BRAZILIAN JOURNAL OF FOOD TECHNOLOGY

ISSN 1981-6723
Online version

ORIGINAL ARTICLE

Dietary fiber, polyphenols and sensory and technological acceptability in sliced bread made with mango peel flour

Fibra alimentar, polifenóis e aceitabilidade sensorial e tecnológica em pães fatiados elaborados com farinha de casca de manga

Cesar Moreno-Rojo[1]*, Luz Maria Paucar-Menacho[1], Saúl Ricardo Chuqui-Diestra[2], Victor Castro-Zavaleta[1]

[1]Universidad Nacional del Santa, Facultad de Ingenieria, Departamento Académico de Agroindustria y Agronomía, Nuevo Chimbote, Ancash - Perú.
[2]Universidad Nacional San Cristóbal de Huamanga, Facultad de Ingeniería Quimica y Metarlurgia, Departamento Académico de Ingeniería Química, Ayacucho - Peru.

***Corresponding Author:** Cesar Moreno-Rojo, Universidad Nacional del Santa, Facultad de Ingenieria, Departamento Académico de Agroindustria y Agronomía, Av. Universitaria, s/n, Urb. Bella Mar, Nuevo Chimbote, Ancash - Perú, e-mail: cmoreno@uns.edu.pe

Cite as: Moreno-Rojo, C., Paucar-Menacho, L. M., Chuqui-Diestra, S. R., & Castro-Zavaleta, V. (2024). Dietary fiber, polyphenols and sensory and technological acceptability in sliced bread made with mango peel flour. *Brazilian Journal of Food Technology*, *27*, e2023073. https://doi.org/10.1590/1981-6723.07323

Abstract

The use of mango peel, an agro-industrial byproduct rich in bioactive compounds, was the subject of this study, seeking an innovative application in the manufacture of sliced bread. This process is proposed as a way to create a nutritious and healthy food, rich in dietary fiber and total polyphenols. Mango peel flour of the Kent variety was obtained by drying, grinding, and sieving. An experimental design through the Response Surface Methodology (RSM) with a central composite rotatable design, was used to evaluate the impact of mango peel flour (5% to15%) and ascorbic acid (20 to100 ppm) in the bread formulation. Technological, sensory evaluations, and determinations of polyphenols and dietary fiber were carried out, using standard methods. The results showed that mango peel flour and ascorbic acid influence the texture of the bread, with formulations of 10% mango peel flour and 60 ppm ascorbic acid obtaining the best sensory ratings in color, appearance, aroma, and texture. The mango peel flour increased the fiber up to 13.25 g/100 g and polyphenols up to 1.187 g AGE/g dry weight (DW) in the sliced bread. These findings suggest that the inclusion of mango peel flour improves the nutritional and sensory quality of bread, showing its potential as a functional ingredient in the food industry.

Keywords: Fruit peel waste; Sliced bread; Fiber-rich bread; Formulation; Agroindustry; Waste recovery.

Resumo

O aproveitamento da casca da manga, subproduto agroindustrial rico em compostos bioativos, foi objeto deste estudo, buscando uma aplicação inovadora na fabricação de pães de forma. Este processo é proposto como forma de criar um alimento nutritivo e saudável, rico em fibras alimentares e polifenóis totais. A farinha de casca de manga da variedade Kent foi obtida por secagem, moagem e peneiramento. Um desenho experimental por meio da Metodologia de Superfície de Resposta (MSR) com um projeto rotativo composto central, foi utilizado para avaliar o impacto da farinha de casca de manga (5% a15%) e do ácido ascórbico (20 a 100 ppm) na formulação do pão. Foram realizadas avaliações tecnológicas, sensoriais e determinações de polifenóis e fibras alimentares, utilizando métodos padronizados. Os resultados mostraram que farinha de casca de manga e ácido ascórbico influenciam na textura do pão, com formulações de 10% de farinha de casca de manga e 60 ppm de ácido ascórbico, assim obtendo as melhores notas sensoriais em cor, aparência, aroma e textura. A farinha de casca de manga aumentou a quantidade de fibra até 13,25 g/100 g e de polifenóis até 1,187 g AGE/g (peso seco) no pão de forma. Esses achados sugerem que a inclusão de farinha de casca de manga melhora a qualidade nutricional e sensorial do pão, mostrando seu potencial como ingrediente funcional na indústria alimentícia.

Palavras-chave: Resíduos de cascas de fruta; Pão de forma; Pão rico em fibras; Formulação; Agroindústria; Aproveitamento de resíduos.

Highlights

- Mango peel flour increased the polyphenols and dietary fiber of the sliced bread
- 10% mango peel flour resulted in a dietary fiber of 11.98 g/100 g in the sliced bread
- 10% mango peel flour and 100 ppm ascorbic acid improved sensory characteristics

1 Introduction

In the mango (*Mangifera indica* L.) agro-industry, a variety of products such as frozen pulp, nectar, juices, and other foods are produced (Wall-Medrano et al., 2020), generating approximately 200,000 tons of biomass during its processing. In addition, large quantities of agro-industrial waste and byproducts such as peels, pits, and discarded mangoes are collected (Teshome et al., 2023; Tirado-Kulieva et al., 2021). However, this biomass is not efficiently utilized, being primarily used as livestock feed or simply discarded in open areas. This practice increases environmental pollution and affects ecological sustainability (Wongkaew et al., 2021).

Mango peel (MP) constitutes 15% to 20% of the total weight of the fruit, and is packed with bioactive compounds such as pectin, cellulose, hemicellulose, and carotenoids (Zhang et al., 2020). Its importance lies in the potent antioxidant and therapeutic activity of these compounds, which are valuable in the food, nutraceutical, and pharmaceutical industries (León-Roque et al., 2023). Additionally, MP is a potential source of polyphenols and compounds such as flavonol O- xanthone C-glycosides, gallotannins, and derivatives of benzophenone, all with bioactive properties (Hashem et al., 2020; Sánchez-Camargo et al., 2019; Lastra Ripoll et al., 2021). MP is also rich in dietary fiber, containing between 5 and 11% of pectin, depending on the fruit cultivar and extraction methods. This expands its usefulness as a functional ingredient in processed foods, providing health benefits (Kaur et al., 2021).

The use of MP in food product development is an innovative pathway for industries processing mangoes, potentially replacing conventional ingredients or additives (Marçal & Pintado, 2021). Jayalaxmi et al. (2018) produced MP flour that contained 69.86% dietary fiber and 4.5 g of total polyphenols per 100 g, with antioxidant activity. Yengle-Perez & Layza-Negreiros (2021) investigated the acceptability of white bread in which wheat flour was partially replaced by MP flour, obtaining positive results in terms of color, flavor, and aroma. Meanwhile, Ajila et al. (2008) found that replacing wheat flour in cookies, increasing the content of MPF in a range of 5 to 20%, decreased the stability and the expansion capacity of the dough, due to a lower gluten content and a higher level of dietary fiber.

