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POWDERS FROM THE PEEL, SEED, AND PULP OF THE CRIOLLO MANGO (*MANGIFERA INDICA L.*) AS ALTERNATIVES FOR THE FUNCTIONALIZATION OF BAKERY PRODUCTS

POWDERS OF PEEL, SEED AND PULP OF MANGO CRIOLLO (*MANGIFERA INDICA L.*) AS ALTERNATIVES FOR THE FUNCTIONALIZATION OF BAKERY PRODUCTS

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Abstract -- The purpose of this research was to evaluate the effect of partially replacing wheat flour with powdered peel (PC), pulp (PP), and seeds (PS) from Creole mangoes (*Mangifera indica L.*) on the physicochemical, functional, and sensory characteristics of a baked product. Four formulations of a loaf-type bread were made, in which 12.5% (F1), 13.0% (F2), 13.5% (F3), and 14.0% (F4) of wheat flour was replaced with a mixture of mango PC, PP, and PS. The formulations were analyzed for protein, fat, ash, moisture, crude fiber, carbohydrates, dietary fiber, and total phenols. Sensory evaluation of aroma, flavor, texture, and overall appearance was performed using a 9-point hedonic scale.

There was a significant effect of the percentage of wheat flour replacement with a mixture of mango peel, pulp, and seed powders on the physicochemical, functional, and sensory characteristics of a loaf-type bread. Formulation F1, with 2.5% PC, 7.5% PP, and 2.5% PP, had a higher protein content (5.946%), while formulation F4, with 4%, 7.5%, and 2.4% PC, PP, and PS, respectively, had a higher fat content (2.465%), crude fiber (6.685%), total dietary fiber (4.847%), and total phenol content (10.386 mgAG/g). The partial replacement of wheat flour with 12.5% of a mixture of PC, PP, and PS scored highly in the sensory evaluation.

Combinations of mango peel, pulp, and seed powders can be used as a substitute for wheat flour, yielding baked goods with good nutritional quality and physicochemical, functional, and sensory characteristics that are acceptable to the general population.

Keywords-- bread, peel, pulp, seed, mango, fiber, phenols.

Abstract -- The purpose of this study was to evaluate the effect of partially replacing wheat flour with mango criollo (*Mangifera indica L.*) peel (PP), pulp (PP), and seed (PS) powders on the physicochemical, functional, and sensory characteristics of a baked product. Four loaf bread formulations were created, in which 12.5% (F1), 13.0% (F2), 13.5% (F3), and 14.0% (F4) of wheat flour was replaced with a mixture of mango peel, pulp, and PS. The formulations were determined for protein, fat, ash, moisture, crude fiber, carbohydrates, dietary fiber, and total phenolic contents. Sensory evaluation of aroma, flavor, texture, and overall appearance was performed using a 9-point hedonic scale.

There was a significant effect of the percentage of wheat flour substitution with a mixture of mango peel, pulp, and seed powders on the physicochemical, functional, and sensory characteristics of a loaf of bread. Formulation F1, with 2.5% CP, 7.5% PP, and 2.5% PP, had a higher protein content (5.946%), while formulation F4, with 4%, 7.5%, and 2.4% of CP and PP, respectively, had a higher fat content (2.465%), crude fiber (6.685%), total dietary fiber (4.847%), and total phenol content (10.386 mg/g). The partial replacement of wheat flour with 12.5% of a mixture of PC, PP, and PS showed high scores in the sensory evaluation.

Combinations of mango peel, pulp, and seed powders can be used as a substitute for wheat flour, resulting in bakery products with good nutritional quality and physicochemical, functional, and sensory characteristics acceptable to the general population.

Key words – bread, peel, pulp, seed, mango, fiber, phenols.

INTRODUCTION

Proper nutrition is essential for human health, well-being, and development. The diet of in today's society is largely influenced by the pace of life, which determines consumption patterns geared towards processed foods high in saturated fats, low in nutritional value, low in dietary fiber, refined sugars, additives, preservatives, high levels of sodium, and high in calories. Excessive intake of these foods is largely the result of the wide availability, affordability, advertising, and promotion of ultra-processed and processed food products that contain excessive amounts of these nutrients [1]. This high consumption, combined with sedentary lifestyles, prevents the body from burning the energy it has accumulated, thus contributing significantly to the increase in the incidence of chronic or noncommunicable diseases (NCDs) that arise as a result of unhealthy eating, such as dyslipidemia, high blood pressure, and cardiovascular disease, malnutrition, obesity, and overweight. The latter are associated with an increased risk of hypertension, dyslipidemia, type I and II diabetes, cardiovascular accidents, biliary disease, osteoarthritis, sleep apnea, and cancer.

