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Mixed flour of wheat and *Acrocomia*: technological quality and shelf life

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Abstract

The mixed wheat and *bocaiuva* (*Acrocomia totai*) flour allow the development of new products to meet the consumer demand for foods with a healthy and functional appeal. Our study aimed to evaluate the physical-chemical and rheological quality of mixed flours during storage. Mixed flours with 10 and 20% replacement of wheat flour with *bocaiuva* flour were conditioned in impermeable films to water vapor, oxygen and light and stored at ambient temperature for up to 120 days. Flours were submitted to periodical physical-chemical and rheological analyses. Moisture stayed within the legal limit, and water activity was considered adequate to inhibit microbial growth. Titrable acidity increased in the first 30 days of storage. Adding 20% of *bocaiuva* to the wheat flour enriched the mixture with twice the carotenoids and higher total phenol content. The bioactive compounds showed a slight reduction during storage. The mixed flour can be indicated for elaborating bread, loaf, pasta, cakes and biscuits. The falling numbers point to the need for correcting the flour by adding enzymes to produce fermented foods.

Keywords: *Triticum aestivum*; *Acrocomia totai*; native fruit; bioactive compounds; technological application.

Practical Application: Technological application of mixed wheat and *bocaiuva* flour for the production of healthy foods

1 Introduction

Bocaiuva is the palm *Acrocomia totai* Mart. (often referred to as *A. aculeata*, but from the Brazilian Cerrado), Arecaceae, distributed in the Southeast and Central-West regions of Brazil (Costa et al., 2020). Its fruit pulp presents carbohydrates, proteins, lipids, fibers (Ramos et al., 2008), carotenoids and antioxidant activity (Silva et al., 2020) with nutritive and functional properties of high relevance to human health, given its high contents of lipids (Costa et al., 2020) and antioxidant compounds (Samtiya et al., 2021).

Lately, research has pursued the objective of enriching food products nutritionally by partial replacement of wheat flour for fruit flours or food industry by-products, considering the functional benefits and the technological quality of mixed flours (Ramos & Haros, 2020).

Partial replacement of wheat flour for non-conventional ingredients can affect the physical and mechanical characteristics of pastas and quality of the final product (Victoriano et al., 2021). Thus, determining flour technological quality is of utmost importance for a good performance in the panification and production of pasta, cakes and biscuits, which application depends on its physical-chemical and rheological characteristics that fundamentally influence the product quality (Costa et al., 2008).

Victoriano et al. (2021) evaluated the effect of addition of chayote flour on the physical-chemical properties and final quality of pastas. They verified that the partial replacement da wheat semolina for chayote flour gave products with good technological and commercial features.

Lou et al. (2022) partially replaced flour with low gluten content for grape residue flour derived from wine production (0 to 20% replacement) and evaluated the rheological properties and the characteristics of the pastes. They also elaborated and characterized biscuits with the mixed flours and verified that the higher percentage of reduced gluten flour for grape residue flour, the lower was the water absorption and the higher the stability. The development time was longer in mixed flours, standing out 15% replacement. Adding grape residue flour increased the antioxidant activity of biscuits and at a proportion of up to 10% resulted in a product with good sensitive acceptability. Those biscuits were considered with high fiber content for consumers of healthy foods.

Given the profile of consumers who look for natural and functional foods and the potentialities of Cerrado fruits, including *bocaiuva*, which is nutritionally rich in bioactive compounds and healthy appeal, Reis & Schmiele (2019) reported that the food industry should develop new products with Cerrado fruits, with added value and long shelf life.

Choosing packages with the desired characteristics is critical in maintaining food quality during storage. The metallized package

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is made of bi-orientated polypropylene (BOPP) and other films, giving it a pearly aspect, barrier to light, low permeability to moisture and oxygen, essential features to keep crispiness and increased shelf life.

Garnes et al. (2022) assessed the physical-chemical stability of *bocaiuva* pulp dehydrated and stored for 90 days in different packages, testing two types of multilayer packages of polypropilene + polyethene (PP+PE) and polypropilene + polyester + polyethene (PP+PET+PE), and a single layer type, made of bioriented polypropilene (BOPP). They verified that all three packages were efficient in maintaining the lipid quality of the pulp and ascorbic acid contents, while BOPP was the most adequate in preserving carotenoids.