Bread, consumed globally, provides valuable nutrients, contributing to the intake of lipids, carbohydrates, and proteins. A strategy to fortify bakery products and improve certain nutritional deficits is to use alternative flours that increase the amount of dietary fiber and polyphenol content (Pourafshar et al., 2015). However, there is scant research that has employed mango peel flour from the Kent variety (Peru) for the production of bread. Therefore, the present study focused on utilizing mango peel flour (Kent variety) to produce sliced bread, to provide a source of dietary fiber and total polyphenols, and evaluating its sensory acceptability and technological characteristics.

2 Materials and methods

2.1 Raw materials and inputs

The Kent variety mangoes were sourced from a mango nectar processing agroindustry, located in the Moro district (Peru) (9°08'20"S 78°10'57"W). Ascorbic acid (AA) (E-300), powder bank of Chemicals Peru, Nicolini special wheat flour, enzymatic improver (BakeZyme®), emulsifier (E-322, Lecithin), vegetable shortening, fresh yeast (Fleischmann), anti-mold (calcium propionate), salt, sugar, and water were obtained from local supermarkets in the Nuevo Chimbote district, Peru.

2.2 Obtaining Mango Peel Flour (MPF)

The mango peel was dried using a Tray Dryer (TORRH model SBT-10XL, USA CHINA) at 55 °C for 4 h, then it was ground and sieved through a Vibratory equipment (SOILTEST model CL-3050-8) with 5 plates (No. 16 to 60 mesh). The flour was packaged in high-density polyethylene bags, lined with aluminum foil, and stored at room temperature (20 °C to 24 °C) (Pathak et al., 2016).

2.3 Bread making with MPF

In the making of bread with MPF, the percentage of MPF and AA was evaluated through the Response Surface Methodology (RSM) with a central composite rotatable design. The symbols and codes of factor levels for these variables are shown in Table 1.

Table 1. Levels of independent variables in the experimental design (CCRD) 22 including 4 trials in axial conditions and 3 repetitions at the central point.

Code	Independent Variables	Levels				
		-α	-1	0	+1	+α
X_1	MPF (%)	5	6.5	10	13.5	15
X_2	AA (ppm)	20	32	60	88	100

Where | α | = ±1.41; MPF: mango peel flour; AA: ascorbic acid.

In turn, each experimental trial of the bread was formulated according to the methodology described by Nasir et al. (2020) in Table 2. For the weighing, an analytical scale (ADAM model PW-254) was used, and the ingredients were mixed in a mixer (NOVA model K23) with speeds, in two stages, of 900 and 1800 RPM, and with times of 8 and 12 minutes respectively; then, the dough was divided into 650 g portions and rolled, and put in an aluminum pan ($10 \times 10 \times 30$ cm^3). Finally, they were baked, at 140 °C for 45 minutes, in a convection rotary oven (NOVA model MAX 1000) and the breads were cut in a slicer (NOVA model Standard). The bread preparations with MPF were called MPFB (Mango Peel Flour Bread).

Table 2. Control formulation for sliced bread (F0) and substitution proportion between MPF and AA (F1-F11).

Formulations	Ingredients									
	X1: MPF (%)	X2: AA (ppm)	a'	b'	c'	d'	e'	f'	g'	h'	i'
F0	0	0	100	1	0.3	2	8	50	2	10	1
F1	6.5	32	93.5	1	0.3	2	8	50	2	10	1
F2	13.5	32	87	1	0.3	2	8	50	2	10	1
F3	6.5	88	93.5	1	0.3	2	8	50	2	10	1
F4	13.5	88	86.5	1	0.3	2	8	50	2	10	1
F5	5.0	60	95	1	0.3	2	8	50	2	10	1
F6	15.0	60	85	1	0.3	2	8	50	2	10	1
F7	10.0	20	90	1	0.3	2	8	50	2	10	1
F8	10.0	100	90	1	0.3	2	8	50	2	10	1
F9	10.0	60	90	1	0.3	2	8	50	2	10	1
F10	10.0	60	90	1	0.3	2	8	50	2	10	1
F11	10.0	60	90	1	0.3	2	8	50	2	10	1

X1: mango peel flour (%); X2: ascorbic acid (ppm); a': wheat flour (%); b': enzyme improver (%); c': anti-mold (%); d': salt (%); e': sugar (%); f': water (%); g': yeast (%); h': shortening (%); i': emulsifier (%).

2.4 Determination of technological characteristics

The specific volume was calculated using the American Association of Cereal Chemists (2000a) method 10-05, as proposed by Renoldi et al. (2022). To evaluate the texture profile, the American Association of Cereal Chemists (2000b) procedure 74-10 A was followed, using the Brookfield TexturePro CT V1.4 Build 17 equipment, a TA4/1000 probe was used with a penetration of 10 mm and a test speed of 0.5 mm/s. All bread samples were cut into 2.5 cm slices and allowed to rest for 5 minutes at equilibrium room temperature before the test (Prokopov et al., 2018).

The values of hardness, firmness, and chewability were calculated using the Texture Pro CT Standard Edition software. Sensory Chewability (mJ) was defined as the force required to disintegrate a solid food until it is ready to be swallowed and was determined from the product between firmness, cohesiveness, and elasticity (Campderrós, 2017).

2.5 Sensory analysis

The MPFBs were estimated by 100 untrained panelists of both sexes and different age groups, and the appearance, crust and crumb color, aroma, texture, flavor, and purchase intent were evaluated. The sensory assessment was developed taking into account a 9-point hedonic scale (1=Do not like it much to 9=Like it a lot) (Lim et al., 2022). The purchase intention was determined on a 5-point scale (1= Would not buy it to 5= Definitely would buy it). This analysis is framed within the UNS Code of Research Ethics, approved by Resolution Nº 560-2017-CU-R-UNS.

2.6 Determination of polyphenols

The total polyphenol content (TPC) of MPFB was determined using the Folin Ciocalteu colorimetric method modified by Lucas et al. (2022). 0.25 g of the sample was added to 10 mL of acidified 80:20 (v/v) methanol/water solution at pH 2 in agitation for 30 min. It was then centrifuged at 3500 rpm for 10 min and the supernatant, referred to as extract A, was separated. The same procedure was repeated to obtain another extract, B. Extracts A and B were combined for the determination of total polyphenols. 500 µL of the extract was mixed with 50 µL of Folin-Ciocalteu, shaken, and left to stand for 5 min, then 100 µL of Na_2CO_3 and 800 µL of distilled water were added, and it was incubated in the dark at room temperature for 1.5 h. Subsequently, 200 µL of each sample was placed in microplate wells and measured at 739 nm in a UV-VIS spectrophotometer (Evolution™ 260 Bio, USA). A standard curve with gallic acid (Sigma Aldrich, USA) was previously performed. The content of polyphenols was expressed as mg of gallic acid in 100 g of sample.

2.7 Determination of dietary fiber

The enzymatic gravimetric method of AOAC 991.43 was used to carry out the analysis of dietary fiber (Ramlan et al., 2021). 1 g of MPFB was used, which was heated at 100 °C for 1 hour with Termamyl, and then digested with protease at 60 °C for 1 hour. To remove starch and protein from the sample, amyloglucosidase was used at 60 °C for 1 hour. The insoluble dietary fiber (IDF) was filtered, and the residues were washed with warm distilled water. To determine soluble dietary fiber (SDF), the filtrate solution and washing water were precipitated with 95% ethanol, filtered, and the resulting precipitate was dried. The residues of SDF and IDF were adjusted for protein, ash, and blank for the final calculation of SDF and IDF values. Total dietary fiber (TDF) was determined by summing SDF and IDF.