According to the World Health Organization [2], NCDs have claimed the lives of 17.9 million people under the age of 70, and in 2019, they were responsible for 44.5% (approximately 3.2 million) of deaths in Latin America. In Mexico, almost half a million people died between January and June 2022, mainly from heart disease, diabetes mellitus, cancer, and liver disease. In the same year, 12.4 million people had diabetes, 38.3% of adults were overweight, and 36.9% were obese. In some of these diseases, the cause is clearly dietary; in some, diet can contribute significantly to the cause or treatment; and in others, the relationship with diet is suspected but has not been proven [3].

Bread is one of the staple foods and is very important in the human diet, forming part of the diet of many civilizations. Mexico ranks as the eighth largest consumer of bread in the world, according to figures from the National Chamber of the Bakery Industry [4]. In 2023, per capita consumption of bakery products was 33.5 kg, of which 70-75% was white bread and the rest was sweet bread, cookies, and cakes.

Bread is a product with high nutritional value, which depends greatly on the quality of the ingredients and additives in its composition. For this reason, it can be used as a carrier for bioactive compounds and other nutritional components by incorporating other flours (derived from seeds, fruits, legumes, roots, or tubers), which can be considered unconventional raw materials in its production [5] and make it a functional food.

According to Chávez *et al*. [6], Mexicans have a high consumption of carbohydrate-rich foods, with sweet bread, white bread, and wheat derivatives among the seven foods that contribute 50% of total energy intake, providing 6.6% and 4.6% of sugars, respectively. Their consumption could explain the prevalence of diabetes and obesity in the country, which affects the health of Mexicans and has positioned the country as the one with the largest population with these conditions.
% and 4.6% of sugars, respectively. Their consumption could explain the prevalence of diabetes and obesity in the country, which affects the health of Mexicans and has positioned the country as the one with the largest population with these conditions [7].

Mangoes are one of the most widely consumed tropical fruits in the world. Certain varieties have been successfully adapted to the climatic conditions of the Acatlán region. There are 7,480 trees of the Creole variety, producing 7,290.26 tons/year, of which only 3% is used for fresh and canned sales in local markets, due to the lack of processing companies for this fruit in the region [8].

Mangoes are mainly composed of skin and pulp (82.97%), seed (7-8%), and pit (15%). This fruit benefits the human body as it provides vitamins A, C, E, and B complex, as well as soluble fiber (pectins), organic acids (citric, malic, and tartaric), and carbohydrates. The skin, pulp, and seed can be considered sources of total dietary fiber and antioxidant compounds such as phenols and flavonoids [9,10]. Therefore, it is possible to incorporate them in powder form into a bakery product, increasing its physicochemical and functional characteristics without losing its acceptable sensory characteristics.

Due to the high consumption of bakery products in the country, considering that 37% of Mexican households consume bread at least once a week (on average 3.3 times) and that excessive intake is related to a higher risk of NCDs due to its high glycemic index, the objective of this project was to evaluate the effect of partially replacing wheat flour with a mixture of powdered peel, pulp, and seed powder from native mangoes (*Mangifera indica* L.) on the physicochemical, functional, and sensory characteristics of a baked product so that it could be considered an alternative for improving health and reducing the risk of certain diseases, taking advantage of the surplus annual production of native mangoes in the Mixtec region, thus adding value to the bioactive compounds present in this fruit.

DEVELOPMENT

This work was carried out in the Food Industry Workshop and in the Research Laboratory of the Higher Technological Institute of Acatlán de Osorio (TecNM-Acatlán de Osorio).

Obtaining raw materials

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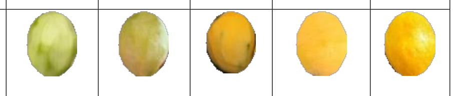
In backyard gardens in the municipality of Acatlán, Puebla, between April and May 2024, mangoes of the Criolla variety were harvested at two stages of ripeness: pintón (ripeness stage 2) and atenque (ripeness stage 3) according to the ripeness stage guide [8], which is presented in Table 1. At these two stages of ripeness, the firmness of the fruit allows the skin to be separated from the fruit without leaving any pulp residue. The mangoes were stored in a commercial refrigerator at the Food Industry Workshop until they were processed.