The objectives of this work were to evaluate the physical-chemical and rheological stability of mixed flour of wheat and *bocaiuva* during storage.

2 Materials and methods

2.1 Elaboration of mixed flours

The wheat flour was provided by Dallas® mill from Nova Alvorada do Sul, MS, classified as Type 1. The handmade *bocaiuva* flour was acquired in Corumbá, MS. Both flours were immediately transported to the Laboratory of Plant Origin Products until the preparation of mixtures. The pure flours of wheat and *bocaiuva* were homogenized manually and evaluated physical-chemically, in triplicate, for levels of moisture, water activity, titrable acidity, pH, carotenoids, total phenols and color.

Mixed flours with 10% and 20% replacement of wheat flour with *bocaiuva* flour were homogenized manually, packed in metallized flexibles for 200 g, impermeable to water vapor, oxygen and light, of polypropylene, metallized polyethene and polyethene terephthalate, 0.04 mm thick, thermo-sealed.

We stored the mixed flours were stored at ambient temperature (21 ± 5 °C) and moisture (64 ± 17%RU) for up to 120 days, sampled randomly and evaluated at 30-day intervals in three replicates concerning moisture level, water activity, titrable acidity, pH, carotenoids, total phenols and color. We made rheological evaluations of pure wheat flour and mixed flours by granule structure and falling number.

2.2 Evaluations

The moisture content of flours was determined by gravimetry in an oven at 130 °C for 1h (Instituto Adolfo Lutz, 2008); water activity (Wa) was assessed in a Hydroplam® gauge model Aw 43. We determined pH with a potentiometer adjusted with a buffer of pH 7.0 and 4.0, according to Instituto Adolfo Lutz (2008); the acidity in soluble alcohol, expressed in mL of a molar solution of NaOH.100 g^{-1}, was determined by titration with a sodium hydroxide solution 0.01 M until persistent pink color (Instituto Adolfo Lutz, 2008). Carotenoids in the flours were assessed according to Rodriguez-Amaya (1999). Phenolic compounds were evaluated in hydroalcoholic extract and determined according to Roesler et al. (2007).

Flour color was evaluated in a spectrophotometer Konica Minolta® CM-2300d, and the results were expressed in L* (100= white; 0= black), a* (positive= red; negative=green) and b* (positive =yellow; negative=blue), according to the color space L*tso*b* of the *Commission Internationale l-Eclairage* (CIE).

The rheological evaluations of flour structure and Falling Number were carried out by the methods 54-21.02 and 56-81.03, respectively, of the American Association of Cereal Chemists (2010).

2.3 Statistical analyses

The shelf life experiment was performed utilizing an entirely randomized design in a factorial (2 × 5), with two replacements of wheat flour with *bocaiuva* flour and 5 storage times (0, 30, 60, 90 and 120 days). When interactions between factors were significant, we made a detailed analysis. The data were submitted for analysis of variance, and the Tukey test compared means at 5% probability.

3 Results and discussion

3.1 Pure flours of wheat and bocaiuva

The results of physical-chemical evaluations of pure flours of wheat and *bocaiuva* are shown in Table 1.

Pure wheat and *bocaiuva* flours presented moisture content below 15% (Table 1), the limit established by the Normative Instruction n. 8 of 2 June 2005 of the Ministry of Agriculture, Animal Husbandry and Supply (MAPA), about the Technical Rule of Identity and Quality of wheat flour (Brasil, 2005), and water activity below 0.6 that inhibits microbial development (Ferreira et al., 2005). According to Tilahun et al. (2020), the water activity is a parameter capable to indicate the food safety, helping in the construction of a standardized protocol of storage chronogram.

Bocaiuva flour presented total titrable acidity above the wheat flour (Table 1), possibly due to organic acids in the *bocaiuva* pulp, 0.69-0.73 g.100g^{-1} of citric acid (Sanjinez-Argandoña & Chuba, 2011). The *bocaiuva* pulp flour also has a high lipid content, 8.14% (Ramos et al., 2008), degradable at processing and storage (Garnes et al., 2022), and then liberating free fatty acids. High acidity values in oily raw matters indicate the product can undergo rancification, as observed by Silva et al. (2023) in *bocaiuva* nut oil.

