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Technological properties of gluten-free biscuits from sorghum flour granifero (*Sorghum bicolor* (L.) Moench)

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Abstract

The objective was to produce flour from sorghum grains, to determine the physicochemical and microbiological characteristics, and to develop different formulations of cookies, with total and partial replacement of rice flour, evaluating the moisture content, color, expansion factor and texture profile - TPA. Five formulations were processed, as follows: control - 0%; F1 - 25%; F2 - 50%; F3 - 75% and F4 - 100% sorghum flour. The sorghum flour showed physical, chemical and microbiological characteristics in accordance with current legislation, and can be inserted into human food. The different cookie formulations after baking had a moisture content below 7%. With the addition of sorghum flour, the cookies showed lower light F4 – 32.35 L*. The addition of sorghum flour did not affect the expansion factor of the cookies, with average value of 2.13. The different concentrations of sorghum flour, showed interference in analysis of the Texture-TPA profile, the F3 formulation, presented higher values of hardness 25594.44 N, fracturability 251 N, cohesiveness 0.27. Elasticity has not been compromised. The highest values of gumminess 53.08 N, chewability 1471.15 mJ were found in the formulation F4 – 100% FS. These results may help improve the quality of sorghum-based gluten-free foods for celiac consumers.

Keywords: cereal; color; hardness; celiac public; TPA.

Practical Application: Physicochemical and microbiological characteristics of sorghum flour and its technological application.

1 Introduction

Brazil occupies the ninth position in world production sorghum, with 2.5 million tons produced in the 2019/20 season, and the states of Goiás, Minas Gerais and Bahia stand out among the largest producers in the country (Companhia Nacional de Abastecimento, 2021). This cereal has sensory and functional potential, such as antioxidants, which are phytochemicals, and besides increasing the sensory properties of foods, such as color and flavor, its regular consumption can help in health promotion, protecting the body from various chronic diseases (Rocchetti et al., 2017).

Worldwide, 0.6-1.0% of the population is diagnosed with celiac disease, so a strict gluten-free diet is required throughout life due to the intolerance (Demirkesen, 2016). For being a gluten-free cereal, sorghum is an excellent alternative for celiac people. Martinez et al. (2021), when using sorghum (BRS 305 genotype) flour in the diet of rats, found reductions in the hepatic levels of triglycerides and uric acid, in addition to improvements in insulin sensitivity and glucose tolerance. Some sorghum-based products have been developed, such as cereal bars (Paiva et al., 2018), powdered preparations for low-calorie drinks (Queiroz et al., 2018) and breakfast cereals (Anunciação et al., 2017), all aimed at diversifying procedures and offering alternatives of consumption to gluten-intolerant people. In this context, the objective was to produce flour from sorghum grains (*Sorghum bicolor* L. Moench) genotype Jade, free from tannins, and to carry out the physicochemical and microbiological characterization, in addition to preparing different formulations of cookies, with partial replacement and full of rice flour per sorghum flour, and to determine moisture content, color, expansion factor and texture profile - TPA.

2 Material and methods

2.1 Obtaining sorghum flour

Grain sorghum (Jade genotype) flour was obtained from its grains, harvested manually in the municipality of Rio Verde-GO, Brazil, with geographical location of 17°44'20.88" S and 50°57'55.79" W. The grains were manually threshed and dried in a forced air ventilation oven at a temperature of 60 °C until reaching the moisture content of 14% w.b. Then, the grains were subjected to the grinding process, in an electric mill (Fortinox STAR FT-80/1) with 1-mm-mesh stainless steel sieve.

Proximal composition of sorghum flour

The moisture content of the flour was determined by the method of drying in an oven at 105 ± 1 °C, for 24 h (Association of Official Analytical Chemists, 2005). Crude protein analysis was performed by the Kjeldahl method, in which the total organic nitrogen content was evaluated according to the official

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method no. 960.52 of Association of Official Analytical Chemists (2005), with nitrogen conversion factor of 5.46. Ash content was determined according to AOAC method no. 923.03 (Association of Official Analytical Chemists, 2005). Lipids were determined according to AOAC method no. 920.39 (Association of Official Analytical Chemists, 2005).

