[-1.75, -1.35]	—

Note: A = percentage of peach palm flour. CI = confidence interval. Std. error = standard error.
Nota: A = porcentagem de farinha de pupunha. IC = intervalo de confiança. Erro padrão = erro padrão.

In all cases, the models showed negative coefficients for the linear term, indicating an initial decrease in sensory acceptance as the proportion of peach palm flour increased. However, for the attributes of odor and flavor, a positive quadratic term (A^2) was included, suggesting a curvilinear trend with potential improvements in sensory perception at intermediate concentrations. The standard errors associated with the coefficients were low, indicating that the estimated effects of the flour proportion on the sensory attributes were measured with a high degree of precision. This implies that the variability of the coefficient estimates across repeated sampling would be minimal, increasing confidence in the reliability of the models. Furthermore, the 95% confidence intervals supported the statistical significance of the observed effects, as they did not include zero. Overall, texture and color followed a simpler linear relationship, whereas odor and flavor responded to a more complex relationship with the flour percentage.

The color model was linear and negative (Figure 3a), indicating that color perception decreased as the peach palm flour content increased. The negative coefficient (−1.4473) suggests that adding this ingredient darkens or alters the hue of the papaya snack, making it less visually appealing. Therefore, adding ingredients containing pigments, such as peach palm flour, could reduce the positive color perception in products with naturally bright hues.

For odor, the model presented a positive quadratic component (Figure 3b), implying that the relationship between peach palm flour and odor is not linear. Initially, increasing A decreases odor perception (−1.2523A), but from a certain point on, the positive quadratic term (+0.3509A^2) indicates a partial recovery of the attribute. This behavior may be due to the release of specific aromatic compounds when larger amounts of peach palm flour are incorporated. Similar results have been reported in products with functional flours, where moderate concentrations decrease the perception of volatile attributes, but high concentrations can enhance new aromatic notes (VILLAVERDE-NICOLAS et al., 2023).

Similar to the odor, the flavor model also presented a quadratic relationship (Figure 3c), but with a more pronounced negative coefficient in the linear term (−1.6628). This suggests that flavor is negatively impacted during the early stages of peach palm flour development. However, the positive quadratic coefficient (+0.3177A^2) suggests that flavor perception improves after a certain point, possibly due to a sensory adaptation effect or changes in the mixture composition. This may be related to the fact that adding flours with high phenolic compounds varies the flavor at low doses. However, it can develop sweet or toasted nuances that consumers are more likely to accept at higher concentrations.

The texture model was negative linear (Figure 3d), meaning that increasing the amount of peach palm flour progressively deteriorates the texture of the papaya paste. The coefficient −1.5478 indicates that the product becomes less acceptable as the peach palm flour content increases, likely due to a reduction in juiciness and an increase in firmness. Research has shown that adding high-fiber flour modifies the product matrix, making it denser and less palatable (SAMANIEGO et al., 2016).

These results highlight the importance of defining an appropriate range for incorporating peach palm flour, avoiding concentrations that compromise product acceptance. For future formulations, it is recommended to evaluate composition adjustments to mitigate the adverse effects and maximize the nutritional benefits of this ingredient. Studentized residuals fit a straight line due to the normal distribution of errors, thus satisfying the assumption of normality (Figure 4).

For the numerical optimization of the formulation, the proportion of peach palm flour (10-40%) was used as a restriction to achieve the best sensory results based on the four evaluated attributes. This restriction was solved with a desirability coefficient of 0.9171. This solution, corresponding to adding 10% peach palm flour to the papaya paste formulation, showed theoretical scores of 6.45, 6.5, 6.6, and 6.48 for color, odor, flavor, and texture, respectively.