The IN n. 8 of 2005 of the Ministry of Agriculture (Brasil, 2005) establishes a maximum limit of 100 mg KOH.100g^{-1} of fat acidity in wheat flour. Wheat flour type 1 consists of wheat endosperm, rich in carbohydrates and gluten proteic constituents; however, it can have reduced lipid content from milling wheat grain. Due to the wheat flour composition, the total acidity (Table 1) includes the fat acidity and other acids from the degradation of grains wheat grains. The total titrable acidity of wheat flour was below the limit established for fat acidity (Brasil, 2005).

Wheat flour pH was 5.32, close to the low acidity (4.5-5.55) of *bocaiuva* flour, which presented 4.95 (Table 1). Such differences can be attributed to the species. The pH of the *bocaiuva* flour

Table 1. Physical-chemical characterization of wheat and *bocaiuva* flours and rheological analysis of wheat flour.

Types of flours	Moisture (%)	Wa	mg $NaOHg^{-1}$	pH	Carotenoids ($mg.100g^{-1}$)	Phenols ($mg.100g^{-1}$)	L	a	b
Wheat flour	9.56	0.58	84.3	5.32	96.42	74.44	99.8	0.23	1.64
Bocaiuva flour	12.36	0.59	165.5	4.95	3,345.89	130.79	74.67	2.69	41.2
Rheological analyses of wheat flour	Moisture (%)	(A)	(S)	(BT)	(DT)	(MTI)	(FN)		
	12.5	61.65%	23.75 min	33.15 min	19.4 min	6.5 FU	989.75 seconds		

Wa = water activity; Coloration = CIE Lab; L = Luminosity (100= White and 0= b;ack); a = (positive= red and negative=green); b (positive = yellow and negative = blue); S = Stability; BT = Breaking Time; A= water absorption; DT = Development time; MTI = mixture tolerance index; and FN = falling number.

was similar to that found in dehydrated *bocaiuva* pulp stored for 90 days (Garnes et al., 2022). Those authors verified a pH reduction during storage to approximately 5.3, explained by the pulp lipids and their degradation during storage.

The pH of flours destined to the production of fermented products such as bread shall present values between 5 and 6 for maintenance of gluten quality, responsible for the formation of the viscoelastic net (Alfaris et al., 2022). That net is responsible for the retention of the carbonic gas during dough growth.

Bocaiuva flour also showed high moisture, carotenoid content and total phenols, compared with pure wheat flour (Table 1), and can be utilized to enrich wheat flour in the production of mixed flours. Silva et al. (2020) also found high levels of carotenoids and antioxidant activity in *bocaiuva* flour.

Wheat flour presented values close to 100 for luminosity, possibly due to reduced ash content in type 1 flour (Brasil, 2005), with low values of a* and b*, indicating high purity. When positive, the values of a* and b* represent the red and yellow tones. *Bocaiuva* flour showed lower luminosity values than wheat flour and higher values of a* and b*, indicating yellowish color, possibly due to the presence of carotenoids, corroborating the results of Silva et al. (2020).

The water absorption value of wheat flour shown in Table 1 was above 58, demonstrating that the flour can be strong or very strong (Pizzinatto, 1997). The higher the percentage of gluten and fibers, the higher the capacity of water absorption of a flour (Martins et al., 2012).

Wheat flour can be classified as very strong, according to the classification of Pizzinatto (1997), regarding the parameters of stability (S), development time (DT), and ITM shown in Table 1. Strong flours can be mixed with other flours, such as *bocaiuva*, to produce strong flours suitable for panification because they have a higher quantity of gliadins and glutenins, gluten net builder proteins (Martins et al., 2012).

The wheat breaking time of wheat flour was 33 minutes and 15 seconds (Table 1); after that, the dough loses resistance to kneading and the capacity to retain CO_2 during fermentation.