Table 1. *Maturity stages of Creole mangoes from the Mixtec region.*

Skin					
Flesh					
State	1 Green	2 Ripe	3 Atenque*	4 Consumption maturity	5 Fully mature
Firmness kg/cm^2	9.1	6.7	5.2	4.36	3.7
SST (°Brix)	6-8.5	10-13	15-17	15-18	19-22

Source: *López-Aranda et al*., 2023

Obtaining powder from peel, pulp, and seeds

The mangoes were washed with drinking water to remove traces of soil and insects. Subsequently, with the help of a potato peeler, the peel was separated from the pulp, which was removed from the stone with a knife and cut into slices approximately
0.5 cm thick. The mango seeds were removed from the pit with a knife and cut into pieces approximately 2 x 2 cm in size. The pulp, peel, and seeds were blanched separately (98°C for 1 minute) and immersed in ice water to remove the transferred heat. The samples were immersed in a citric acid solution (5% w/v) [11] and then in sodium bisulfite (1% w/v) to prevent enzymatic browning and the proliferation of fungi and yeasts during the convective drying process [8].

To reduce the moisture content of the shells, pulp, and seeds, hot air at 60°C was used in a tray dehydrator (Aresma, model 100) for 24 hours, until the final moisture content was less than 5% [8,12]. Once dehydrated, they were reduced in size using an electric mill for periods of 1 minute, thus controlling the overheating of the powders that would cause damage to the protein and excessive water removal [13]; The powders obtained were screened into granules that passed through a sieve with an opening equivalent to 500 microns [8], then packaged in hermetically sealed polyethylene bags
, labeled with the date of manufacture and the initials PC, PP, and PS for mango peel, pulp, and seed powders, respectively. The bags were stored at room temperature until incorporation into the baked goods.

Formulation of the baked goods product

An initial formulation of sliced bread (F0) was standardized, from which the percentages of substitution of all-purpose wheat flour (HT) with a mixture of shell powder (PC), pulp powder (PP), and seed powder (PS) were varied in an interval from 5 to 30%. A total of ten formulations were made and four were selected, F1, F2, F3, and F4 (Table 2), considering those in which the substitution percentage did not affect the viscosity of the dough, kneading time, and fermentation [12]; Organoleptic acceptance was obtained through a ranking test carried out by a group of ten untrained panelists aged 20 to 50 years old, belonging to the technological community of TecNM-Acatlán de Osorio. Taking these considerations into account, it was found that a substitution of more than 15% of the mixture of mago powders caused the dough to be dry and difficult to handle, fermentation was not prolonged, the breads were not light and airy, and they had an astringent aftertaste, which meant that they were not accepted by the panel of tasters, in comparison with the base formulation, F0.

Table 2. *Percentage of wheat flour replacement with husk, pulp, and seed powders in sliced bread.*

Formulación	% HT	Porcentaje de sustitución, %	Composición de la sustitución, %		
			PC	PP	PS
F0	100	0	0	0	0
F1	87.5	12.5	2.5	7.5	2.5
F2	87	13.0	3	7.5	2.5
F3	86.5	13.5	3.5	7.5	2.5
F4	86	14.0	4.0	7.5	2.5

Source: *Own elaboration*, 2025.

The standardized process for making sliced bread began with the reception and subsequent weighing of the raw materials (flour, yeast, milk, water, sugar, butter, salt) using an electronic grain scale. To facilitate the mixing process, the all-purpose wheat flour was sifted together with the mixture of creole mango peel, pulp, and seed powders and salt into a previously sanitized stainless steel bowl. The yeast activated in the mixture of water and milk at 30°C was added to this combination of powders. To develop the gluten that would allow the formation of a crumb suitable for the baked product, an industrial mixer was used, using the dough hook for 5 minutes. Finally, the butter was added, and the mixer was used for another 5 minutes, until the "medium or window" point was reached.

industrial mixer with a dough hook for 5 minutes. Finally, the butter was added, and the mixer was used for another 5 minutes until the "medium or window" point was reached, which guarantees maximum elasticity and crumb formation.

