Revista Brasileira de Milho e Sorgo
Brazilian Journal of Maize and Sorghum

ISSN 1980 - 6477
Journal homepage: www.abms.org.br/site/paginas

WHOLE SORGHUM FLOUR PROCESSED AS COOKIES MAINTAINED BIOACTIVE COMPOUNDS AT STORAGE

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Abstract – Sorghum is a highlighted cereal due to its bioactive phenolic compounds with health-protective effects for consumers. This study aimed to evaluate the technological, sensory, and chemical features of cookies made with different proportions of sorghum flour and the effect of cookie storage on the content of phenolic compounds and antioxidant capacity. Cookies were prepared with whole flour from sorghum genotype BRS 506 and cornstarch in proportions of 50 (50 SF), 75 (75 SF), and 100 (100 SF) g sorghum/ 100g of total flour. Cookie measurements, sensory analysis, and chemical composition were determined. Phenolic compounds were analyzed during 45 days of storage. Sorghum flour increased cookies expansion factor, especially for 75 SF and 100 SF. Except for texture and purchase intention, sorghum cookies had an acceptance index higher than 70%. The sorghum flour improved the nutritional properties and showed higher total phenolic, tannins, anthocyanins, and antioxidant capacity compared to the control. They maintained the total phenolic content and increased the antioxidant capacity for 45 days, particularly those added with 50 g and 75 g of sorghum flour. These outcomes indicate that whole grain sorghum flour is an option for the food industry searching for to attempt new products with health benefits.

Keywords: *Sorghum bicolor*; Sensory analysis; Antioxidant capacity; Tannin-sorghum

FARINHA DE SORGO INTEGRAL PROCESSADA COMO BISCOITOS MANTEVE OS COMPOSTOS BIOATIVOS DURANTE O ARMAZENAMENTO

Resumo - O sorgo é um cereal que se destaca pela concentração de compostos fenólicos, que estão relacionados a benefícios para saúde dos consumidores. O objetivo desse estudo foi avaliar as características tecnológicas e sensoriais de biscoitos elaborados com diferentes proporções de sorgo assim como o efeito do armazenamento sobre os teores de compostos fenólicos e capacidade antioxidante. Os biscoitos foram elaborados com farinha integral de sorgo genótipo BRS 506 e amido de milho, nas proporções de 50 (50 SF), 75 (75 SF), e 100 (100 SF) g sorgo / 100 g do total de farinhas. Análises das medições, composição centesimal, sensorial e química foram determinadas. Os compostos fenólicos foram analisados durante 45 dias de armazenamento. A inclusão de farinha de sorgo, nas proporções de 75 SF e 100 SF, aumentou o fator de expansão dos biscoitos. Todos os biscoitos de sorgo obtiveram índice de aceitação para sabor superior a 70 %. Os biscoitos contendo sorgo apresentaram maiores teores de fenólicos totais, taninos e antocianinas em relação ao controle. Houve manutenção dos compostos fenólicos durante o armazenamento e um aumento da capacidade de antioxidante durante os 45 dias, particularmente nos biscoitos contendo 50 g e 75 g de farinha de sorgo. Esses resultados indicam que a farinha de sorgo integral é uma opção para a indústria de alimentos em busca de experimentar novos produtos com benefícios à saúde.

Palavras-chave: *Sorghum bicolor*; Análise sensorial; Capacidade antioxidante; Taninos.

How to cite

PANSINI, D. D.; NASCIMENTO, R. C.; QUEIROZ, V. A. V.; FIGUEIREDO, J. E. F.; SILVA, E. M. M.; MORAES, E. A. Whole sorghum flour processed as cookies maintained bioactive compounds at storage. **Revista Brasileira de Milho e Sorgo**, v.21 e1247, 2022.

DOI: https://doi.org/10.18512/rbms2022vol21e1247

Sorghum [*Sorghum bicolor* (L.) *Moench*] is a cereal grain crop noteworthy by the high phenolic compounds content, such as phenolic acids, anthocyanins, and tannins. These compounds have antioxidant capacities related to health benefits. In several African countries, sorghum is a staple food consumed as grain and flour to make bread, porridge, and cookies, while in Europe and America, most sorghum production is used for animal feed (Awika & Rooney, 2004; Moraes et al., 2020).