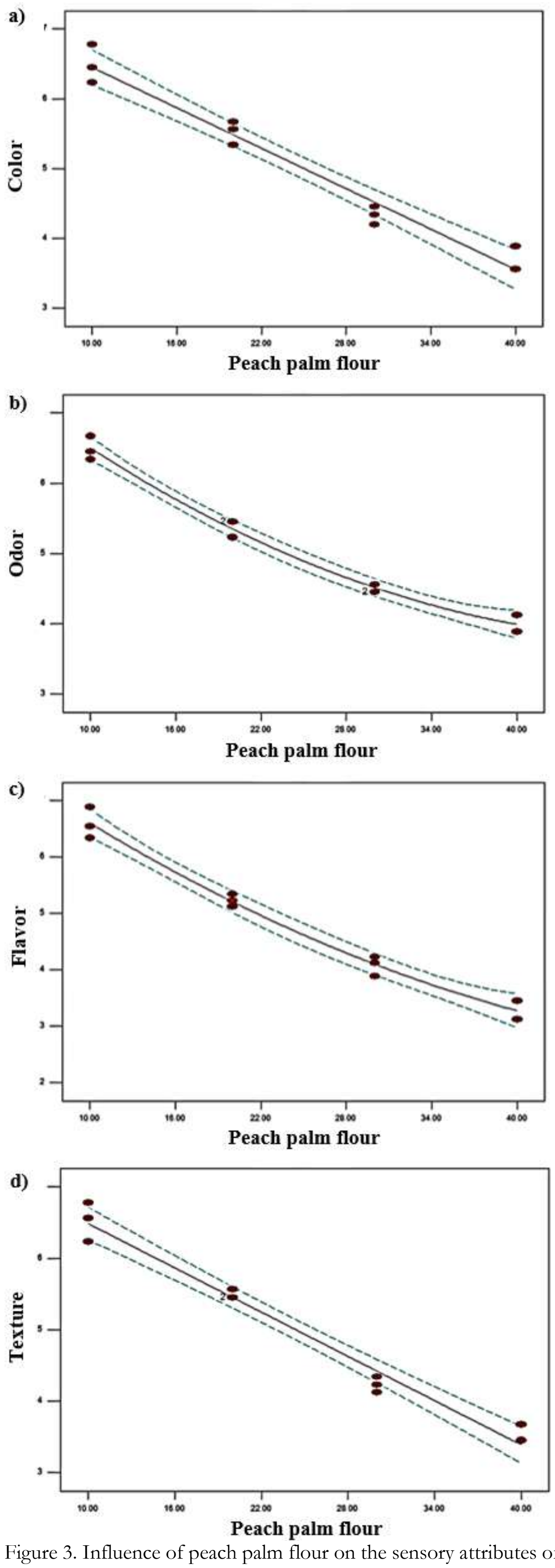

Figure 3. Influence of peach palm flour on the sensory attributes of a papaya paste. a) Color; b) Odor; c) Flavor; d) Texture.
Figura 3. Influência da farinha de pupunha nos atributos sensoriais de uma pasta de mamão. a) Cor; b) Odor; c) Sabor; d) Textura.