Carbohydrate content was calculated by the difference between 100 and the sum of lipids, proteins and ash, according to the methodology of AOAC no. 926.08 (Association of Official Analytical Chemists, 2005). The caloric value was obtained using Atwater conversion factors (4 kcal g^{-1} protein × 9 kcal g^{-1} lipid × 4 kcal g^{-1} and carbohydrate). Minerals were determined by dry digestion of the sample with nitric acid, according to Carmo et al. (2000). Calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn) were determined by atomic emission spectrometry using an atomic absorption spectrometer (AAS-Vario 6, Analytik Jena). Phosphorus content was evaluated by calorimetry and potassium by flame photometer (Pineli et al., 2015).

Physicochemical analyses

The pH was determined according to the method, 943.02 da American Association of Cereal Chemists (2006), Titratable acidity was determined according to the methodology of the Adolfo Lutz Institute (Instituto Adolfo Lutz, 2008). Instrumental color was measured at room temperature using the Hunter Lab Colorimeter, Color Flex EZ model. The results were expressed in color coordinates of the CIELAB space (L* a* b*).

Bioactive compounds

Antioxidant activity was determined by the ability to scavenge the DPPH free radical, according to the methodology described by Rufino et al. (2009). Total polyphenol index was determined by the spectrophotometric method developed by Folin-Ciocalteu (Rossi & Singleton, 1965).

Microbiological analyses

Tests were performed to estimate molds and yeasts, thermotolerant coliforms and detection test for Salmonella sp.. Counting of molds and yeasts was performed by spread plate in PDA medium incubated at 25 ºC for five days. The result was expressed in colony forming units per gram of product (CFU.g-1), according to Silva et al. (2007). Thermotolerant coliforms were quantified using the most probable number technique (NMP.g-1), according to the methodology proposed by Hunt & Rice (2005). A presumptive test was previously performed by inoculating sample aliquots (25 g diluted in 225 mL of sterile 0.1% peptone water) in a series of three tubes containing Durhan tubes and lauryl tryptose broth (LST), which were incubated at 35 °C for 24 to 48 h. Positive tubes were those that showed turbidity and gas formation. From these tubes, aliquots were transferred from the positive tubes of the presumptive test to tubes containing Escherichia coli broth (EC broth). Cultures were incubated at 44.5 ºC for 24 to 48 h. Positive tubes were those that showed turbidity and gas formation.

The detection of Salmonella sp. was performed according to the BAM/FDA-2006 method (Andrews et al., 2006), for which 25 g of flour was used in sterilized peptone water, incubated at 35 ºC for 24 h, followed by selective enrichment in tetrathionate broth and Rappaport broth incubated at 35 ºC for 24 h. Selective plating was performed in enteric Hectoen (HE) and bismuth sulfite (BS) media and confirmation of Salmonella sp. made on Triple Sugar Iron Agar (TSI) and Lysine Iron Agar (LIA). As a biochemical test, the urease test was performed with Rustigian & Stuart urea broth.

2.2 Production of cookies

Cookies were formulated with different levels of replacement of rice flour (RF) with sorghum flour (SF), and five formulations were prepared: Control - 0% SF; F1 - 25% SF; F2 - 50% SF; F3 - 75% SF and F4 - 100% SF (Table 1).

The obtained dough was laminated to a thickness of approximately 15 mm, cut in circular shape with a 32-mm-diameter cutter, and baked in a conventional oven at temperature of 180 °C for 25 min. After baking, the cookies were naturally cooled to room temperature and evaluated for physical characteristics. Physical analyses of moisture content, color (L*, a*, b*) and texture profile - TPA of the cookies were performed before and after baking.