The dough was placed in a greased plastic container, covered with plastic wrap, and placed in a draft-free area at a temperature between 25 and 30°C, ideal for the yeast to metabolize the sugars in the dough. During this time, the dough doubled in volume, indicating optimal fermentation. Once the fermentation time was reached, the dough was transferred to the work table, and to reduce the carbon dioxide content produced by the yeast, it was lightly beaten with the palm of the hand, then molded into rectangles measuring 15 x 20 cm and 3 cm thick. These were placed in rectangular molds, previously greased and floured, in which a second fermentation took place, helping to improve the quality of the bread crumb. The bread loaf formulations were baked at 200°C in a cabinet oven, with water regularly sprayed onto the surface of the loaves using an atomizer, which allowed them to have a soft crust and ensured optimal moisture. After 20 minutes, the bread crust was formed and the brown color indicated that the bread was optimally baked. Once out of the baking oven, the bread was taken to the work table to cool to 30°C, then packaged in brown paper bags and stored in a moisture-free place to prevent the presence of microorganisms that could affect the product.

Analysis of bread formulations

a) Physicochemical characteristics

Using the official AOAC methods [14], the following were determined in the sliced bread formulations: crude protein content was determined using the Kjeldahl method (950.36), crude fiber (950.37), ash (930.22), fat (935.38), and moisture, using the rapid thermobalance method (NMX-F-428-1982) [15,12]. The carbohydrate content was calculated by difference [16, 17, 12]. All analyses were performed in triplicate.

b) Total dietary fiber

The total soluble and insoluble dietary fiber in the samples was obtained using the enzymatic-gravimetric method [14] developed by Asp *et al.* [18] and modified by Parra & Meza [19] and López-Aranda *et al.* [12] using alpha-amylase, pancreatin, and pepsin from Sigma Aldrich®.

Obtaining sample extracts

Extracts were prepared from 1 g of sample, macerated with 25 mL of ethyl alcohol (95% v/v) and shaken for 30 minutes at 5000 rpm [19]. The supernatant was filtered using Whatman No. 1 filter paper and centrifuged at 2000 rpm for 20 minutes and immediately used in the determination of total phenolic compounds [12].

c) Total phenol content

The total phenols in the extracts of the five formulations were determined colorimetrically using the *Folin-Ciocalteu* method, as described by Singleton *et al*. [20], with some modifications [12] and gallic acid from Sigma-Aldrich® as the standard; 0.5 mL aliquots of the extract were added to 0.5 mL of *Folin-Ciocalteu* reagent, followed by the addition of 0.5 mL of a 7.5% (w/v) aqueous sodium carbonate solution. The mixture was stirred and allowed to stand for 30 min. The absorbance at 765 nm was measured using a VELAB model VE-5000V spectrophotometer. A blank sample composed of water and reagents was used as a reference. The results were expressed as milligrams of gallic acid equivalents per gram of powder (mg GAE/g powder) by reference to the gallic acid calibration curve using the following equation:

$$y = 0.044\,x + 0.1645 \qquad \text{Eq. (1)}$$
$$R^2 = 0.996$$

d) Sensory evaluation

A panel of seven tasters, made up of students and teachers from the Food Industry Engineering program, carried out the sensory evaluation by attributes. This panel of evaluators held five one-hour training sessions, during which references were presented to enable the panel to achieve optimal assessment and develop the descriptors to be evaluated in the formulations of sliced bread with partial substitution of wheat flour with a mixture of PC, PP, and PS. In this way, a ballot was prepared for the evaluation of aroma, flavor, texture, and overall appearance attributes. The samples consisted of bread baked one day in advance, which was stored in brown paper bags at room temperature to preserve its organoleptic characteristics. The samples were cut using a serrated knife to keep the loaf intact. The samples were presented on disposable plates, accompanied by water as a rinsing substance and the evaluation form [12]. A 9-point hedonic scale was used, in which 1 = I dislike it very much, 5 = I neither like nor dislike it, and 9 = I like it very much [17, 16, 22, 23, 39].