Sorghum nutritional and functional features associated with health-related eating habits and the need for food diversification raise the industry interest to introduce this cereal in food products. Thereby, investments in new sorghum products have increased in recent years (Adeyeye, 2016; FAO, 2019; Stefoska-Needham & Tapsell, 2020). Cookies should be highlighted among those products due to the high intake and acceptance by people of all ages and an extensive shelf-life (Cheng & Bhat, 2016).

However, the shelf-life, technological, sensory, and chemical features, such as the phenolic compounds content of sorghum products, may be altered during storage. Thus, studies to evaluate these changes are relevant to know the correct amount of these compounds in processed and stored foods (Sharma & Riar, 2020).This study aimed to evaluate the technological, sensory, and chemical features of cookies made with different proportions of sorghum flour and the effect of storage on phenolic compounds content and antioxidant capacity.

Material and methods

Cookies formulation

Cookies were prepared with whole sorghum flour of BRS 506 genotype, with gray pericarp and tannins (Embrapa Milho e Sorgo, Sete Lagoas, MG, Brazil), and cornstarch (Maizena®) following the proportions of 50g:50g (50 SF), 75g:25g (75 SF), 100g:0g (100 SF),respectively, according to Ferreira et al. (2009), with modifications. Salted butter, margarine, and sugar were added in the same amount in all cookie recipes (Table 1).Furthermore, a cornstarch cookie recipe was considered as a control (CC) (Table 1).

Table 1. Sorghum cookies formulations (g/100g).

Ingredients (g)	CC	50 SF	75 SF	100 SF
Whole sorghum flour	0	30	45	60
Corn starch	60	30	15	0
Butter	14	14	14	14
Margarine	14	14	14	14
Sugar	12	12	12	12

CC: cornstarch cookie (control); 50 SF: Cookies of 50 g of whole sorghum flour/100g total flour (whole sorghum flour + corn starch);75 SF: Cookies of whole sorghum flour 75g/100g total flour (whole sorghum flour + corn starch), and 100 SF: Cookies of whole sorghum flour 100 g/100g total flour (whole sorghum flour + cornstarch).

DOI: https://doi.org/10.18512/rbms2022vol21e1247

Cookies measurements

Five cookies of each formulation, randomly selected from three different batches, were analyzed as weight, diameter, and thickness before and after baking (American Association for Clinical Chemistry, 2010). Weight was measured on a digital scale (Even CT= 6200 – BI), cookies diameter and thickness were determined with a Vernier Caliper (150 x 0.05 mm). The expansion factor was obtained from the ratio of the diameter and thickness values of the cookies.

Proximate composition

Moisture, protein, lipids, and ash were determined, according to Association of Official Analytical Chemists (2002). The carbohydrate content was calculated by difference using the equation: 100 - (moisture + protein + lipid + ash). The energetic value was calculated by the Atwater conversion factors: 9 kcal per gram of lipid, 4 kcal per gram of carbohydrate, and 4 kcal per gram of protein. Data were expressed as g/100g of sample.

Sensory analysis

Cookies were submitted to an acceptance test using a 9-point hedonic scale (9 = liked a lot and 1 = disliked extremely). Sensory attributes included were color, appearance, flavor, and texture. Moreover, purchase intention was evaluated using a structured 9-point scale, where 1 = certainly would not buy, and 9= certainly would buy (Minim, 2006).

Untrained judges were invited to participate voluntarily and signed the Free and Informed Consent Form (ICF). All participants under 18, unsigned ICF, who gave up or had any illness, were excluded from the analysis. Untrained judges randomly received cookie samples with three-digit coding, a glass of mineral water, and a product evaluation form. The tests were individually conducted.

Sensory analysis data were submitted to the acceptance index test, represented by the formula:

$$AI\% = X * \frac{100}{N}$$

AI=acceptance index, X = average of each sample, N = maximum score of each sample, given by the evaluators. The cookies were considered accepted when the acceptance index was higher than 70%.