2.8 Statistical analysis

The results were evaluated using the statistical software Statistica 12.0 (StatSoft, Inc., Tulsa, OK, USA). Regression coefficients, analysis of variance (ANOVA), and response surfaces were constructed to determine the effect of the independent variables, with a significance level of 5% ($p < 0.05$).

3 Results and discussion

3.1 Determination of technological characteristics of MPFB

Table 3 presents the data corresponding to different formulations of the MPF-based bread product, and texture profile and specific volume analyses were conducted to evaluate their physical and organoleptic properties. It can be observed that, for all formulations, increasing the concentration of MPF (X_1: 5% to 15%) while maintaining the concentration of AA (X_2: 20 to 100 ppm) results in an increase in the texture profile and specific volume properties. In particular, the formulation with the highest concentration of MPF and AA (15%, 100 ppm) exhibits the highest values in all texture profile properties and specific volume, with a hardness of 6.82 N, firmness of 3.95 N, chewability of 36.19 mJ, and specific volume of 4.77 cm^3/g.

Ajila et al. (2008) demonstrated that the MPF influences the volume of bread, gradually decreasing it as the amount of flour used increases. This phenomenon of reduced specific volume was also reported by Ktenioudaki & Gallagher (2012) when adding cereal fiber to bread making. Han et al. (2019) pointed out that the inclusion of MPF in the bread formulation results in the dilution of glutenin. This effect can lead to inadequate gluten network development during kneading, which in turn causes the release of fermentation gas and a decrease in the specific volume of the bread. Furthermore, considering the high dietary fiber content of the flour, these fibers tend to deposit around the gas cells during fermentation, forming physical barriers that limit cell development in the final stages of fermentation.

The formulation with the lower concentration of AA (20 ppm) and the lowest concentration of MPF (5%) exhibited the lowest values in all texture profile properties and specific volume, with a hardness of 4.44 N, firmness of 2.74 N, chewiness of 24.82 mJ, and specific volume of 4.66 cm^3/g.

Table 3. Responses obtained from the texture profile of breads with the addition of MPF and AA, for formulations between F0 and F11.

Formulations	X_1: MP (%)	X_2: AA (ppm)	Texture profile analysis			Specific volume
			Hardness (N)	Firmness (N)	Chewiness (mJ)	(cm^3/g)
F0	-	-	2.81 ± 0.014	1.83 ± 0.057	16.30 ± 0.021	4.87 ± 0.158
F1	6.5	32	5.05 ± 0.141	2.75 ± 0.041	24.28 ± 0.12	4.60 ± 0.0387
F2	13.5	32	7.22 ± 0.240	3.74 ± 0.071	30.17 ± 0.057	3.81 ± 0.0995
F3	6.5	88	4.16 ± 0.014	2.33 ± 0.035	20.58 ± 0.092	4.68 ± 0.0849
F4	13.5	88	6.20 ± 0.049	3.31 ± 0.014	27.99 ± 0.141	4.28 ± 0.641
F5	5.0	60	3.51 ± 0.721	2.22 ± 0.035	19.64 ± 0.057	4.77 ± 0.202
F6	15.0	60	6.82 ± 0.021	3.95 ± 0.134	36.19 ± 0.021	4.77 ± 0.114
F7	10.0	20	4.44 ± 0.042	2.74 ± 0.042	24.82 ± 0.134	4.66 ± 0.127
F8	10.0	100	4.02 ± 0.035	2.55 ± 0.141	23.37 ± 0.057	4.58 ± 0.085
F9	10.0	60	2.43 ± 0.042	1.63 ± 0.042	14.41 ± 0.064	4.68 ± 0.125
F10	10.0	60	2.64 ± 0.021	1.75 ± 0.057	15.41 ± 0.028	4.63 ± 0.0235
F11	10.0	60	2.64 ± 0.007	1.82 ± 0.028	16.33 ± 0.064	4.58 ± 0.159

Values are mean ± standard deviation. Analysis was done in triplicate. MPF: mango peel flour; AA: ascorbic acid; Hardness (N); Firmness (N); Chewiness (mJ); specific volume (cm^3/g).

In Figure 1, the analysis of the central composite rotatable design is shown, where the effect of two factors, MPF and AA, on the response of hardness, firmness, and chewability of the MPFB, was evaluated. Figures 1A, 1B, and 1C show the optimal response surface plots for hardness, firmness, and chewiness of the white bread, where it was found (according to Equations 2, 3, and 4) that the optimal concentrations were 8.7%, 9%, and 8.71% of MPF and 60 ppm, 63.9 ppm, and 60 ppm of AA, respectively.

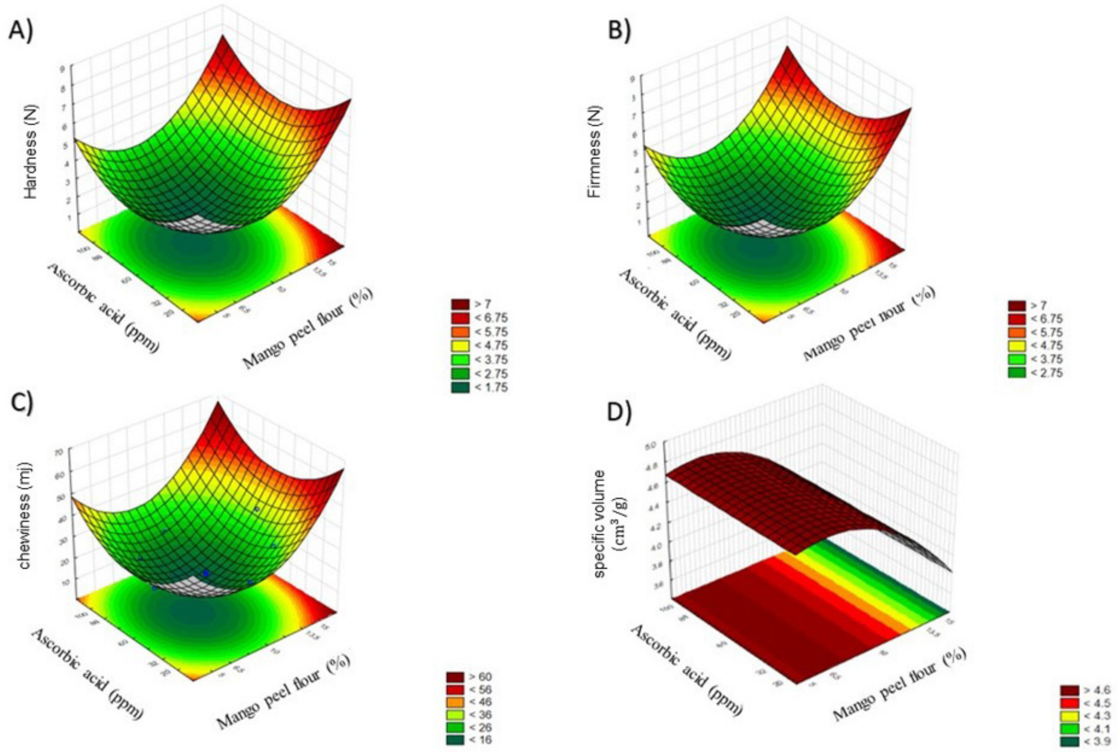

Figure 1. Response surface plots for hardness, firmness, chewiness, and specific volume of breads as a function of MPF (%) and AA (ppm). (A) Response surfaces for sliced bread hardness; (B) Response surfaces for sliced bread firmness; (C) Response surfaces for sliced bread chewiness; (D) Response surfaces for sliced bread volume.