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Statistical Analysis

The results were expressed as the average value of 3 determinations ± standard deviation. The results of the physicochemical properties, dietary fiber content, and total phenols, as well as the sensory characteristics of the sliced bread formulations, were subjected to analysis of variance (ANOVA) for a completely randomized design [17, 16, 23, 12] to determine the existence of significant differences and Tukey's test for comparison between means. All analyses were performed using the Minitab statistical package (Version 17), considering an Alpha value ≤ 0.05 as a significant effect.

DISCUSSION AND ANALYSIS OF RESULTS

The results obtained for the moisture, carbohydrate, protein, crude fiber, fat, and ash content in the bread formulations with partial substitution of wheat flour with a mixture of creole mango peel, pulp, and seed powders are presented in Table 3. These were compared with bread without wheat flour substitution, which was used as a standard. Statistical analyses indicated that there were significant differences in the moisture, protein, fat, crude fiber, ash, and carbohydrate contents of the breads under study ($p = 0.00$), as can be seen in the table, the chemical composition varies with respect to the percentage of substitution. This was observed in loaves of bread made with wheat flour substituted by sacha inchi flour (*Plukenetia volubilis L.*) [24], green banana [25], potato and corn [26], kiwicha (*Amaranthus caudatus Linnaeus*) [27], and flaxseed hulls (*Linum usitatissimum L.*) [39] developed in other studies.

Formulation F1 had a higher protein content than the other formulations and a lower content than F0. The percentage of protein decreased in relation to the percentage of wheat flour substitution because PC, PS, and PP have a lower protein content [12] than that reported for the commercial wheat flour used (10.8%). This behavior coincides with that published by Zuleta *et al*. [25] for a loaf of bread that included 50% green banana flour and with what was reported in partial substitutions of wheat flour with potato flour (6 and 5%) and corn flour (6% and 5%) [26]. The protein percentages found in the formulations in this study are higher than those reported in two bread formulations, the first made with a 50:50 mixture of green banana flour and commercial flour, and the second made with a mixture of 25% carob (*Ceratonia siliqua L.*) and the rest commercial wheat flour, whose protein content was 4.70% and 5.20%, respectively [25], and lower than the protein content reported in breads with 16.05-13.85% tapirama flour (*Phaseolus lunatus*) [28], 9.32-11.37% pituca flour [29], 10.8-13.10% flour corn and potato to [26], with kiwicha flour, 8.0-9.7% [27] and with flour from an extruded sacha inchi cake [24]

The fat content in the formulations was slightly higher than in formulation F0 (2.1 g). The higher the substitution, the higher the fat content in the formulations; this behavior coincides with breads made with partial substitution of up to 20% wheat flour with kiwicha flour [27], with 30 to 70% tapirama flour [28], and in breads with 6.3-25% sacha inchi extruded pulp powder. The slightly similar fat content between formulations may be due to the fact that the PS content is the same (10%).

With regard to moisture content, the greater the substitution of HT with a mixture of mango powders, the higher the percentage of moisture. This behavior coincides with that reported in breads made with green banana flour (50%) and carob powder [25], in breads with potato flour and corn flour [26], in bread with added kiwicha flour [27], and in bread enriched with extruded sacha inchi cake [13]. This increase in moisture content with respect to PC, PS, and PP is due to the fact that both the peel and the seed have a higher dietary fiber content that traps moisture and therefore increases water absorption, due to the interaction between water and hydroxyl groups of the carbohydrates that form dietary fiber and their hydrogen sources. It should be noted that, during kneading, the water needed to prepare the bread dough increased in the presence of PC, PP, and PS [33]. Compared to formulation F0, formulations F1 and F3 in this study have a higher carbohydrate content. The greater the substitution of wheat flour with a mixture of PC, PP, and PS, the higher the carbohydrate content of the formulations. The percentages of carbohydrates found in the bread formulations are similar to those reported by Obregón *et al*. [26] in breads made with potato flour and corn flour and in bread with added kiwicha flour [27].