Diameter, height, expansion factor of cookies

Diameter (mm) and height (mm) were determined before and after baking, using a digital caliper (Digimess), with resolution of 0.01 mm. The expansion factor was calculated based on the diameter/height ratio according to method 10-50D of American Association of Cereal Chemists (2000).

Texture Profile Analysis – TPA – of cookies

Texture Profile analyses were performed at the Laboratory of Postharvest of Plant Products in different formulations using a Brookfield Engineering Labs, Inc. CT3 texture analyzer coupled to the Texture Pro CT V1.4 Build 17 program. The cookies had diameter of approximately 27.76 and 31.20 mm and thickness of approximately 28.78 and 14.70 mm before and after baking, respectively. The cookies were then subjected to the compression

Table 1. Ingredients used to manufacture cookies in the total and partial replacement of rice flour.

Ingredients	Formulations				
	Control	F1	F2	F3	F4
Sorghum flour (g)	-	28.75	57.5	86.25	115
Rice flour (g)	115	86.25	57.5	28.75	-
Sucrose (g)	40	40	40	40	40
Milk Butter (g)	20	20	20	20	20
Egg (un)	1	1	1	1	1
Baking powder (g)	2	2	2	2	2
Salt (g)	0.4	0.4	0.4	0.4	0.4

test. Texture was measured using a modification of the method described by Mancebo et al. (2015). The samples were arranged horizontally on the metal platform of the deice, using the TA 4/100 flat bottom probe (38.46 mm in diameter), distance of 191.5 mm and pre-test, test and post-test speeds of 2 mm.s^{-1}, 2 mm.s^{-1} and 4.5 mm.s^{-1}, respectively. The parameters analyzed were: Hardness (N), fracturability (N), cohesiveness, elasticity (mm), gumminess (N) and chewability (mJ).

2.3 Experimental design and statistical analysis

The experiment was carried out in a completely randomized design. The data obtained were submitted to analysis of variance (ANOVA), followed by the Scott Knott mean test at a significance level of 5%, using the Sisvar® software. All analyzes were performed in triplicate, except for mineral analysis, which was performed by Solotech.

3 Results and discussion

The moisture content of the flour was 11.65% w.b (Table 2), hence in accordance with the standard required by Brazilian legislation, which establishes a maximum limit of 15% w.b. according to RDC nº 263 (Brasil, 2005). Prado et al. (2019) evaluated whole flours from two sorghum cultivars and reported moisture contents, close to those found in the present study, of 11.44 (g 100 g^{-1}).

The results of proteins, ash, lipids and carbohydrates found were 7.19%, 1.71%, 2.58% and 88.52%, respectively. Caloric value of 359.46 kcal 100 g^{-1}. The acidity showed a value of 1.93 meq NaOh 100 g^{-1} and a pH of 6.24. Brazilian legislation does not establish the aforementioned parameters for sorghum flour, however, it establishes a maximum acidity limit of 3% for common wheat flour (Brasil, 1978).

Studies carried out with sorghum flour showed results similar to those of the present work. Queiroz et al. (2015) who evaluated the nutritional composition of 100 sorghum genotypes, and reported variations from 8.6 to 18.9 g 100 g^{-1} of protein, 1.1 to 2.4 g 100 g-1 of ash, 1.7 to 1.7 to 1.7 to 4.9 g 100 g^{-1} of lipids and 55.2 and 75.2 g 100 g^{-1} of carbohydrates. Caloric value similar to the results of Tasie & Gebreyes (2020) when analyzing 35 sorghum varieties grown in Ethiopia, with values between 329.05 kcal 100 g^{-1}and 364.24 kcal 100 g^{-1}.