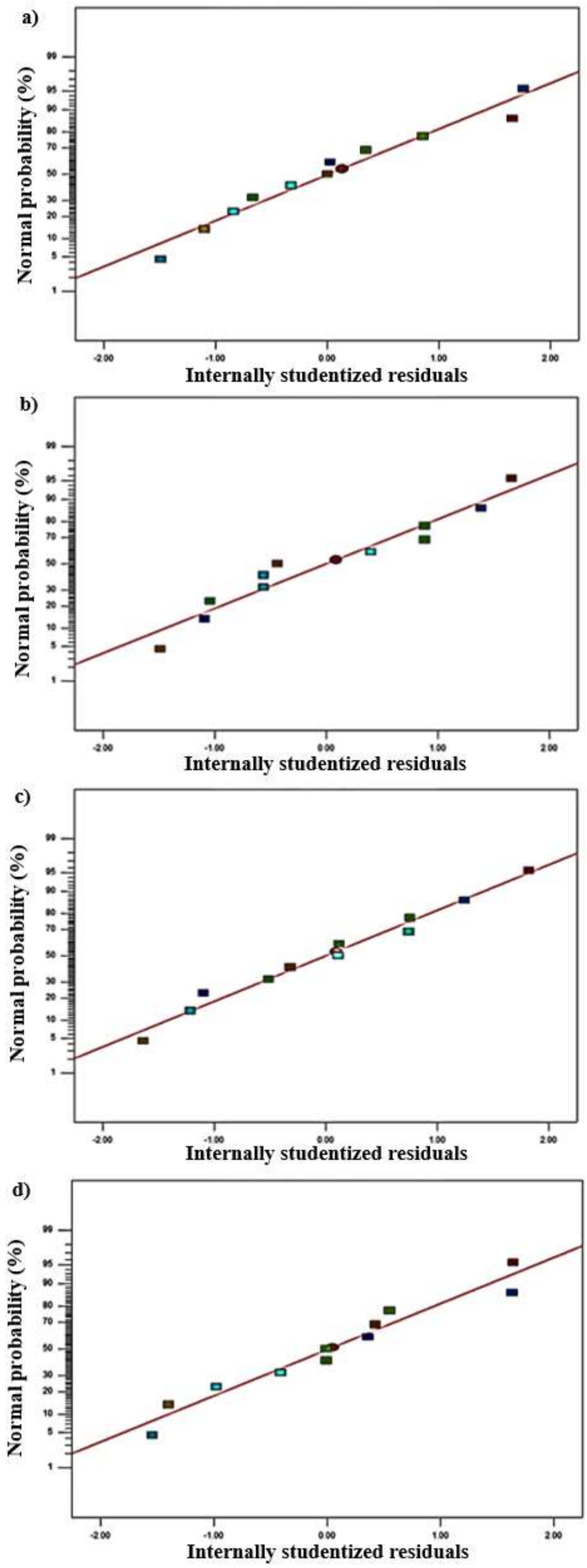

Figure 4. Normal probability of the internally studentized residuals for the analysis of variance of the sensory attributes of a papaya paste. a) Color; b) Odor; c) Flavor; d) Texture.
Figura 4. Probabilidade normal dos resíduos internamente estudentizados para a análise de variância dos atributos sensoriais de uma pasta de mamão. a) Cor; b) Odor; c) Sabor; d) Textura.

3.3. Physical and chemical parameters of papaya paste

To assess the influence of incorporating 10% peach palm flour on the quality of papaya paste, physical and chemical parameters were measured. These provide information on the product's stability, nutritional composition, and overall suitability for consumption and marketing. Table 5 summarizes the results for moisture content, pH, total soluble solids, and titratable acidity, which are indicators of the paste's physical and chemical properties.

In terms of nutritional value, the addition of peach palm flour generated a significant increase in protein and fat content. The papaya paste with 10% peach palm flour contained 2.2% protein, compared to 0.3% in the control, a difference attributed to the flour, whose protein content (2.15%) is significantly higher than that of papaya and sugar. Similarly, the fat content increased from 0.1% in the control to 1.6% in the flour-based snack, thanks to the high lipid content of chontaduro (15.44%).

Table 5. Physical and chemical parameters of papaya paste with and without peach palm flour
Tabela 5. Parâmetros físicos e químicos da pasta de mamão com e sem farinha de pupunha

Parameters	Papaya paste without peach palm flour	Papaya paste with 10% of peach palm flour
Energy (kcal) [a]	292.5 (1.5) a	286.4 (0.7) b
Humidity (% m/m)	27.0 (0.5) a	26.4 (0.4) b
Total proteins (% m/m)	0.3 (0.1) b	2.2 (0.2) b
Total carbohydrates (% m/ m) [b]	72.6 (0.9) a	69.8 (0.8) b
Total fat (% m/m)	0.1 (0.05) b	1.6 (0.1) a
Soluble solids (ºBrix)	71.0 (0.2) a	71.5 (0.1) a
Acidity (% m/m citric acid)	1.05 (0.03) a	1.10 (0.03) a
pH	3.35 (0.06) a	3.32 (0.06) a
a_w	0.835 (0.002) a	0.831 (0.002) a
Penetration force (N)	3.0 (0.1) b	3.2 (0.1) a

Mean (standard deviation); n = 3. Different letters in the same row indicate significant differences. [a] Estimated from the composition of the product. [b] Estimated by difference.
Média (desvio padrão); n = 3. Letras diferentes na mesma linha indicam diferenças significativas. [a] Estimado a partir da composição do produto. [b] Estimado pela diferença.