A decrease in specific volume was observed when MPF and AA were added, and the values obtained for the formulations were within the range of 3.86 (F2) to 4.68 (F3 and F9). However, according to the statistical analysis, the concentration of AA was not significant ($p > 0.05$). F5 and F6 had values close to F0 ($p > 0.05$), while the other formulations had lower values.

Table 3 presents the values of structure and specific volume of the breads, where it can be observed that breads F2, F4, and F6 exhibited significantly higher hardness and firmness values compared to the control bread F0 ($p < 0.05$). This increase can be attributed to the absence of gluten in the MPF, as proposed by Ning et al. (2017), to its high phenolic content, to the lower moisture content in the breads, or the interaction between polyphenols and proteins in the dough. Conversely, breads F9 (10% MPF, 60 ppm AA), F10, and F11 showed hardness values similar to the control sliced bread ($p > 0.05$), which is consistent with the results found by Conforti & Davis (2006) who investigated the incorporation of flaxseed and soy flour in bread making, showing that the inclusion of these ingredients affects the volume, texture, and color of yeast bread.

Alvis et al. (2011) found that the hardness of wheat flour bread ranged from 4 to 11 N, while a sample of bread with 30% sweet potato flour had a hardness of 3.92 N, equivalent to 400 gf. In this study, breads F9 (10% MPF, 60 ppm AA), F10, and F11 approached the value of 2.81 N for the hardness of bread with 100% wheat flour, while the other treatments recorded higher values, ranging from 4 to 7 N. Ulziijargal et al. (2013) indicated that the ingredients in bread create cohesion among themselves, resulting in lower moisture content and reduced intramolecular association, thus leading to increased hardness and firmness. Similarly, Wang et al. (2002) reported an increase in hardness and stickiness values with the increase in green tea extract content in bread. This situation is caused by the interaction between polyphenols, enzymes, and yeast activity.

The chewiness of the bread crumb varies between 14.4 and 36.19 mJ (Table 3). According to Ordoñez et al. (2012), sliced bread with a 30% substitution of sweet potato flour has a chewiness value ranging from approximately 37.6 to 110.8 mJ. It is understood that the more chewable bread has a lower value since, from a sensory perspective, it requires more time to chew before swallowing. The specific volume of the control sliced bread obtained in this study (4.87 cm^3/g) is lower than that described by Vega Castro et al. (2018) in breads made with different enzyme formulations, which ranged from 4.76 cm^3/g to 7.84 cm^3/g. Specifically, when comparing it to the specific volume obtained for the formulation of bread made with laccase-xylanase-lipase, which was 5.23 cm^3/g, our control bread had a lower volume.

The predictive models obtained for hardness (N) (R^2=0.92), firmness (N) (R^2=0.97), chewiness (R^2=0.96), and specific volume (R^2=0.87) are presented below using coded factors. Equation 1 shows a linear and quadratic trend of MPF (X_1) and a quadratic trend of AA (X_2), indicating that both factors have effects on the hardness of the sliced bread. Therefore, optimal values of MPF and AA that should be used in bread making can be calculated. Equation 2 shows a linear and quadratic trend of MPF (X_1) and a quadratic trend of AA (X_2), noting that both factors affect the firmness of the sliced bread. Therefore, optimal values of MPF and AA that should be used in bread making can be calculated. Equation 3 shows a linear and quadratic trend of MPF (X_1) and a quadratic trend of AA (X_2), expressing that both factors affect the chewability of the sliced bread. Therefore, optimal values of MPF and AA that should be used in bread making can be calculated. Equation 4 shows a linear and quadratic trend, but only for the effect of MPF (X_1) on the specific volume of the sliced bread. This implies that by adding higher percentages of MPF (from 5 to 15%), lower volumes (less than 4.6 cm^3/g) are obtained in the bread.

$$\text{Hardness}=2.57+2.22X_1-3.08X_1^2+2.14X_2^2 \quad (1)$$

$$\text{Firmness}=1.73+1.10X_1+1.44X_1^2-0.28X_2+0.99X_2^2 \quad (2)$$

$$\text{Chewiness}=15.38+9.18X_1+12.41X_1^2+8.51X_2^2 \quad (3)$$

$$\text{Specific volume}=4.63-0.53X_1-0.29X_1^2 \quad (4)$$

3.2 Sensory evaluation

Table 4 shows the mean ratings assigned by the panelists to each formulation. Figure 2 displays the visual appearance of the formulations for sensory evaluation. It was observed that models F4 and F11 obtained the highest scores for color ($p < 0.05$), appearance ($p < 0.05$), aroma ($p < 0.05$), and texture ($p < 0.05$) among the treatments. Specifically, F11 received the highest approval rating from the panelists (89.40 ± 18). Additionally, F6 and F7 showed values close to F0 in terms of color, appearance, aroma, and texture. According to the statistical analysis, the addition of MPF and AA had a significant effect on the color and texture of the bread, achieving a maximum sensory score of 7% MPF - 60 ppm AA and 5% MPF - 88 ppm AA, respectively.

Table 4. Acquired responses from the sensory evaluation of breads with the addition of MPF and AA, for formulations between F0 and F11.

Run	MPF (%)	AA (ppm)	Color	Appearance	Aroma	Texture	Flavor	Purchase intent
F0	-	-	5.50 ± 1.6	5.69 ± 1.5	5.78 ± 1.8	5.81 ± 1.4	4.91 ± 1.9	53.20 ± 1.8
F1	6.5	32	4.78 ± 1.74	5.06 ± 1.62	6.00 ± 1.8	5.06 ± 1.6	4.38 ± 1.7	49.40 ± 2.2
F2	13.5	32	6.22 ± 1.8	6.28 ± 1.8	6.22 ± 1.5	6.31 ± 1.6	6.03 ± 1.9	71.80 ± 2.2
F3	6.5	88	5.13 ± 2.1	5.25 ± 1.8	5.97 ± 1.3	5.69 ± 1.5	5.16 ± 1.9	57.60 ± 2.0
F4	13.5	88	6.53 ± 1.7	6.63 ± 1.7	6.34 ± 1.4	6.78 ± 1.7	6.59 ± 2.1	80.60 ± 2.4
F5	5.0	60	4.13 ± 2.0	4.28 ± 1.7	5.00 ± 1.4	4.97 ± 1.1	4.28 ± 1.6	46.80 ± 2.0
F6	15.0	60	5.44 ± 1.7	5.50 ± 1.8	5.81 ± 1.7	5.66 ± 2.0	5.50 ± 2.1	60.00 ± 2.6
F7	10.0	20	5.50 ± 1.6	5.59 ± 1.7	6.00 ± 1.6	5.88 ± 1.6	5.59 ± 1.6	63.80 ± 2.0
F8	10.0	100	6.26 ± 1.9	5.92 ± 1.8	5.95 ± 1.7	6.10 ± 2.0	6.28 ± 1.9	67.00 ± 2.6
F9	10.0	60	6.25 ± 2.0	5.84 ± 2.0	5.81 ± 1.8	6.00 ± 2.0	6.22 ± 1.9	66.80 ± 2.6
F10	10.0	60	6.28 ± 1.6	6.10 ± 1.9	6.10 ± 1.6	6.20 ± 1.8	6.31 ± 1.6	68.00 ± 2.2
F11	10.0	60	7.69 ± 1.6	7.66 ± 1.4	7.16 ± 1.3	7.75 ± 1.4	7.34 ± 1.6	89.40 ± 1.8

Values are mean ± standard deviation. Analysis was done in triplicate. MPF: mango peel flour; AA: ascorbic acid; Purchase intent (%).