The pH value of sorghum flour was 6.24, which is similar to that found by Marston et al. (2016) when analyzing commercial whole flour, with value of 6.14. Acidity was equal to 1.93 (meq NaOh 100 g^{-1}). Brazilian legislation does not establish specific acidity parameters for sorghum flour, but it establishes a maximum acidity limit of 3% for common wheat flour (Brasil, 1978). The acidity value of sorghum flour (1.93 meq NaOh 100 g^{-1}) is within the range required by legislation.

Color is visually one of the most attractive quality attributes for consumers and directly influences product acceptance. The jade sorghum flour had an L* value of 71.40, showing a tendency towards white despite being a wholemeal flour. The pericarp of jade sorghum grains has low pigmentation with luminosity tending to white, thus having a light colored wholemeal flour Oliveira et al. (2017), reports that it is not only the external characteristic of the grain that will influence the color of the flour, but also The particle size of the sieved flour, as larger particles have a higher fraction of the external parts of the grains, while smaller particles have a greater amount of starches, proteins and lipids, which are located in the endosperm region of the grain with cream color. The positive values of a* 4.68 and b*15.31 characterize sorghum flour as being red and yellow, respectively.

The macro and micromineral values are presented in Table 3. The mineral composition of sorghum flour showed satisfactory amounts of macro and micro minerals for the Recommended Daily Intake - RDI, with emphasis on P (140 mg.100-1 g); Mg (70 mg.100-1 g) Fe (12.17 mg.100-1 g), Mn (1.03 mg.100-1 g) and P (140 mg.100-1 g). The Recommended Daily Intake (RDI)

Table 2. Physicochemical characterization of Jade genotype sorghum flour and color parameters L*, a*, b*.

Parameters	Proximate composition
Moisture content (g 100 g^{-1})	11.65 ± 0.42
Protein (g 100 g^{-1})	7.19 ± 0.29
Ashes (g 100 g^{-1})	1.71 ± 0.10
Lipids (g 100 g^{-1})	2.58 ± 0.27
Carbohydrate (g 100 g^{-1})	88.52 ± 0.47
Caloric value (kcal 100 g^{-1})	406.06 ± 0.52
Acidity (meq NaOh 100 g^{-1})	1.93 ± 0.06
pH	6.24 ± 0.08
L*	71.48 ± 0.47
a*	4.68 ± 0.14
b*	15.31 ± 0.48
Graphical color	
Image of grain sorghum (Jade) flour	

L* = lightness (0 black to white 100); a* = (-a* green to +a* red); b* = (-b* blue to +b* yellow).

Table 3. Values of macro and microminerals of Jade genotype sorghum flour.

Macro and Microminerals	Values (mg.100 g^{-1})
N	1580
P	140
K	300
Ca	10
Mg	70
S	105
Fe	12.17
Mn	1.03
Cu	0.07
Zn	0.87
B	5.64

N = Nitrogen; P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; S = Sulfur; Fe = Iron; Mn = Manganese; Cu = Copper; Zn = Zinc; B = Boron.

values recommended for adults (19 to 50 years old), respectively are: P (700 mg per day), Ca (1000 mg per day), Mg (260 mg per day), Fe (14 mg per day), Mn (2.3 mg per day), Cu (900 mg per day) and Zn (7 mg per day) (Brasil, 2005). The Jade genotype sorghum flour is considered a source of minerals, as it presents a minimum of 15% of the reference RDI per 100 g (solids) (Brasil, 1998).

Tasie & Gebreyes (2020) evaluated the mineral contents of thirty-five sorghum varieties and found values similar to those obtained in this study for P (112.554-367.965 mg.100 g^{-1}), Mg (62.09-207.53 mg.100 g^{-1}), Ca (9.594-67.158 mg.100 g^{-1}), Fe (2.262-14.08 mg.100 g^{-1}) and Zn (0.698-6.484 mg.100 g^{-1}).