The Ethics Committee on Research of the Universidade Federal do Espírito Santo Health Sciences Center approved this study under CAAE: 91748418.3.0000.5060.

Cookies storage

Cookies formulations that showed higher acceptance index scores were analyzed at storage. They were packed with a low-density polyethylene bag and stored under dark conditions at room temperature (±30 ºC). Total phenolic, tannin, anthocyanins, and antioxidant capacity were determined every 15 days for 45 days.

Phenolic extracts of cookies

Approximately 1 g of each sample was extracted in 5 mL of 1% HCl/methanol (v/v) for 2 h, under mechanical shaking at low speed. Samples were stored at 20 ºC in the dark overnight. Then, the samples were equilibrated at room temperature (25 ºC ± 5) and centrifuged at 872 g (2790 rpm) for 10 min. Sample residues were rinsed with two additional 5 mL volumes of solvent with shaking for 5 min, then centrifuged. Three aliquots were mixed and stored at 20 ºC in the dark until analysis (Awika et al., 2003).

For condensed tannin assay, samples (0.8 g) were extracted for 20 min in 10 mL of 1% HCl/

methanol (v/v) at 30 °C in a water bath. The extracts were centrifuged at 3000 rpm for 10 min, and the supernatant was used for the assay (Awika et al., 2003). Two aliquots were taken (two repetitions), and the absorbance was read in three replicates.

Total phenolic, tannin, and anthocyanins

The cookie total phenolic content was performed using the Folin–Ciocalteu method (Singleton et al., 1999). The samples and gallic acid standard curve (0.016-0.5 mg gallic acid/mL; y = 1.9142x – 0.0261; R^2 = 0.9988) were read at 725 nm. Results were expressed as mg gallic acid equivalent/g of sample.

The condensed tannins were measured by the vanillin/HCl reaction method reported by Price et al. (1980). The samples and catechin standard curve (0.05-0.5 mg catechin/mL; y = 0.2189x+ 0.0055; R^2 = 0.9939) were read at 500 nm. Results were expressed as mg catechin equivalent /g of sample.

The total anthocyanin concentration was performed by the differential pH method described by Fuleki and Francis (1968) and modified by Awika et al. (2005). Total anthocyanin was diluted in potassium chlorite 0.0025 M, pH 1.0 and read at 300 and 700 nm. The results were expressed as mg/100g of sample.

Antioxidant capacity

The DPPH assay was done according to Awika et al. (2003) for sorghum samples. A methanol solution containing 0.06 mM DPPH was used. The absorbance of samples was measured 8 h after reaction and read at 517 nm. Absorbance values of colorimetric assays were read in a spectrophotometer (Nova Instruments, model NI 2000, Piracicaba/SP, Brazil). Results were expressed as percentage following equations: % discoloration of DPPH = [(Sample - Sample Absorption / Control)] x 100.

Statistical analysis

The data were performed by the Analysis of Variance method (ANOVA; α= 5%). For significant "F", the posthoc Tukey test was used to determine significant differences among the means (α = 5%). The data analyses were carried out with the GraphPad Prism 5.0 software (GraphPad Software, Inc. La Jolla, CA, USA).

Results and discussion

There was no difference in cookie weight ($p>0.05$) (Table 2). This fact showed that different proportions of whole sorghum flour addition did not influence this parameter as Ferreira et al. (2009) described. Sorghum cookies showed a higher diameter than the control ($p\leq0.05$). Nevertheless, 100 SF had the lowest values among sorghum cookies (Table 2). This outcome may be explained due to the higher amount of cornstarch in control cookies. Cornstarch (after heat treatment in a humid environment) has a higher water absorption capacity, which raises the dough viscosity and prevents its scattering. Thus, it may reduce the cookie diameter (Adeyeye, 2016). The thickness did not differ among sorghum cookies ($p>0.05$) (Table 2). This data corroborates to Adeyeye, 2016, who showed that partial or total substitution of wheat flour for sorghum flour on cookies reduced their thickness compared to those made only with wheat flour. Fibers, especially, are responsible for the lower formation of air bubbles inside the cookies. The addition of sorghum flour increased the cookies expansion factor, especially for 75 SF and 100 SF ($p\leq0.05$) (Table 2). This outcome produced cookies with a larger diameter and less thickness compared

DOI: https://doi.org/10.18512/rbms2022vol21e1247

Table 2. Physical measurements and proximal composition of cookies prepared with cornstarch (control) or different proportions of the whole sorghum flour of genotype BRS 506.