A different behavior was observed in the aroma, as it was independent of the addition of MPF and AA ($p > 0.05$), suggesting that any level of MPF and AA, within the studied ranges, will not lead to a difference in the final product. Appearance was only affected by MPF ($p < 0.05$), with a range of 5% to 6.5% of MPF (Figure 2). Regarding taste, the addition of MPF and AA had a positive influence ($p < 0.05$), with concentrations higher than 5% of MPF and 20 ppm of AA (> F2) improving the flavor of the bread, reaching a maximum sensory score when adding 8% of MPF and 60 ppm of AA. These results differ from those obtained by Fadhel-Weshah & Al-Hafud (2023), who used mango peel powder and found that a replacement proportion of 10% showed higher acceptability in cake production. Additionally, Chen et al. (2019) demonstrated that as the proportion of mango peel powder increases, the brightness and color values of the crumb (a* and b*) tend to increase, as mango peel powder contains reducing sugars and proteins that facilitate the Maillard reaction during high-temperature baking, producing dark brown substances that intensify the color of the bread (Martínez-Girón et al., 2017).

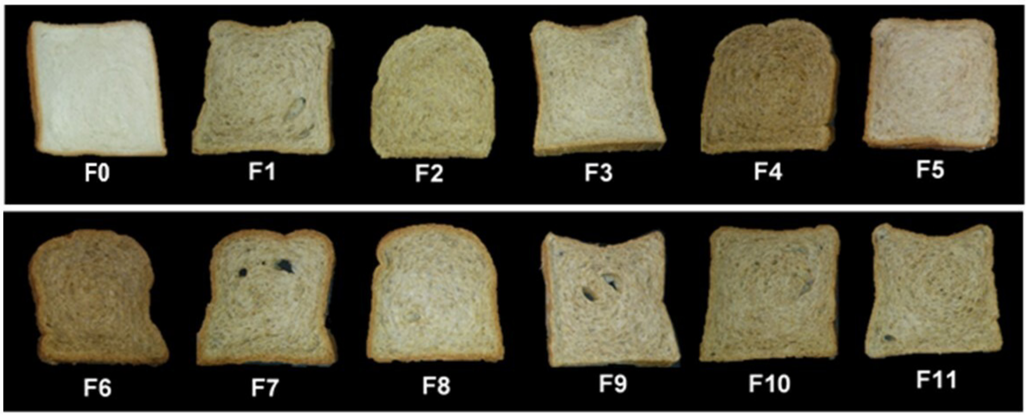

Figure 2. Visual appearance of breads with MPF and AA and control (F0).

3.3 Polyphenol and dietary fiber content

Table 5 shows TPC and TDF in different formulations varying in MPF and AA content. The effects obtained for TPC in all trials ranged from a minimum of 0.576 to a maximum of 1.187 mg GAE/g. However, Ho et al. (2013) obtained 2.04 mg GAE/g for bread with 10% banana peel flour, compared to the control which had 1.39 mg GAE/g. Furthermore, Eshak (2016) evaluated the impact of the partial substitution of wheat flour with banana peels (5% and 10%) in Egyptian "balady" bread, finding that up to 10% banana peel flour resulted in higher phenolic content and dietary fiber, improving its nutritional profile and being sensorially acceptable. Additionally, it should be noted that during the baking process, the initial polyphenol content can decrease by up to 75% (van der Sluis et al., 2001), which may explain why the levels of polyphenols were relatively low in the 11 MPFB treatments. Consequently, all formulations (F1 to F11) of sliced bread with MPF can be classified as high-fiber food (> 6% TDF) (Angulo-López et al., 2022).

According to Figure 3, an increase in the levels of MPF used (from 13.5 to 15%) resulted in an increase in the phenolic content up to 118.70 mg of gallic acid equivalents per 100 g of polyphenols. AA did not show a reaction to the TPC, as demonstrated graphically by the constant green area across the five levels studied. These results are consistent with those obtained by Mayo-Mayo et al. (2020), who reported TPC values between 1.4-3.7 mg/100 g when adding MPF to tortilla chips. Bread with MPF, in addition to being used as a source of fiber, can be considered functional and can help in the treatment of certain pathologies associated with cell oxidation (Izidoro et al., 2023).

The results obtained from the Total Dietary Fiber (TDF) for the different trials showed minimum and maximum values of 8.18 g/100 g and 13.25 g/100 g, respectively. These values are significantly higher than those obtained by Pourfarzad et al. (2013) when enriching bread with 5% coffee husk residue, which resulted in a TDF of 2.95 g/100 g. Additionally, they surpass the results obtained by Gutierrez-Castillo et al. (2023) when using 13.35% quinoa flour and 6.65% tarwi flour in bread production, yielding 5.1 g/100 g of TDF. These values are much lower than the ones achieved by Acosta-Estrada et al. (2014), who used 9% Nejayote solids (NS) in the breadmaking process and obtained up to 54 g/100 g of TDF in composite bread. These values are also comparable to those obtained by Nasution et al. (2012) using 7% banana peel flour, which resulted in higher TDF (14.4 g/100 g), and by García-Ramón et al. (2023), who obtained 13.01 g/100 g of TDF when using 30% Peruvian Andean grains as a replacement for making sliced bread.

Table 5. Responses obtained from total polyphenols and total dietary fiber of the sliced breads with the addition of MPF and AA, for formulations between F0 and F11.

Formulations	X_1: MPF (%)	X_2: AA (%)	Total phenolic content (mg GAE/ 100 g DW)	Total dietary fiber (g/100 g)
F0	-	-	39.2 ± 0.984	3.26 ± 0.517
F1	6.5	32	57.60 ± 0.417	9.49 ± 1.012
F2	13.5	32	107.12 ± 0.628	13.1 ± 0.952
F3	6.5	88	58.3 ± 0.547	8.18 ± 0.845
F4	13.5	88	106.8 ± 0.447	12.80 ± 0.987
F5	5.0	60	44.3 ± 0.385	9.86 ± 0.584
F6	15.0	60	118.7 ± 0.896	13.25 ± 0.897
F7	10.0	20	79.1 ± 0.768	12.09 ± 0.741
F8	10.0	100	81.2 ± 0.825	11.98 ± 0.968
F9	10.0	60	79.6 ± 0.759	12.03 ± 0.879
F10	10.0	60	82.3 ± 0.594	12.04 ± 0.908
F11	10.0	60	81.1 ± 0.628	12.34 ± 0.899

Values are mean ± standard deviation. Analysis was done in triplicate. MPF: mango peel flour; AA: ascorbic acid; Total phenolic content (mg GAE/100 g DW); Total dietary fiber (g/100 g).