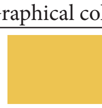
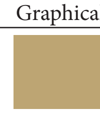
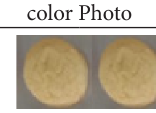
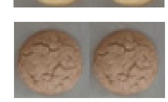
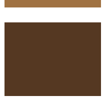
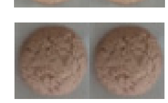
Jade genotype sorghum flour showed antioxidant activity of 57.32% when scavenging the DPPH free radical, which has good antioxidant activity. The value of phenolic compounds was 46.50 mg GAE g^{-1}, which indicates results higher than those reported by Rao et al. (2018), who evaluated the total phenolics of six sorghum genotypes and found values from 0.75 to 11.50 (mg GAE g^{-1}), and higher than those reported by Mohapatra et al. (2019), who evaluated raw sorghum flour, cooked sorghum flour, fermented sorghum flour, fermented and steamed sorghum flour and steamed and flaked sorghum flour and found total phenolic contents ranging from 5.53 to 8.61 mg GAE g^{-1}.

Microbiological analyses of Jade sorghum flour obtained satisfactory values according to the microbiological standards for foods, fungi and yeasts, 4 x 10^2 CFU.g^{-1}, a result that is in accordance with the National Commission of Norms and Standards for Food - CNNPA, Resolution No. 12 of 1978, which establishes a maximum value of 10^3 CFU.g^{-1}. The level of thermotolerant coliforms was 29 MPN.g^{-1}, in accordance with the RDC No. 12 of Anvisa 2001, which establishes a maximum value of up to 10^2 MPN.g^{-1}. The evaluation of salmonella indicated absence (Brasil, 2001).

An analysis of the moisture content of the cookies was carried out after cooking, and an average loss of 78.42% was verified. The loss of water after cooking is a normal process in the cooking stages of baked foods. The moisture content of cookies after cooking showed low values, with averages of 4.66% b.u. Low moisture content values are responsible for crispness, an important sensory attribute for cookies. There is no established moisture content for cookies, however they need to maintain the crunch, being a specific characteristic of the product.

Rao et al. (2018), when evaluating cookies produced with flours from different sorghum cultivars, found results lower than that of the present study, with moisture content varying from 2.13 to 3.23% w.b. On the other hand, higher results were found by Infante et al. (2017), when analyzing the proximate chemical composition of cookies based on sorghum flour and biofortified sweet potatoes, with values from 7.06 to 11.57% w.b. In Table 4, the results of the color analysis are presented, before and after the cooking of cookies, produced with different concentrations of sorghum flour. As for the L* parameter before cooking, it can be observed a decrease in luminosity with the increase in the concentration of sorghum flour, the jade genotype had an influence on the color of the cookies, presenting a dark color. Formulation F3 (75% sorghum flour) and F4 (100% sorghum flour) showed lower luminosity, L*30, 32 and 31.31, respectively, the control formulation (0% sorghum flour) showed higher

Table 4. Color analysis (values in L*, a* and b*) of cookies produced with different concentrations of sorghum flour before and after baking.

Formulations	Cookies before baking			Cookies after baking		
	L*	a*	b*	L*	a*	b*
Control	54.60 ± 0.28Aa	6.24 ± 0.08Bb	38.62 ± 0.36Aa	45.18 ± 0.19Ab	13.24 ± 0.23Aa	29.88±0.19Ab
F1	41.66 ± 0.15Ba	6.85 ± 0.07Ab	21.11 ± 0.11Ba	36.41 ± 0.7Bb	12.37 ± 0.32Ba	21.79±0.68Ba
F2	34.66 ± 0.40Ca	6.26 ± 0.16Bb	14.18 ± 0.37Cb	35.71 ± 0.21Ba	12.01 ± 0.21Ca	20.42±0.21Ca
F3	31.31 ± 0.40Db	6.23 ± 0.21Bb	11.93 ± 0.52Db	35.70 ± 0.60Ba	11.39 ± 0.43Da	19.44±0.60Ca
F4	30.22 ± 0.07Db	5.89 ± 0.35Cb	10.2 ± 0.8Eb	32.35 ± 0.60Ca	10.50 ± 0.31Ea	15.77±0.60Da
	Graphical color	Photo		Graphical	color Photo	
Control						
F1						
F2						
F3						
F4						