The addition of 10% peach palm flour to the papaya snack formulation resulted in a significant reduction in carbohydrate content (69.8% *vs.* 72.6% in the control), attributed to a relative dilution effect due to the lower carbohydrate content of the flour compared to sugar. Although the amount of sugar and papaya was not modified, the inclusion of flour changed the total proportion of ingredients, reducing the density of simple sugars without negatively affecting sweetness or sensory acceptability. Furthermore, this modification was accompanied by an increase in protein and fat, improving the overall nutritional profile of the product. This improvement was also reflected in a slight decrease in energy value (286.4 kcal *vs.* 292.5 kcal in the control), which can be attributed to the lower caloric density of flour compared to sugar, resulting from its higher fiber content and lower digestibility.

Both products exhibited similar values for moisture, water activity, pH, acidity, and soluble solids, all of which remained within safe storage ranges. However, slightly greater firmness was observed in the pasta with flour, suggesting a more cohesive texture without negatively affecting its sensory acceptability.

These results confirm the feasibility of incorporating functional ingredients, such as peach palm flour, into traditional products, thereby improving their nutritional profile without compromising their technological properties.

Figure 5 shows a high level of consumption intention among respondents of papaya paste with 10% peach palm flour. The majority of respondents indicated that they would "always" (42%) or "often" (45%) consume the product, representing an 87% acceptance rate.

Only a tiny percentage expressed a less favorable attitude: 7% mentioned that they would eat it "sometimes", while 3% would eat it "rarely", and only 2% stated that they would "never" consume it.

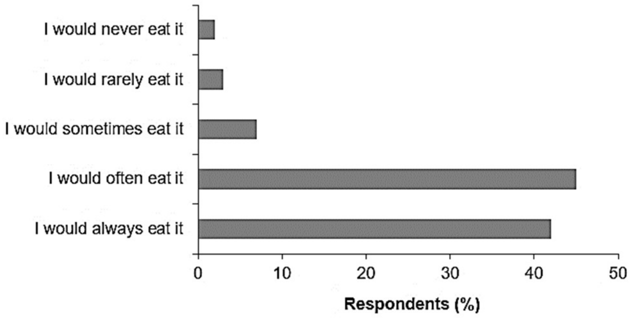

Figure 5. Results of the consumption intention of papaya paste with 10% peach palm flour.
Figura 5. Resultados da intenção de consumo de pasta de mamão com 10% de farinha de pupunha.

These results suggest that the product formulation was well-accepted by consumers, indicating that the balance of ingredients, texture, and flavor met their expectations. If an appropriate balance is achieved in the formulation, incorporating flour and other alternative ingredients in processed products can improve sensory perception.

3.4. Behavior of the parameters of the papaya paste with peach palm flour during storage

The storage study of papaya paste with 10% peach palm flour allowed for the evaluation of its characteristics over 90 days under controlled conditions (15-20 °C and 60-70% relative humidity) (Table 6). Regarding the soluble solids of the papaya snack, a slight decrease was observed, going from

71.5 °Brix at the beginning to 70.0 °Brix at the end of the storage period.

Table 6. Behavior of the physical, chemical, and microbiological parameters of a papaya paste with peach palm flour during storage.
Tabela 6. Comportamento dos parâmetros físicos, químicos e microbiológicos de uma pasta de mamão com farinha de pupunha durante o armazenamento.