The flour falling number was high (Table 1), indicating low alfa-amylase activity, which can be corrected by adding enzymes. The wheat named improved shall present a minimum breaking number of 250 s, while the appropriate for panification shall have values below 250 s. Low falling numbers indicate high alfa-amylase activity, resulting in sticky and low-volume products (Costa et al., 2008).

3.2 Physical-chemical evaluation of mixed flour of wheat and bocaiuva

Our results of physical-chemical analyses of mixed flours of wheat and *bocaiuva*, with 10% e 20% of replacement, during storage for up to 120 days, are shown in Table 2.

Moisture content was higher in mixed flours with a 10% replacement of wheat with *bocaiuva*. Both replacements did not surpass the limit of 15% (Table 2), established by the Normative Instruction n. 8, of 2nd June 2005, showing that this flour can be utilized as food (Brasil, 2005). During storage for up to 120 days, moisture did not change, possibly due to the package efficiency as a water vapor barrier. Our moisture values shown in Table 2 were below those found by Akhlaq et al. (2023) in mixed flour with 10 and 20% of replacement of wheat flour for quinoa flour (12.83-13.53%).

Water activity was also higher in flours with 10% replacement, with a mean value of 0.62, while flours with 20% replacement presented 0.59 of Wa (Table 2). Such values inhibit microbial development (Ferreira et al., 2005). Splitting the significant interactions for water activity, shown in Table 3, revealed that values between 0.6 and 0.65 were superior in flours with 10% replacement only at 30 and 90 days of storage.

Water activity varied during storage, with a minimum value of 0.57 and 0.55 in flours with 10% and 20% replacement, respectively, and a maximum of 0.65 in flours with 10% replacement and 0.60 with 20%. Ferreira et al. (2005) verified increased water activity during storage for 180 days at 25 °C, 30 °C and 35 °C in dry and spiced cassava flours (obtained through addition of spices and roasting). The maximum values of water activity were below 0.6. The dry flour was kept in low density polyethene packages and the spiced flours in pigmented polypropilene bags.

Flours with 20% of replacement of wheat for *bocaiuva* had total titrable acidity of 0.69-0.73 $g.100g^{-1}$ of citric acid, possibly due to its higher content in *bocaiuva* pulp. The lipidic fraction of mixed flours can have undergone partial degradation during storage, explaining the increased acidity over time (Table 2),

Table 2. Physical-chemical characterization of mixed flours of wheat and *bocaiuva*, with 10 and 20% of replacement of wheat with *bocaiuva*, during storage.

% of replacement of wheat flour with bocaiuva	Moisture (%)	Wa	Acidity mg $NaOHg^{-1}$	pH	Carotenoids ($mg.100g^{-1}$)	Phenols ($mg.100g^{-1}$)	L	a	b
10%	11.78 a	0.62 a	121.54 b	5.56 a	591.48 b	151.58 b	88.54 a	2.23 b	18..4 b
20%	11.10 b	0.59 b	163.65 a	5.54 a	1126.2 a	160.13 a	85.55 b	3.50 a	24.04 a
Teste F	25.6*	50.09*	104.36*	1.2 NS	42.94*	113.19*	710*	445.38*	775.69*
0	11.32 a	0.56 c	108.52 c	5.90 a	895.92 a	164.38 a	87.40 a	2.78 a	21.88 a
30	11.59 a	0.63 a	151.17 ab	5.57 b	847.10 a	167.28 a	86.70 b	2.94 a	21.75 ab
60	11.32 a	0.60 b	164.61 a	5.53 b	838.86 a	161.89 a	86.98 ab	2.89 a	21.14 abc
90	11.64 a	0.63 a	146.47 ab	5.38 c	796.65 a	143.66 b	87.06 ab	2.86 a	20.93 bc
120	11.35 a	0.59 b	142.19 b	5.34 c	915.66 a	142.07 b	87.08 ab	2.86 a	20.74 c
F test	1.09NS	35.58*	20.42*	151.6*	0.27 NS	20.89*	4.0*	0.72 NS	5.26*
Treatment x time	2.37 NS	3.5*	0.50 NS	1.5 NS	0.38 NS	7.63*	3.0*	1.41 NS	0.42 NS
CV (%)	4.61	5.14	22.93	3.65	38.46	9.16	1.80	2.28	13.49

Means followed by at least one lower case letter did not differ in the column by the Tukey test ($p<0.05$). Wa = Water activity; Coloration = CIE Lab; L = Luminosity (100= White and 0 = black); a = (positive= red and negative=green); b (positive = yellow and negative = blue). CV = Coefficient of variance. *Significant. NS = Not significant. Acidity, carotenoids, phenols = calculation, sample with 11% (wet base) of moisture.