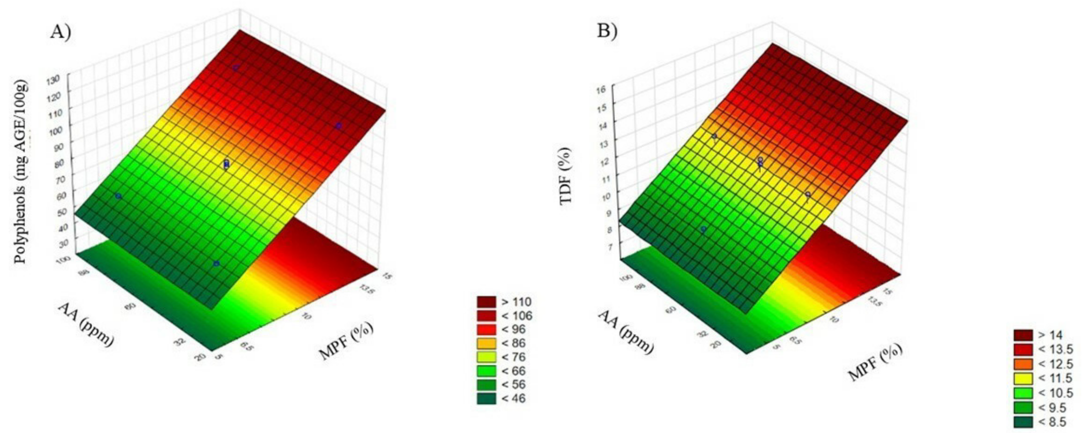

Figure 3. Response surfaces for total phenolic content (A) and total dietary fiber (B) of the sliced bread, based on mango peel flour (MPF, %) and ascorbic acid (AA, ppm) content.

Furthermore, according to the statistical analysis, the presence of AA (20 to 100 ppm) did not have a significant influence on the variable under study. However, adding MPF percentages greater than 13.5% resulted in higher TDF values in sliced bread, with a maximum of 13.25 g/100 g.

Le Bouthillier et al. (2021) mentioned that a food is considered a good source of fiber when it contains between 3% and 6% of this nutrient. Consequently, all formulations (F1-F11) developed for sliced bread fall into the category of high-fiber foods. This suggests their suitability for consumption by individuals looking to meet their daily dietary fiber intake, which is recommended at 14 g/1000 kcal for both children and adults, as indicated by Anderson et al. (2009).

The predictive models obtained for TDF (R^2=0.87) and TPC (R^2=0.99) are presented below using coded factors. Equation 5 shows a linear trend, only for the effect of MPF (X_1) on the TDF of the sliced bread. This implies that by adding higher percentages of MPF (from 5% to 15%), higher fiber contents (up to 13.25 g/100 g) are obtained in bread. Equation 6 shows a linear trend, only for the effect of MPF (X_1) on the TPC of the sliced bread. This implies that by adding higher percentages of MPF (from 5% to 15%), higher polyphenols contents (up to 118.70 mg GAE/100 g DW) are obtained in bread

$$Total\ Dietary\ Fiber\ (TDF)\ =\ 12.14\ +3.26X_1 \quad (5)$$

$$Total\ Polyphenol\ Content\ (TPC)\ =\ 81+50.81X_1 \quad (6)$$

4 Conclusion

In conclusion, the results obtained using the rotating composite central design and response surface methodology demonstrated that the addition of MPF and AA in the production of sliced bread had a significant effect on the technical and sensory characteristics. It is possible to substitute, at F8, up to 10% of wheat flour with MPF and 100 ppm AA in the bread recipe, improving the texture and flavor of the bread and making it a source of polyphenols and dietary fiber. This addition increased TPC by approximately 107% and TDF by almost 267% compared to the F0 formulation (without MPF and AA).

Additionally, the results of the purchase intentions indicate that consumers would be willing to buy bread made with these ingredients. In summary, MPF and AA can be used as functional ingredients in sliced bread manufacturing to enhance its nutritional and sensory properties.

Acknowledgements

The authors would like to express their gratitude to Agroindustrias La Morina, COLECBI SAC, and the Institute of Technological Agroindustrial Research at the National University of Santa (IITA) for their collaboration and support in conducting this study.

References

Acosta-Estrada, B. A., Lazo-Vélez, M. A., Nava-Valdez, Y., Gutiérrez-Uribe, J. A., & Serna-Saldívar, S. O. (2014). Improvement of dietary fiber, ferulic acid and calcium contents in pan bread enriched with nejayote food additive from white maize (Zea mays). *Journal of Cereal Science*, *60*(1), 264-269. http://doi.org/10.1016/j.jcs.2014.04.006

Ajila, C. M., Leelavathi, K., & Prasada-Rao, U. J. S. (2008). Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *Journal of Cereal Science*, *48*(2), 319-326. http://doi.org/10.1016/j.jcs.2007.10.001

Alvis, A., Pérez, L. J., & Arrazola, G. S. (2011). Estudio de propiedades físicas y viscoelásticas de panes elaborados con mezclas de harinas de trigo y de arroz integral. *Información Tecnológica*, *22*(4), 107-116. http://doi.org/10.4067/S0718-07642011000400012

American Association of Cereal Chemists – AACC. (2000a). *AACC method 10-05.* St. Paul: AACC.

American Association of Cereal Chemists – AACC. (2000b). *Procedure 74-10 A.* St. Paul: AACC.

Anderson, J. W., Baird, P., Davis Junior, R. H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V., & Williams, C. L. (2009). Health benefits of dietary fiber. *Nutrition Reviews*, *67*(4), 188-205. PMid:19335713. http://doi.org/10.1111/j.1753-4887.2009.00189.x

Angulo-López, J. E., Flores-Gallegos, A. C., Ascacio-Valdes, J. A., Contreras Esquivel, J. C., Torres-León, C., Rúelas-Chácon, X., & Aguilar, C. N. (2022). Antioxidant dietary fiber sourced from agroindustrial byproducts and its applications. *Foods*, *12*(1), 159. PMid:36613377. http://doi.org/10.3390/foods12010159

Campderrós, M. E. (2017). Effect of okara flour addition on the physical and sensory quality of wheat bread. *MOJ Food Processing & Technology*, *4*(6), 184-190. http://doi.org/10.15406/mojfpt.2017.04.00111

Chen, Y., Zhao, L., He, T., Ou, Z., Hu, Z., & Wang, K. (2019). Effects of mango peel powder on starch digestion and quality characteristics of bread. *International Journal of Biological Macromolecules*, *140*, 647-652. PMid:31446101. http://doi.org/10.1016/j.ijbiomac.2019.08.188