Time (d)	Soluble solids (°Brix)	Acidity (% m/m citric acid)	pH	Water activity (a_w)	Penetration force (N)	Chromatic coordinates		
						L*	a*	b*
0	71.5 (0.1)	1.10 (0.03)	3.32 (0.06)	0.831 (0.002)	3.2 (0.2)	49.4 (1.1)	57.3 (0.8)	45.2 (0.9)
15	71.3 (0.2)	1.08 (0.01)	3.30 (0.05)	0.835 (0.001)	3.1 (0.1)	49.8 (1.0)	57.3 (0.7)	45.4 (0.8)
30	71.0 (0.5)	1.05 (0.03)	3.28 (0.03)	0.839 (0.002)	3.0 (0.3)	49.5 (0.9)	57.1 (0.6)	45.2 (0.8)
45	70.8 (0.1)	1.03 (0.02)	3.25 (0.06)	0.842 (0.003)	2.9 (0.1)	49.2 (0.9)	55.9 (0.6)	45.0 (0.7)
60	70.6 (0.6)	1.00 (0.03)	3.23 (0.05)	0.846 (0.005)	2.8 (0.2)	48.8 (0.8)	55.6 (0.6)	43.8 (0.7)
75	70.3 (0.1)	0.98 (0.02)	3.20 (0.02)	0.850 (0.002)	2.7 (0.4)	48.5 (0.7)	55.4 (0.5)	43.5 (0.6)
90	70.0 (0.3)	0.95 (0.02)	3.18 (0.05)	0.855 (0.001)	2.5 (0.6)	48.2 (0.7)	55.2 (0.5)	43.3 (0.6)

This reduction suggests a slight loss of soluble sugars, possibly attributable to non-enzymatic hydrolysis processes or interactions between free sugars and compounds in the added peach palm flour, such as polysaccharides or phenolic compounds. These interactions could alter the availability of sugars by forming complexes or modifying the food matrix.

The acidity reduced from 1.10 to 0.95%, while the pH increased from 3.32 to 3.18, suggesting a slight neutralization of the organic acids in the formulation. This behavior may be associated with the degradation of organic acids or their volatilization, a common phenomenon in fruit-derived products stored under ambient conditions (CORPAS et al., 2016).

The a_w value gradually increased from 0.831 to 0.855, indicating greater availability of free water in the product matrix. This increase, related to moisture absorption from the environment, is a critical factor since values above 0.85 can promote the development of microorganisms and accelerate deterioration processes.

Regarding texture, the penetration force decreased from 3.2 to 2.5 N, demonstrating a loss of firmness over time. This can be explained by moisture absorption and structural modifications in the sandwich matrix, such as the degradation of the polysaccharide network that provides cohesion. In products with high sugar content, the reduction in firmness has been linked to changes in the aw and microstructure of the material, which in turn affect its sensory acceptability (RODRÍGUEZ et al., 2018).

Analysis of the chromatic coordinates revealed a decrease in L* from 49.4 to 48.2, indicating a slight darkening of the product. On the other hand, the a* -value decreased from 57.3 to 55.2, while b* decreased from 45.2 to 43.3, suggesting a loss of intensity in the paste's coloration. These changes may be related to oxidation reactions of phenolic compounds or degradation of natural pigments (VIDOT et al., 2020).

The decrease in soluble solids and acidity is a recurring phenomenon in fruit-derived products stored for long periods, affecting their sensory characteristics and stability. The increase in a_w and decrease in firmness have been identified as risk factors for the product's shelf life; therefore, the use of packaging with a moisture barrier or the incorporation of stabilizing agents is recommended to prolong its textural stability (BOURLIEU et al., 2008; SAHA; BHATTACHARYA, 2010).

The microbiological results presented in Table 7 demonstrate the stability and hygienic quality of the papaya paste formulated with 10% peach palm flour over a 90-day storage period. During the first 45 days, the product maintained microbial counts for aerobic mesophilic bacteria, molds, and yeasts below the detection threshold (<1.0 log CFU/g), indicating effective microbial control and suggesting that the initial processing conditions, packaging, and formulation provided a favorable environment for microbial stability. This phase is crucial, as it corresponds to the period during which the product retains its microbiological safety and is most suitable for consumption without the risk of spoilage.

Table 7. Behavior of the microbiological indicators of a papaya snack with peach palm flour during storage
Tabela 7. Comportamento dos indicadores microbiológicos de um snack de mamão com farinha de pupunha durante o armazenamento.