Table 3. Splitting the significant interactions for water activity, phenols and luminosity of mixed flour of wheat and *bocaiuva*.

Treatment	Storage time (days)				
	0	30	60	90	120
			Aw		
10% (T1)	0.57 dA	0.65 aA	0.62 bcA	0.64 abA	0.60 dcA
20% (T2)	0.55 bA	0.60 aB	0.59aA	0.61 aB	0.59 aA
CV (%)	2.52	5.65	3.50	3.39	1.18
			Phenols ($mg.100g^{-1}$)		
10% (T1)	159.45 aA	168.56 aA	165.42aA	137.42 bA	127.07 bB
20% (T2)	169.31aA	165.99 abA	158.35 abA	149.90 bA	157.08 abA
CV (%)	4.24	1.08	3.08	6.14	14.93
			Luminosity		
10% (T1)	88.80 aA	87.86 bA	88.56 abA	88.75 aA	88.75 aA
20% (T2)	86.00 aB	85.55 aB	85.40 aB	85.36 aB	85.42 aB
CV (%)	2.26	1.88	2.56	2.75	2.70

Means followed by the same capital letter in the column did not differ, and lower case in the line by the Tukey test ($p<0.05$). CV = Coefficient of variance. Phenols = calculation, sample with 11% (wet base) of moisture.

by forming free acids, as mentioned by Silva et al. (2020) for dehydrated *bocaiuva* fruit pulp under different temperatures and storage for up to 120 days. There is no specific legislation for total titrable acidity in mixed fours; however, the limit for fatty acidity of wheat flour is 100 mg $KOH.100g^{-1}$.

Mixed fours with 10 and 20% replacement did not differ in pH levels, reduced during storage, from 5.90 to 5.34 (Table 2), i.e., flours became more acidic over time; however, pH was adequate to produce fermented doughs such as bread, indicated to preserve gluten quality (Alfaris et al., 2022). Such behavior was observed by Garnes et al. (2022) in *bocaiuva* flour, attributed to the degradation of its lipid fraction, liberating fatty acids.

The level of carotenoids practically doubled with twice *bocaiuva* flour replacing wheat flour. During storage, that bioactive compound was preserved in mixed flours (Table 2), different from the observed by Garnes et al. (2022) in pure *bocaiuva* flour stored in various packages for up to 90 days, whose contents presented a reduction of approximately 50%. They found that the oriented prolypropilene package was the most efficient in preserving carotenoids. According to Rodriguez-Amaya (1999), processing and storage can affect the carotenoid content in food products. The package utilized in that research could have contributed to the maintenance of carotenoid levels in mixed flours during storage.

β-carotene corresponds to c. 80% of total carotenoids in the *bocaiuva* pulp (Ramos et al., 2008) and is bioactive for its conversion capacity into vitamin A, related to vision, bone health and tissue differentiation (Olson, 1999) & (Institute of Medicine (US) Food and Nutrition Board, 2001). Carotenoid pigments also help fight Non-transmissible Chronic Diseases (NTCD), such as Type 2 Diabetes Mellitus and obesity (Marcelino et al., 2020) and act as antioxidants against free radicals that cause cell ageing and lesions, highly contributing to health programs. Conservation of carotenoids in food is vital for presenting a functional claim, minimizing the occurrence of NTCD and degenerative eye diseases, such as cataracts (Mesquita & Torquilho, 2016).

Levels of total phenols were approximately 6% higher in flours with 20% replacement of wheat with *bocaiuva*. Splitting significant interactions (Table 3) revealed that the difference between treatments occurred at 120 days of storage.