Parameters	CC	50 SF	75 SF	100 SF
Weight (g)	7.59^{a}±1.11	8.04^{a}±1.13	7.87^{a}±1.56	7.42^{a}±0.73
Diameter (cm)	3.85^{c}±0.06	4.36^{a}±0.21	4.37^{a}±0.21	4.17^{b}±0.12
Thickness (cm)	0.73^{a}±0.05	0.61^{b}±0.02	0.53^{b}±0.07	0.53^{b}±0.08
Expansion factor	5.32^{b}±0.42	7.20^{ab}±0.37	8.36^{a}±1.39	8.18^{a}±1.75
Moisture	3.39^{a}±0.03	3.10^{a}±0.16	3.41^{a}±0.25	3.22^{a}±0.20
Ash	0.44^{c}±0.04	0.71^{b}±0.04	0.83^{b}±0.01	1.10^{a}±0.02
Lipids	31.02^{a}±0.52	31.22^{a}±4.37	33.56^{a}±2.92	35.35^{a}±0.11
Proteins	0.87^{d}±0.00	5.18^{c}±0.13	7.47^{b}±0.12	9.64^{a}±0.12
Carbohydrate	64.28^{a}±0.61	61.04^{a}±5.36	54.73^{a}±2.46	50.86^{a}±0.25
Energy (Kcal)	539.79	545.86	550.84	560.15

CC: cornstarch cookie (control); 50 SF: Cookies of 50 g of whole sorghum flour /100g total flour (whole sorghum flour + corn starch);75 SF: Cookies of whole sorghum flour 75g/100g total flour (whole sorghum flour + corn starch) and 100 SF: Cookies of whole-grain sorghum flour 100 g/100g total flour (whole sorghum flour + corn starch). Data are expressed as the mean± standard deviation. Means followed by the same lowercase letters in line do not differ from each other according to the Tukey test at 5% probability ($p \leq 0.05$).

to the control.

There was no difference in cookies moisture ($p>0.05$) (Table 2).Protein and ash were higher in sorghum cookies, especially 100 SF ($p\leq0.05$). The sorghum genotype BRS 506, used in the present study, has 11.43 g/100 g protein and 1.93 g/100 g of ash (Martino et al., 2012). It is also a source of iron, phosphorus, magnesium, and zinc which may increase the ash content of sorghum flour (0.44 g CC to 1.1 g/100 g 100 SF). This situation may also occur on the protein content, which ranged from 0.87 g/100 g on CC to 9.64 g/100 g (100 SF) (Table 2). There was no difference in cookie carbohydrate ($p>0.05$) (Table 2). It could be related to a high content of this macronutrient in corn starch and sorghum flour, 86.97 g/100 g and 72.4 g/100 g, respectively (Batista et al., 2010; Martino et al., 2012). In this context, cornstarch replacing sorghum flour was not enough to influence carbohydrate contents.

There was no difference in the lipid content ($p>0.05$) of cookies (Table 2). This outcome is due to the same amount of margarine and butter designed in all formulations. It demonstrates that the different amount of lipids content between sorghum flour and corn starch (respectively 2.36 g/100 g and 1.19g/100 g) could not influence the final lipid content of the cookies (Batista et al., 2010; Martino et al., 2012).

DOI: https://doi.org/10.18512/rbms2022vol21e1247

A total of 97 consumers participated in the present study. The average age was 26 ± 8.78 years old and 90% were graduate students and university staff. The color and appearance scores from the control cookies were higher than sorghum cookies ($p \leq 0.05$). However, there was no difference among cookies with different proportions of whole sorghum flour ($p > 0.05$) (Table 3).The color of sorghum pericarp, which varies with sorghum genotype, may influence the product appearance (Awika & Rooney, 2004).The sorghum genotype BRS 506 used in this study has a gray pericarp, which provides a grayish color to the product, while the control cookie presented a cream color. The difference of color between the sorghum and maize cookies (control) could explain the difference in the consumer acceptance of both cookies. Furthermore, all cookies showed an acceptance index above 70% for this sensory attribute, indicating that the addition of different proportions of sorghum flour was well accepted by the consumers (Table 3).The food color directly influences its appearance, and product evaluation is firmly based on this feature. Moreover, food color may affect consumer attitudes, indicating the importance of color for accepting a new product.