Time (d)	Aerobic mesophilic microorganisms (log CFU/g)	Molds and yeasts (log CFU/g)
0	<1.0	<1.0
15	<1.0	<1.0
30	<1.0	<1.0
45	<1.0	<1.0
60	<1.0	1.0
75	1.3	1.3
90	1.7	1.7

However, from day 60 onwards, a slight but detectable growth of molds and yeasts was observed (1.0 log CFU/g), indicating the onset of microbial activity, likely due to the gradual loss of preservative efficacy or increased water activity within the product matrix. This growth continued moderately over time, with both molds and yeasts reaching 1.3 log CFU/g by day 75 and 1.7 log CFU/g by day 90. Although these values remain below the typical spoilage threshold (generally considered to be around 4.0–5.0 log CFU/g for yeasts and molds), their progressive increase indicates that the shelf life in terms of microbiological safety is limited beyond 45 days under the tested storage conditions.

4. DISCUSSION

The characterization of raw materials is a fundamental step in the design and development of new food products, as their physicochemical, functional, and nutritional properties directly influence the behavior of the food during processing and the quality of the final product. In this study, papaya was selected as the basis for the formulation due to its content of bioactive compounds and dietary fiber, as well as its characteristic texture and flavor, which favor its use in semi-solid products such as fruit pastes.

The high moisture content of papaya contributes to its low firmness and increased susceptibility to mechanical damage, as evidenced by the reduced penetration force measured in this study. Santamaría et al. (2009a) and Alcántara et al. (2019) reported soluble solids values around 11.5 °Brix, while Krongyut et al. (2011) documented a penetration force of 10 N, indicating that the papayas used here exhibited greater ripeness and lower firmness. This is further supported by the ripening index (96), which exceeds the values reported in other studies (ranging from 70 to 80), reflecting advanced ripening stages characterized by the enzymatic degradation of cell wall components and intracellular substances (BRAGA et al., 2020).

The sensory evaluation of food products is a critical step in determining consumer acceptance and guiding formulation decisions. Understanding how peach palm flour, as a functional ingredient, influences sensory perception is essential for optimizing its use without compromising the product's appeal. In this context, the results of the present research are consistent with previous studies on peach palm flour-based products. Samaniego et al. (2016) reported that the addition of peach palm flour in baked products at levels above 30% resulted in a denser texture and lower sensory acceptance. Similarly, Martínez et al. (2019) found that a mortadella with the addition of peach palm flour up to 1% improved sensory characteristics and sliceability.

In this case, incorporating peach palm flour into papaya paste at an optimal concentration of 10% preserved sensory acceptability. At the same time, higher levels significantly reduced consumer preference, mainly due to unfavorable changes in texture and flavor. These results underscore the importance of maintaining ingredient balance in the development of functional products, ensuring the nutritional benefits of peach palm flour can be harnessed without compromising sensory quality or consumer acceptance.

Although texture measurement using penetration force has been employed in previous studies with semi-solid papaya products (García et al., 2013), this technique may not accurately reflect the sensory perception that consumers experience when consuming the product, particularly in terms of its cohesiveness, elasticity, and adherence. In this sense, it is suggested that future research employ instrumental methodologies such as texture profile analysis, which allow for a comprehensive evaluation that can be correlated with perceived sensory attributes. This methodological improvement would contribute to a better understanding of the influence of functional ingredients, such as peach palm flour, on the internal structure of the product and its acceptability.

García et al. (2013) developed a papaya paste with the addition of Spirulina. Formulations containing up to 1% Spirulina exhibited adequate values for their physicochemical, microbiological, and sensory parameters. Additionally, the paste's iron, protein, cysteine, methionine, and polyunsaturated fatty acid contents increased. In this study, peach palm flour contributed favorable characteristics to the product. Given the high level of acceptance, it is recommended to continue with market studies and broader sensory tests to confirm the product's commercial viability.