Table 3. *Proximal composition of sliced bread with various levels of wheat flour substitution by mixtures of powdered rind, pulp, and seeds of Creole mango (Mangifera indica L.)**

Característica (%)	Formulaciones				
	F0	F1	F2	F3	F4
Humedad	19.6	20.41±0.23^{a}	20.00±0.59^{b}	24.74±0.19^{c}	21.67±0.03^{d}
Cenizas	1.4	0.68±0.17^{a}	0.57±0.18^{b}	0.62±0.63^{c}	0.79±0.19^{d}
Proteínas	8.3	5.95±0.78^{a}	5.78±0.46^{ab}	5.63±0.734^{ab}	5.20±0.70^{b}
Grasa	2.1	2.26±0.53^{a}	2.32±0.89^{b}	2.35±0.16^{bc}	2.47±0.02^{c}
Fibra Cruda	4.2	5.60±0.79a	5.74±0.28b	6.36±0.84^{c}	6.68±0.80^{d}
Hidratos de Carbono	64.4	65.12±0.18^{a}	65.67±0.06^{b}	60.49±0.46^{c}	63.19±0.94^{d}

* Different letters indicate significant differences, according to Tukey's test at 95%.
Source: *Own elaboration*, 2025

Dietary fiber content

The analysis of variance found a significant difference in the content of dietary fiber, soluble dietary fiber, and insoluble dietary fiber with respect to the substitution of wheat flour with the mixture of PC, PP, and PS ($p<0.05$). The total dietary fiber values found in the formulations with partial substitution of wheat flour by the mixture of peel, pulp, and seed powders were higher than the base formulation (F0) and lower than those reported by Escobar-Paz [30], who substituted 10% of wheat flour with Kent mango peel flour. The total fiber content in formulation F1, with 12.5% substitution (2.5% PC, 7.5% PP, and 2.5% PC), was higher than that found in bread with 10% HT substitution with cocoa husk flour made by Noreña-Merina [31]. The amount of total dietary fiber in all treatments was higher than that reported in a bread formulation with a partial substitution of 30% wheat flour with a mixture of quinoa flour (*Chenopodium quinoa Willd*, 12.75%) and brown rice (17.24%) made by Holguín & Vélez [32]. Table 4 shows that formulations F3 and F4 had the highest total dietary fiber content, as they contain a higher amount of PC, whose fiber content (51.89%) is higher than the 31.92% provided by PS [12, 33].

Table 4. *Dietary fiber content of sliced bread with various levels of wheat flour substitution with mixtures of powdered rind, pulp, and seeds of Creole mango (Mangifera indica L.)**

Formulaciones	Fibra Dietética Total	Fibra Dietética Insoluble	Fibra Dietética Soluble
F0	3.65	2.80	0.84
T1	4.64 ± 0.14^{b}	3.30 ± 0.10^{d}	1.35 ± 0.04^{a}
T2	4.60 ± 0.01^{b}	3.783 ± 0.01^{b}	0.81 ± 0.02^{c}
T3	4.34 ± 0.02^{c}	3.58 ± 0.01^{c}	0.77 ± 0.03^{c}
T4	4.85 ± 0.01^{a}	3.92 ± 0.01^{a}	0.92 ± 0.03^{b}

* Different letters indicate significant differences, according to Tukey's test at 95%.
Source: *Own elaboration*, 2025

Total phenols

There were significant differences in total phenol content, expressed as mg AGE/g, between the samples from the treatments in this study. Table 5 shows that the incorporation of a mixture of 4.0% PC, 7.5% PP, and 2.5% PS% showed the highest total phenol value, 10,386 mgGAE/g. As can be seen, the content of these bioactive compounds increases with the percentage of substitution of the mixture of peel, pulp, and seed powders. This behavior coincides with that reported in cookies made with mango peel flour [33, 34, 21, 35] *and* mango seed flour [36]. mango [21,35, 36], cake with bone powder [22], muffins with peel [37], bread with flaxseed peel [39]. The total phenolic content values found in this research are higher than those reported in bread containing 5% mango peel flour, 7.57 mgEGA/g, developed by *Pathak et al.* [38], *and* 8.1 mgEGA/g developed by Sęczyk *et al.* [39] with flaxseed husks. These authors argue that although fortification with phenol-rich ingredients is commonly used to promote cereal-based functional properties, there are many factors that affect its efficiency and biological effects. Processes applied during dough and bread production, such as mixing, fermentation, and baking, can significantly affect the content and activity of phenols.