Equal uppercase letters in columns and equal lowercase letters in rows do not differ from each other by the Scott-Knott test at 5% significance level. Control - 0% sorghum flour; F1 - 25% sorghum flour; F2 - 50% sorghum flour; F3 - 75% sorghum flour; F4 - 100% sorghum flour; L* lightness (0 black to white 100); a* (-a* green to +a* red); b* (-b* blue to +b* yellow).

brightness L* 54.60, because rice flour has greater brightness compared to sorghum flour.

In previous studies, Awobusuyi et al. (2020) observed a similar effect for cookies with sorghum mixtures; the cookies became darker with the increasing concentration of sorghum flour mixture. The L* lightness values of the cookies after baking differ from each other between the formulations. The formulation F4 (100% sorghum flour) had L* = 32.35, the lowest lightness among the formulations and the Control (0% sorghum flour) had the highest lightness (L* = 45.18), being closer to white, being characteristic of rice flour. The formulations F1, F2 and F3 showed no difference from each other, with values of 36.41, 35.71 and 35.70, respectively.

Formulations with higher concentrations of sorghum flour approached black (0). Rao et al. (2016) found lightness for sorghum cookies within the range from 55 to 70, closer to white. However, the sorghum used here was white, thus resulting values in close to 100. The parameter a* for cookies before baking showed positive values, that is, reddish color. The formulation F1 (25% sorghum flour) had the highest value of a*: 6.85, while the formulation F4 (100% sorghum flour) had the lowest value of a*: 5.89. The formulations Control, F2 and F3 showed no difference regarding the parameter a*, with values of 6.24, 6.26 and 6.23, respectively. It is also observed that there was a difference ($p < 0.05$) in relation to the b* coordinate for all formulations before baking. The formulation Control (0% sorghum flour) had the highest value of b*: 38.62, with a more yellowish color compared to the other formulations. On the other, the formulation F4 (100% sorghum flour) had the lowest value for b*. However, all values were positive, and the color was yellowish. There were differences ($p < 0.05$) for the coordinates a* and b* in the formulations after baking.

The values of the parameter a* ranged from 10.50 to 13.24 and the values of the parameter b* ranged from 15.77 to 29.88. It can also be noticed that the cookies before and after baking differed from each other in relation to these parameters. The colors of the cookies after baking are not only related to the color of the flour used, but also to the reactions that occur during the baking process. It can be seen in the images in Table 5 that, after baking the cookies, their lightness values were higher. This is related to the depigmentation caused by the baking process, since the pigments were denatured due to the temperature used. The mean values of the diameter, height and expansion factor of the cookies formulated with different concentrations of grain sorghum flour, before and after baking, are presented in Table 5.

For the physical characterization, the mean values of diameter (mm), height (mm) were determined before and after cooking the cookies for each formulation and expansion factor after cooking. The results obtained showed that there was no difference ($p < 0.05$) in the parameters of diameter and height between the different formulations. When comparing the parameters of diameter (mm) and height (mm), before and after cooking, it was found that there was an increase, which is an important and expected factor, showing that sorghum flour has technological quality for expansion.

Due to the use of baking powder for the preparation of cookies. The heat of the oven is responsible for the rapid reaction of sodium acid pyrophosphate and sodium bicarbonate, causing greater amounts of carbon dioxide, generating an increase in dough. As for the expansion factor, it was found that there was no difference between the formulations, the substitution of rice flour for sorghum flour did not interfere in the technological expansion of cookies. The height and diameter measurements of the cookies after baking are dependent on the ingredients used, as are the measurements of the cutting mold used to make the cookies. Awobusuyi et al. (2020), when preparing cookies with partial replacement of wheat flour (WF) with sorghum flour (SF), observed higher expansion factor for cookies with 100% (WF), 6.2, followed by T2 - 5.9 for cookies produced with 80% WF and 15% SF, while treatments T3 and T4 with replacement of 30 and 45% SF had lower values of expansion factor, 5.5 and 5.2, with no difference between the two treatments.