The microbiological behavior observed in the papaya paste with peach palm flour can be explained by changes in its physicochemical properties during storage. One key factor is the progressive increase in a_w, which, while keeping the product within a range that prevents the growth of pathogenic bacteria, favors the development of molds and yeasts, which can proliferate under moderately humid conditions.

Likewise, the reduction in acidity and the slight increase in pH may decrease the inhibitory effect on certain acidophilic microorganisms, facilitating their development. The slight decrease in soluble solids suggests a possible absorption of moisture, which could be related to the increase in a_w, generating a more favorable environment for osmotolerant microorganisms (TAPIA et al., 2020). Furthermore, the loss of firmness of the paste may be associated with changes in its structure, which would facilitate microbial colonization. On the other hand, variations in color parameters, such as progressive darkening and reduction in yellowness, could be related to oxidative processes and pigment degradation, factors that can be influenced by mold growth. Together, these physicochemical changes account for the paste's microbiological stability.

The shelf life of papaya paste with 10% peach palm flour can be more accurately estimated by considering microbiological quality and physical and chemical stability criteria. Although the study extended the analysis to 90 days, the results indicated that the product maintained optimal quality up to 45 days. During that time, no microbial activity was detected, and the texture remained unchanged from its initial values. From day 60 onward, changes in aw, firmness, and microbial count began to progressively compromise the product's safety and sensory quality.

Therefore, it is recommended to establish a conservative shelf-life limit of 45 days for storage conditions between 15 and 20°C, which would ensure product safety without compromising its texture or sensory perception. However, considering that microbial counts remained low (<2 log CFU/g) up to day 90, the shelf-life could be extended to 60 days.

Studies on products with high sugar content and low pH have reported similar trends. Molds and yeasts are the primary microorganisms that proliferate due to their ability to grow in low-humidity and acidic pH conditions (LORENZO et al., 2018; TAPIA et al., 2020). These findings suggest that natural antimicrobial agents or modified atmosphere packaging could extend the paste's microbiological stability and prolong its shelf life.

These findings underscore the importance of monitoring microbial indicators during storage and highlight that, despite the inclusion of peach palm flour and the product's low initial microbial load, shelf-life remains constrained primarily by fungal development. Future studies should evaluate alternatives to extend the shelf life without compromising the product's functional quality.

5. CONCLUSIONS

The incorporation of peach palm flour into papaya paste proved to be a viable strategy for improving the nutritional profile of the product, particularly through increased dietary fiber and protein content, without compromising sensory acceptability.

These enhancements position the formulation as a promising candidate for commercial development in specific market niches, such as functional foods aimed at health-conscious consumers, vegan-friendly products, and school meal programs that require nutritious and appealing alternatives.

Additionally, the product's format and composition make it suitable for applications as a natural snack, dessert substitute, or ready-to-eat functional food.

Future research should focus on identifying and quantifying specific bioactive compounds responsible for the sensory modifications observed, evaluating consumer acceptance at a larger scale, and exploring packaging technologies or natural preservatives that could extend shelf life while maintaining product safety and quality.

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Authors' contributions: Conceptualization, M.A.G. and A.C.; methodology, V.B.S.P. and D.R.; software, M.A.G.; validation, M.A.G. and A.C.; formal analysis, V.B.S.P., D.R., M.A.G. and A.C.; investigation, V.B.S.P., D.R., M.A.G. and A.C.; resources, V.B.S.P. and D.R.; data curation, M.A.G. and A.C.; writing - original draft preparation, M.A.G.; writing - review and editing, V.B.S.P., D.R., M.A.G. and A.C.; visualization, V.B.S.P. and D.R.; supervision, M.A.G. and A.C.; translation, M.A.G. All authors read and agreed to the published version of the manuscript.

Financing: This research received no external funding.

Data availability: Study data can be obtained by email from the corresponding author or the second author upon request. It is not available on the website as the research project is still under development.

Conflict of interest: The authors declare no conflict of interest. Supporting entities had no role in the study's design, data collection, analysis, interpretation, manuscript writing, or decision to publish the results.