Table 5. *Total phenol content of loaves of bread with varying levels of wheat flour replacement by mixtures of powdered shells, pulp, and seeds of Creole mango (Mangifera indica L.)**

Formulaciones	Fenoles Totales, mgEGA/g
F0	0.58
T1	15.42 ± 0.06^{c}
T2	16.49 ± 0.02^{b}
T3	28.33 ± 0.06^{a}
T4	27.06 ± 0.14^{d}

* Different letters indicate significant differences, according to Tukey's test at 95%.
Source: *Own elaboration*, 2025

Sensory evaluation

Table 6 shows the results of the evaluation of aroma, flavor, texture, and overall appearance, using a 9-point hedonic scale. As can be seen in the data, the greater the substitution of wheat flour with mango flour, the lower the perception of aroma, flavor, texture, and overall appearance in the formulations. The aroma and flavor of the bread changed slightly with the substitution of HT with the mixture of PC, PP, and PS. With greater substitution, the flavor was intense and unpleasant in the formulations due to the high content of polyphenols and tannins present in the peel and seed. Therefore, ratings below the optimal level of acceptance were obtained, This coincides with the findings reported by Sęczyk *et al.* [39]. Regarding aroma, the formulation with the lowest substitution (F1) received ratings above the optimal level of acceptance. This is consistent with reports on breads made with corn and potato flour [26] and with the findings published by Gracia-Cisneros *et al*. [29] on bread made with pituca flour. The F1 formulation received a rating of 7 (moderately liked).

While the other formulations were rated as "I don't like it very much," this assessment of taste perception differs from that reported for breads made with corn and potato flour [26], bread with added kiwicha flour [27], and breads with added green banana flour [25]. The sensory perception of the texture of the breads developed in this research, as assessed by the panel of tasters, coincides with that reported for pituca flour [29]. The sensory perception of the panel of tasters regarding the overall appearance indicates that in bread formulations with a higher substitution of wheat flour, there was less acceptance of this attribute, as can be seen in formulation F1, which was the best evaluated. This behavior is similar to that published by Dominguez-Zarate *et al*. [5] in breads with added ramón flour (*Brosimum alicastrum*).

Table 6. *Sensory evaluation of sliced bread with varying levels of wheat flour substitution with mixtures of powdered rind, pulp, and seeds of Creole mango (Mangifera indica L.)**

Formulaciones	Aroma	Sabor	Textura	Apariencia general
F0	9.13	9.48	9.43	9.41
F1	7.2 ± 0.95^{a}	7 ± 1.0^{c}	7.2 ± 0.84^{d}	7.6 ± 0.54^{a}
F2	7 ± 0.86^{d}	6.8 ± 0.47^{a}	6.8 ± 0.84^{c}	6.8 ± 1.09^{c}
F3	6.8 ± 1.16^{c}	6.6 ± 0.89^{d}	6.6 ± 1.14^{b}	6.6 ± 0.55^{b}
F4	6.4 ± 0.55^{b}	6.4 ± 0.55^{b}	6.4 ± 0.89^{a}	6.4 ± 0.59^{d}

* Uncommon letters indicate significant differences, according to Tukey's test at 95%.
Source: *Own elaboration*, 2025

CONCLUSIONS

There was a significant effect on the functional physicochemical and sensory properties of partially replacing wheat flour with Creole mango flour.

The higher the substitution, the lower the protein content, while moisture, fat, and crude fiber increased in the four bread formulations in this study. Formulation F1 was superior in protein content (5.95%), while formulation T4 had higher total dietary fiber (4.85%) and phenols (27.06 mgEGA/g).

The higher the substitution, the lower the sensory evaluation of aroma, flavor, texture, and overall acceptance that the tasters had of the formulations. However, the bread formulation with the highest score was formulation F1 with 12.5% wheat flour due to the mixture of husk, seed, and pulp flour.

According to the results of this research, the powders obtained from the pulp, peel, and seeds of the Creole mango from the Mixtec region can be considered a functional substitute for wheat flour, as they have a high potential to promote health in bread consumers who may or may not have a chronic disease.

Combinations of powders from the peel, pulp, and seeds of Creole mangoes can be used to make baked goods with good nutritional quality and physicochemical, functional, and sensory characteristics that are acceptable to the general population. This consideration will be important for future research.

One proposed line of research will be based on the development of functional ingredients such as flours, powders, and extracts rich in dietary fiber and antioxidants obtained from the peel and seed of Creole mango to enrich existing products and make them functional foods.

In addition, evaluating the functionality of these ingredients in different food matrices such as baked goods, dairy products, beverages, jams, among others, would be another line of future research that would allow testing their effectiveness during processing, as well as during shelf life.

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