Conforti, F. D., & Davis, S. F. (2006). The effect of soya flour and flaxseed as a partial replacement for bread flour in yeast bread. *International Journal of Food Science & Technology*, *41*(2), 95-101. http://doi.org/10.1111/j.1365-2621.2006.01410.x

Eshak, N. S. (2016). Sensory evaluation and nutritional value of balady flat bread supplemented with banana peels as a natural source of dietary fiber. *Annals of Agricultural Science*, *61*(2), 229-235. http://doi.org/10.1016/j.aoas.2016.07.002

Fadhel-Weshah, S., & Al-Hafud, A. (2023). The effect of replacing wheat flour with mango peel powder and studying its chemical and microbial properties in the laboratory cake. *IOP Conference Series. Earth and Environmental Science*, *1158*(11), 1-9. http://doi.org/10.1088/1755-1315/1158/11/112005

García-Ramón, F., Sotelo-Méndez, A., Alvarez-Chancasanampa, H., Norabuena, E., Sumarriva, L., Yachi, K., Gonzales Huamán, T., Naupay Vega, M., & Cornelio-Santiago, H. P. (2023). Influence of Peruvian Andean grain flours on the nutritional, rheological, physical, and sensory properties of sliced bread. *Frontiers in Sustainable Food Systems*, *7*, 1202322. http://doi.org/10.3389/fsufs.2023.1202322

Gutierrez-Castillo, C., Alcázar-Alay, S., Vidaurre-Ruiz, J., Correa, M. J., Cabezas, D. M., Repo-Carrasco-Valencia, R., & Encina-Zelada, C. R. (2023). Effect of partial substitution of wheat flour by quinoa (*Chenopodium quinoa* Willd.) and tarwi (*Lupinus mutabilis* Sweet) flours on dough and bread quality. *Food Science & Technology International*, *29*(6), 619-630. PMid:35673705. http://doi.org/10.1177/10820132221106332

Han, W., Ma, S., Li, L., Zheng, X., & Wang, X. (2019). Impact of wheat bran dietary fiber on gluten and gluten-starch microstructure formation in dough. *Food Hydrocolloids*, *95*, 292-297. http://doi.org/10.1016/j.foodhyd.2018.10.033

Hashem, N. M., Gonzalez-Bulnes, A., & Simal-Gandara, J. (2020). Polyphenols in farm animals: Source of reproductive gain or waste? *Antioxidants*, *9*(10), 1-30. PMid:33096704. http://doi.org/10.3390/antiox9101023

Ho, L. H., Abdul Aziz, N. A., & Azahari, B. (2013). Physico-chemical characteristics and sensory evaluation of wheat bread partially substituted with banana (*Musa acuminata* × balbisiana cv. Awak) pseudo-stem flour. *Food Chemistry*, *139*(1-4), 532-539. PMid:23561142. http://doi.org/10.1016/j.foodchem.2013.01.039

Izidoro, M., Leonel, M., Leonel, S., Lossoli, N. A. B., Cândido, H. T., Züge, P. G. U., & Assis, J. L. J. (2023). Nutritional and technological properties of pulp and peel flours from different mango cultivars. *Food Science and Technology*, *43*, 1-10. http://doi.org/10.1590/fst.107922

Jayalaxmi, B., Vijayalakshmi, D., & Maruthesha, A. (2018). Application of polyphenol extract from mango peel powder as a source of natural phytonutrients into biscuits. *International Journal of Current Microbiology and Applied Sciences*, *7*(05), 1206-1213. http://doi.org/10.20546/ijcmas.2018.705.147

Kaur, B., Panesar, P. S., & Thakur, A. (2021). Extraction and evaluation of structural and physicochemical properties of dietary fiber concentrate from mango peels by using green approach. *Biomass Conversion and Biorefinery*, http://doi.org/10.1007/s13399-021-01740-2

Ktenioudaki, A., & Gallagher, E. (2012). Recent advances in the development of high-fibre baked products. *Trends in Food Science & Technology*, *28*(1), 4-14. http://doi.org/10.1016/j.tifs.2012.06.004

Lastra Ripoll, S. E., Quintana Martínez, S. E., & García Zapateiro, L. A. (2021). Rheological and microstructural properties of xanthan gum-based coating solutions enriched with phenolic mango (*Mangifera indica*) peel extracts. *ACS Omega*, *6*(24), 16119-16128. PMid:34179657. http://doi.org/10.1021/acsomega.1c02011

Le Bouthillier, M., Perron, J., Pomerleau, S., Gagnon, P., Labonté, M.-È., Plante, C., Guével, M.-H., & Provencher, V. (2021). Nutritional content of sliced bread available in Quebec, Canada: Focus on sodium and fibre content. *Nutrients*, *13*(12), 4196. PMid:34959748. http://doi.org/10.3390/nu13124196

León-Roque, N., Romero Guzmán, B. M., Oblitas-Cruz, J. F., & Hidalgo-Chávez, D. W. (2023). Optimization of total polyphenol extraction and flavonoid screening by mass spectrometry in mango (*Mangifera indica* L.) waste from Peru. *Food Science and Technology*, *43*, e105322. http://doi.org/10.1590/fst.105322

Lim, S. H., Chin, N. L., Sulaiman, A., Tay, C. H., & Wong, T. H. (2022). Sensory analysis for cow milk product development using high pressure processing (HPP) in the Dairy Industry. *Foods*, *11*(9), 1233. PMid:35563957. http://doi.org/10.3390/foods11091233

Lucas, B. N., Dalla Nora, F. M., Boeira, C. P., Verruck, S., & Da Rosa, C. S. (2022). Determination of total phenolic compounds in plant extracts via Folin-Ciocalteu's method adapted to the usage of digital images. *Food Science and Technology*, *42*, e35122. http://doi.org/10.1590/fst.35122

Marçal, S., & Pintado, M. (2021). Mango peels as food ingredient/additive: Nutritional value, processing, safety and applications. *Trends in Food Science & Technology*, *114*, 472-489. http://doi.org/10.1016/j.tifs.2021.06.012

Martínez-Girón, J., Figueroa-Molano, A. M., & Ordóñez-Santos, L. E. (2017). Effect of the addition of peach palm (*Bactris gasipaes*) peel flour on the color and sensory properties of cakes. *Food Science and Technology*, *37*(3), 418-424. http://doi.org/10.1590/1678-457x.14916

Mayo-Mayo, G., Navarrete-García, A., Maldonado-Astudillo, Y. I., Jiménez-Hernández, J., Santiago-Ramos, D., Arámbula-Villa, G., Álvarez-Fitz, P., Ramirez, M., & Salazar, R. (2020). Addition of roselle and mango peel powder in tortilla chips: A strategy for increasing their functionality. *Journal of Food Measurement and Characterization*, *14*(3), 1511-1519. http://doi.org/10.1007/s11694-020-00400-9

Nasir, S., Allai, F. M., Gani, M., Ganaie, S., Gul, K., Jabeen, A., & Majeed, D. (2020). Physical, textural, rheological, and sensory characteristics of amaranth-based wheat flour bread. *International Journal of Food Sciences*, *2020*(1), 8874872. PMid:33354562. http://doi.org/10.1155/2020/8874872

Nasution, Z., Yang, L., & Shukri, W. Z. (2012). Banana peel flour: An alternative ingredient for wholemeal bread. In *Proceedings of the 11th International Annual Symposium on Sustainability Science and Management 2012.* Kuala Nerus: Universiti Malaysia Terengganu. Retrieved in 2023, June 12, from https://www.researchgate.net/publication/279921919_Banana_peel_flour_an_alternative_ingredient_for_wholemeal_bread/comments

Ning, J., Hou, G. G., Sun, J., Wan, X., & Dubat, A. (2017). Effect of green tea powder on the quality attributes and antioxidant activity of whole-wheat flour pan bread. *Lebensmittel-Wissenschaft + Technologie*, *79*, 342-348. http://doi.org/10.1016/j.lwt.2017.01.052

Ordoñez, H., Duran, M., & Daniel, O. (2012). Rheological characteristics of the water pan indigenous product of Pamplona (Norte de Santander). *Revista de La Facultad de Ciencias Básicas*, *10*(2), 61-74.