In analyzing the behavior of phenol contents during storage, we verified that they were preserved for up to 60 days; after that, they decreased by 12% (Table 2). Machado et al. (2013) verified a reduction in total phenols in fruits and vegetables (black mulberry, prunes, nectarine, kiwi, mango, strawberry, red cabbage, purple lettuce and eggplant) under increased temperature and exposition time and change in coloration of the phenolic compounds under changed pH. The compounds are also diminished by freeze/defrost cycles of plant products, suggesting that they are unstable under processing.

According to Neves (2015), phenols are important bioactives since they have antioxidant action against free radicals, preventing damage to lipids, proteins and nucleic acids and, in consequence, cell lesions and death, acting as functional elements to help fight diseases.

Lou et al. (2022) also verified an increased antioxidant activity (method DPPH) in biscuits elaborated with mixed flour the higher the percentage of replacement of flour with reduced gluten for grape residue flour from vine production.

Mixed flours of wheat and *bocaiuva* showed positive values of a* and b*, representing red and yellow tones, respectively, higher for b* than a* in both replacements (Table 2), predominating yellow. A 20% replacement had higher values of a* and b* (Table 2), indicating more red and yellow tones. These tones can be attributed to higher carotenoid levels in flours with 20% of *bocaiuva* (Table 2). Concerning storage periods, no significant changes occurred in a* values, but b* had a slight reduction, from 21.88 to 20.74 (Table 2), possibly due to the preservation of carotenoids during storage.

Luminosity presented a slight reduction in the first 30 days of storage; however, in the other evaluated times, the values did not differ from those found at early storage (Table 2). Splitting of significant interactions for luminosity (Table 3) showed that such behavior occurred in flours with 10% replacement, while with 20%, the luminosity did not change during storage. Values close to 100 characterize a clear flour, and our results demonstrated values below 100 since carotenoids are responsable for the pigmentation.

The color of mixed flours was preserved during storage (Tabela 2), although we observed a slight reduction in b* values, different from that reported by Silva et al. (2020) in *bocaiuva* fruit pulp dehydrated at different temperatures and stored for up to 120 days in raffia bags, which had reduction in all color parameters. According to Rodriguez-Amaya (1999), the content of carotenoids that can explain the red and yellow tones in mixed flours varies in foods depending on several factors, among them the type of processing and storage, indicating that the package may have contributed to the color maintenance of flours during storage without refrigeration.

Table 4 shows our results for the parameters Absorption (A), Stability (S), Breaking Time (BT), Development Time (DT), Mixture Tolerance Index (MTI) and Falling Number (FN) of mixed flours of wheat and *bocaiuva*.

Flour water absorption capacity depends on the content of gluten and fibers, plus gluten quality, existing a direct relation between flour quality and absorption values (Martins et al., 2012). The higher water absorption in flours with a 20% replacement of wheat flour with *bocaiuva* flour can be attributed to its fibers. According to Ramos et al. (2008), the *in natura bocaiuva* pulp contains 13.76% de fibers.

Lou et al. (2022) verified that water absorption diminished in mixed flour compared pure flour with reduced gluten content, when partially replaced for flour of grape residue from wine production, wigh high fiber content (65 $g.100g^{-1}$).

Splitting significant interactions showed that flour water absorption increased with storage time independently of the replacement percentage with *bocaiuva* flour. After 90 days of

Table 4. Absorption, Stability, Breaking Time, Development Time, Mixture Tolerance Index and Falling Number of mixed flours of wheat and *bocaiuva*, with 10 and 20% of replacement of wheat with *bocaiuva*, during storage.

% of replacement	(Wa) min	(BT) min	(S) %	(DT) min	(MTI) UF	(FN) Seconds
10%	60.88 b	18.47 b	18.47 a	13.98 b	30.70 b	892.20 a
20%	61.92 a	21.12 a	18.88 a	16.30 a	36.40 a	843.07 a
F test	67.6*	152.47*	4.93 NS	57.37*	6.24*	4.20 NS
Time (days)						
0	61.20 c	21.11 a	19.96 a	16.05 a	30.75 a	901.50 a
30	61.12 c	18.52 c	17.31 d	14.35 a	38.25 a	833.00 a
60	61.56 ab	19.09 bc	18.05 cd	14.87 a	37.25 a	843.33 a
90	61.70 a	20.06 ab	18.92 bc	15.32 a	31.75 a	863.17 a
120	61.42 b	20.22 a	19.14 ab	15.12 a	29.75 a	897.17 a
F test	29*	17.71*	25.56*	3.29 NS	2.35 NS	1.33 NS
Treatment x time	16*	0.69 NS	0.54 NS	0.27 NS	0.1036 NS	0.412 NS
CV (%)	0.80	8.54	5.42	9.38	17.81	8.20