With the reduction in wheat flour concentration, there is less expansion of the dough, linked to the weakening of the gluten network, as CO_2 disperses from the dough, compromising the height and diameter of the product, which can be explained in the present study by the absence of the gluten network of cookies formulated with sorghum flour in the replacement of rice flour; the different formulations showed no significance regarding the expansion factor. After baking, the baking soda in the presence of heat releases CO_2, stimulating dough rise. This factor is important because the doughs are aerated, causing cookies to be crunchy and easily chewable.

The texture profile analysis (hardness, fracturability, cohesiveness, elasticity, gumminess and chewability) of gluten-free cookies with different concentrations of sorghum flour are presented in Table 6. The texture parameters analyzed before

Table 5. Diameter, height and expansion factor of cookies formulated with different concentrations of grain sorghum flour, before baking and after baking.

Parameters		Formulations				
		Control	F1	F2	F3	F4
Before baking	Diameter (mm)	28.54 ± 0.27Ba	28.39 ± 0.30Ba	27.57 ± 0.55Ba	27.70 ± 0.21Ba	26.60 ± 0.27Ba
	Height (mm)	11.32 ± 0.26Ba	11.49 ± 0.23Ba	12.17 ± 0.20Ba	11.05 ± 0.30Ba	11.22 ± 0.05Ba
After baking	Diameter (mm)	31.62 ± 0.26Aa	31.51 ± 0.23Aa	30.4 ± 0.30Aa	31.21 ± 0.41Aa	31.40 ± 0.04Aa
	Height (mm)	14.44 ± 0.05Aa	14.77 ± 0.17Aa	14.36 ± 0.57Aa	15.10 ± 0.29Aa	14.85 ± 0.38Aa
	Expansion factor	2.19 ± 0.09a	2.14 ± 0.08a	2.14 ± 0.22a	2.06 ± 0.04a	2.12 ± 0.13a

Equal uppercase letters in columns and equal lowercase letters in rows do not differ from each other by the Scott-Knott test at 5% significance level. Control - 0% sorghum flour; F1 - 25% sorghum flour; F2 - 50% sorghum flour; F3 - 75% sorghum flour; F4 - 100% sorghum flour.

Table 6. Mean values of hardness, fracturability, cohesiveness, gumminess and chewability of cookies formulated with different concentrations of grain sorghum flour, before and after baking.