Pathak, D., Majumdar, J., Raychaudhuri, U., & Chakraborty, R. (2016). Characterization of physicochemical properties in whole wheat bread after incorporation of ripe mango peel. *Journal of Food Measurement and Characterization*, *10*(3), 554-561. http://doi.org/10.1007/s11694-016-9335-y

Pourafshar, S., Rosentrater, K. A., & Krishnan, P. G. (2015). Using alternative flours as partial replacement of barbari bread formulation (traditional Iranian bread). *Journal of Food Science and Technology*, *52*(9), 5691-5699. PMid:26344982. http://doi.org/10.1007/s13197-014-1640-z

Pourfarzad, A., Mahdavian-Mehr, H., & Sedaghat, N. (2013). Coffee silverskin as a source of dietary fiber in bread-making: Optimization of chemical treatment using response surface methodology. *Lebensmittel-Wissenschaft + Technologie*, *50*(2), 599-606. http://doi.org/10.1016/j.lwt.2012.08.001

Prokopov, T., Chonova, V., Slavov, A., Dessev, T., Dimitrov, N., & Petkova, N. (2018). Effects on the quality and health-enhancing properties of industrial onion waste powder on bread. *Journal of Food Science and Technology*, *55*(12), 5091-5097. PMid:30483005. http://doi.org/10.1007/s13197-018-3448-8

Ramlan, N. A. F. M., Mohammad, S. M., Karim, R., Muhammad, S. K. S., Ismail, M., & Zawawi, N. (2021). Nutritional composition, techno-functional properties and sensory analysis of pan bread fortified with kenaf seeds dietary fibre. *Sains Malaysiana*, *50*(11), 3285-3296. http://doi.org/10.17576/jsm-2021-5011-12

Renoldi, N., Lucci, P., & Peressini, D. (2022). Impact of oleuropein on rheology and breadmaking performance of wheat doughs, and functional features of bread. *International Journal of Food Science & Technology*, *57*(4), 2321-2332. http://doi.org/10.1111/ijfs.15585

Sánchez-Camargo, A. del P., Gutiérrez, L. F., Vargas, S. M., Martinez-Correa, H. A., Parada-Alfonso, F., & Narváez-Cuenca, C. E. (2019). Valorisation of mango peel: Proximate composition, supercritical fluid extraction of carotenoids, and application as an antioxidant additive for an edible oil. *The Journal of Supercritical Fluids*, *152*, 104574. http://doi.org/10.1016/j.supflu.2019.104574

Teshome, E., Teka, T. A., Rout, J. R., Voukang Harouna, D., & Astatkie, T. (2023). Exploring the potentials of fruits by-products and their full industrial applications for nutritional benefits and health promotion: A comprehensive review. *Sustainability*, *15*(1), 1-27.

Tirado-Kulieva, V., Atoche-Dioses, S., & Hernández-Martínez, E. (2021). Phenolic compounds of mango (*Mangifera indica*) by-products: Antioxidant and antimicrobial potential, use in disease prevention and food industry, methods of extraction and microencapsulation. *Scientia Agropecuaria*, *12*(2), 283-293. http://doi.org/10.17268/sci.agropecu.2021.031

Ulziijargal, E., Yang, J. H., Lin, L. Y., Chen, C. P., & Mau, J. L. (2013). Quality of bread supplemented with mushroom mycelia. *Food Chemistry*, *138*(1), 70-76. PMid:23265457. http://doi.org/10.1016/j.foodchem.2012.10.051

van der Sluis, A. A., Dekker, M., De Jager, A., & Jongen, W. M. F. (2001). Activity and concentration of polyphenolic antioxidants in apple: Effect of cultivar, harvest year, and storage conditions. *Journal of Agricultural and Food Chemistry*, *49*(8), 3606-3613. PMid:11513636. http://doi.org/10.1021/jf001493u

Vega Castro, Ó., De-Marco, R., & Di-Risio, C. (2018). Propiedades físicas y sensoriales de un pan fresco, con la adición de las enzimas Lacasa, Xilanasa y Lipasa. *Revista EIA*, *12*(24), 87-100. http://doi.org/10.24050/reia.v12i24.876

Wall-Medrano, A., Olivas-Aguirre, F. J., Ayala-Zavala, J. F., Domínguez-Avila, J. A., Gonzalez-Aguilar, G. A., Herrera-Cazares, L. A., & Gaytan-Martinez, M. (2020). Health benefits of mango by-products. In R. Campos-Vega, B. Dave-Oomah & H. A. Vergara-Castañeda (Eds.), *Food wastes and by-products: Nutraceutical and health potential* (pp. 159-191). New York: Charles Wiley. http://doi.org/10.1002/9781119534167.ch6

Wang, J., Rosell, C. M., & Benedito-Barber, C. (2002). Effect of the addition of different fibres on wheat dough performance and bread quality. *Food Chemistry*, *79*(2), 221-226. http://doi.org/10.1016/S0308-8146(02)00135-8

Wongkaew, M., Chaimongkol, P., Leksawasdi, N., Jantanasakulwong, K., Rachtanapun, P., Seesuriyachan, P., Phimolsiripol, Y., Chaiyaso, T., Ruksiriwanich, W., Jantrawut, P., & Sommano, S. R. (2021). Mango peel pectin: Recovery, functionality and sustainable uses. *Polymers*, *13*(22), 1-16. PMid:34833196. http://doi.org/10.3390/polym13223898

Yengle-Perez, K. F., & Layza Negreiros, V. R. (2021). Current challenges and future trends in nutritional fortification and reduction of harmful substances in mass consumption foods: Pasta, sausages and cheeses. *Manglar*, *18*(3), 329-341. http://doi.org/10.17268/manglar.2021.043

Zhang, L., Ren, Y., Xue, Y., Cui, Z., Wei, Q., Han, C., & He, J. (2020). Preparation of biochar by mango peel and its adsorption characteristics of Cd(ii) in solution. *RSC Advances*, *10*(59), 35878-35888. PMid:35517110. http://doi.org/10.1039/D0RA06586B

Funding: None.

Received: June 12, 2023; Accepted: Mar. 14, 2024

Associate Editor: Elizabeth H. Nabeshima