Means followed by the same lower case letter did not differ in the column, by the Tukey test ($p<0.05$). Wa = water absorption; BT = Breaking Time; S = Stability; DT = Development time; MTI = mixture tolerance index; FN = falling number. CV = Coefficient of variance. *Significant. NS = Not significant.

storage, the absorption presented a slight reduction in flours with 20% replacement, with values similar to the beginning of storage (Table 5). According to this parameter, the mixed flours can be classified as strong or very-strong (Pizzinatto, 1997).

Breaking time corresponds to the time from the beginning of the mixture until it drops 30 units of flour structure, concerning the curve top. The longer the breaking time, the higher the flour resistance to kneading. According to Sarker et al. (2008), the more starch in three potato cultivars (Eniwa, Benimaru and Norin) added to the mixture of wheat flour, the higher the breaking time, similar to our results, whereby the wheat flour with 10% of *bocaiuva* flour had a shorter breaking time than 20%. Such outcome was also reported by Lou et al. (2022), i.e., the higher the replacement of low gluten flour for grape residue flour, up to 15% of replacement, the longer was the breaking time.

Breaking time diminished between the second and third months of storage and after 90-120 days (Table 4) but did not differ significantly from the beginning. The pure wheat flour exhibited a longer breaking time than the mixed flour (Table 1). Thus, the longer the breaking time, the higher resistance to kneading.

Treatments did not differ in stability, i.e., more *bocaiuva* flour in the mixture did not affect the flour tolerance to the process, possibly due to the characteristics of pure wheat flour, classified as very strong (Table 1). During storage, the stability values of mixed flour varied between 17.30 and 19.96 min, lower than in pure flour (Table 1), without altering the mixed flour classification as very strong (Pizzinatto, 1997). Lou et al. (2022) verified that the stability increased with the replacement proportion of low gluten flour for grape residue flour.

Concerning DT, the treatments had results above 10 min, meaning that mixed flours can be classified as very strong (Pizzinatto, 1997), as observed in pure wheat flour (Table 1). The development time did not change in stored flours (Table 4). That is the time needed until the dough reaches a plastic and smooth consistency.

MTI was superior in flours with 20% replacement (Table 4), indicating that the higher the *bocaiuva* proportion, the lower the flour tolerance to the mixture. Mixed flour can be classified as strong when MTI between 15 and 50 UF (Pizzinatto, 1997), higher than pure flour (Table 1), which can be classified as very strong (Pizzinatto, 1997). MTI of mixed flour did not change over time (Table 4).

Flours did not differ in the falling number concerning the replacement percentage and storage time (Table 4). Our results point to the need for correcting flours with alfa amylase for fermented products.

Table 5. Splitting the significant interactions for absorption of mixed flour of wheat and *bocaiuva*.

Treatment	Storage time (days)				
	0	30	60	90	120
	Absorption				
10% (T1)	60.65 bB	60.45 bB	61.05 aB	61.05 aB	61.20 aB
20% (T2)	61.75 bcA	61.80 bcA	62.05 abA	62.35 aA	61.65 dcA
CV (%)	1.27	1.56	1.14	1.48	0.51

Means followed by the same lower case letter in the same line and by the same capital letter in the column did not differ, by the Tukey test ($p<0.05$). CV = Coefficient of variance.

4 Conclusion

Adding 20% *bocaiuva* flour to wheat flour enriches the mixture to twice the level of carotenoids and higher content of total phenols. The mixed flours can be stored for up to 120 days and preserve their bioactive compounds and indicated for pasta and bread production, with alfa amylase correction for fermented products.

Conflict of interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study, in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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Author contributions

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved the final version.

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