TPA parameters		Formulations				
		Control	F1	F2	F3	F4
Before baking	**Hardness (N)**	19.53 ± 1.62Ba	12.81 ± 1.52Ba	6.65 ± 1.39Ba	8.62 ± 1.43Ba	6.57 ± 1.95Ba
	Fracturability (N)	19.53 ± 0.52Ba	12.81 ± 0.50Ba	6.65 ± 0.25Ba	9.54 ± 1.24Ba	6.85 ± 0.74Ba
	Cohesiveness	0.13 ± 0.05Aa	0.13 ± 0.05Aa	0.14 ± 0.03Aa	0.16 ± 0.03Aa	0.13 ± 0.06Ba
	Elasticity (mm)	9.45 ± 0.05Aa	11.71 ± 2.67Ba	18.65 ± 1.63Aa	17.19 ± 3.86Aa	17.48 ± 1.03Aa
	Gumminess (N)	2.53 ± 0.85 Ba	1.65 ± 0.73 Ba	0.80 ± 0.60Ba	1.52 ± 0.30Ba	0.94 ± 0.42Ba
	Chewability (mJ)	28.99 ± 0.29Aa	25.01 ± 0.12Aa	17.47 ± 0.56Aa	27.82 ± 4.28Aa	20.78 ± 0.45Ba
After baking	**Hardness (N)**	22275.11 ±220Ab	17421.55±350.72Ac	17908.44 ± 35.36Ac	25594.44 ± Aa	21308.22±148,96Ab
	Fracturability (N)	218.45 ± 3.76 Ab	170.85 ± 6.48Ac	175.67 ± 3.44Ac	251.00 ± 0.35 Aa	208.9 ± 1.46Ab
	Cohesiveness	0.05 ± 3.76Bc	0.05 ± 6.4Bc	0.07 ± 3.44Bc	0.10 ± 0.35Bb	0.27 ± 1.46Aa
	Elasticity (mm)	22.46 ± 4.28Aa	31.29 ± 0.66Aa	24.77 ± 0.92Aa	16.42 ± 0.82Aa	28.56 ± 0.30Aa
	Gumminess (N)	9.98 ± 2.25Ac	9.56 ± 2.01Ac	12.37 ± 1.13Ac	26.36 ± 1.92Ab	53.08 ± 0.78Aa
	Chewability (mJ)	225.34 ± 1.96Ab	305.18 ± 1.72Ab	311.87 ± 21.87Ab	437.64 ± 0.46Ab	1471.15±0.56Aa

Equal uppercase letters in columns and equal lowercase letters in rows do not differ from each other, according to the Scott-Knott test at 5% significance level. Control - 0% sorghum flour; F1 - 25% sorghum flour; F2 - 50% sorghum flour; F3 - 75% sorghum flour; F4 - 100% sorghum flour.

baking, between the analyzed formulations, showed no difference according to the Scott-Knott test at 5% significance level.

It is verified that the different concentrations of sorghum flour did not interfere in the Texture Profile of the cookies before baking. Regarding the hardness parameter, the F3 formulation resulted in the highest value 25,594.44 N, being the most resistant cookie formulation. The hardness is proportional to the force applied to cause a deformation, the greater the force needed to penetrate the food, the greater its hardness, being an important parameter for the acceptance of cookies, since it is desirable that they present the crunchiness of the food. The highest fracturability after cooking was in F3 with 251 N, it is the force necessary for the food to break.

The elasticity parameter was not influenced by the substitution of rice flour for sorghum flour. Similar behaviors were reported by Storck et al. (2021), when preparing breads with different concentrations of sorghum flour (ranging from 10%, 20%, 30% and 40%), where there was no variation in elasticity between the formulations studied. In the cohesiveness parameter, the formulation F4 (100% sorghum flour) with 0.27 mm had the highest value, followed by F3 - 0.10 mm. The values of F2, F1 and control, 0.07; 0.05 and 0.05 mm, respectively, did not differ from each other. Curi et al. (2017) define chewability as the energy needed to chew a solid food to the point of being ingested. Therefore, it can be affirmed that the F4 formulation, with 1,471.15 mJ, has higher resistance to chewing compared to the others: Control - 225.34, F1 - 305.18, F2 - 311.87, F3 - 437.64 mJ.

4 Conclusion

The sorghum grain flour presented physicochemical and microbiological characteristics in accordance with the current legislation in Brazil. All cookie formulations had a moisture content of less than 8%. The increase of sorghum flour in the substitution of rice flour, showed interference in the color, causing dark color. The use of sorghum flour did not affect the expansion factor parameter. The substitution of rice flour for sorghum flour showed variation in the texture aspect of the cookies. Formulation F3-75% sorghum flour showed greater hardness and brittleness, while formulation F4-100% sorghum flour showed greater cohesiveness, gumminess and chewiness. It is hoped that this work will contribute to the dissemination of information on the nutritional aspects of sorghum grains, being better used in food.

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