Regarding flavor, sorghum cookies showed an acceptance index above 70%, and among them, 50 SF and 75 SF had the most significant scores ($p \leq 0.05$) (Table 3). Rai et al. (2014) studied the quality characteristics of cookies with different gluten-free flour mixtures. They reported that samples with sorghum flour had high overall acceptance scores. These results reinforce the endorsement of sorghum products.

Regarding texture, control cookie and 50 SF had the highest score, while 100 SF scored the lowest ($p \leq 0.05$) (Table 3). Similarly, Chiremba et al. (2009) conducted a sensory analysis with sorghum cookies from three different genotypes (with and without tannin). Compared to wheat cookies (control), sorghum cookies showed the lowest texture scores.

Table 3. Sensory analysis of cookies made with cornstarch (control) or different proportions of whole sorghum flour (genotype BRS 506).

Attributes	**CC**		**50 SF**		**75 SF**		**100 SF**	
	Score	**AI (%)**	**Score**	**AI (%)**	**Score**	**AI (%)**	**Score**	**AI (%)**
Color	$8.19^{a}\pm1.21$	91.07	$6.89^{b}\pm1.59$	76.63	$7.01^{b}\pm1.50$	77.89	$7.20^{b}\pm1,36$	80.07
Appearance	$8.24^{a}\pm0.11$	91.63	$6.79^{b}\pm1.61$	75.49	$7.10^{b}\pm1.46$	79.22	$7.11^{b}\pm1,46$	79.03
Flavor	$8.20^{a}\pm1.35$	91.18	$8.00^{ab}\pm1.24$	88.89	$7.63^{b}\pm1.11$	84.88	$6.69^{c}\pm1,57$	74.34
Texture	$7.96^{a}\pm1.69$	88.54	$7.54^{ab}\pm1.53$	83.84	$7.10^{b}\pm1.48$	78.92	$6.24^{c}\pm1,97$	69.41
PI	$7.88^{a}\pm2.05$	87.57	$7.08^{ab}\pm1.80$	78.70	$6.70^{bc}\pm1.55$	74.49	$5.91^{c}\pm2,55$	65,72

CC: cornstarch cookie (control); 50 SF: Cookies of 50 g of whole sorghum flour /100g total flour (whole sorghum flour + corn starch);75 SF: Cookies of whole sorghum flour 75g/100g total flour (whole sorghum flour + corn starch) and 100 SF: Cookies of whole sorghum flour 100 g/100g total flour (whole sorghum flour + cornstarch). IA=Acceptance index. PI=purchase intent .Data are expressed as the mean± standard deviation. Means followed by the same lowercase letters in line do not differ from each other according to the Tukey test at 5% probability($p \leq 0.05$).

Furthermore, they reported that tannin sorghum cookies had the lowest scores for sensory attributes, including texture. In the present study, lower flavor and texture scores were observed for 100 SF (Table 3). These scores probably had a considerable influence on purchase intent, leading to an acceptance index below 70% for 100 SF.

Cookies made with flour of 50 SF and 75 SF, which showed higher acceptance and purchase intention, were selected for further analyzing the phenolic compounds content and antioxidant capacity and were compared to the control cookie during storage.

The total phenolic content of sorghum cookies, 50 SF and 75 SF, was higher than CC during storage ($p \leq 0.05$) (Table4). The formulation 75 SF was approximately three times higher in these compounds than CC for all analyzed weeks. This outcome is due to the higher amount of sorghum total phenolic, while corn starch did not have a significant amount of these compounds (Mazur, 2016; Moraes et al., 2020).

There was no difference in cookie's total phenolic between the 1^{st} and the 45^{th} day ($p \leq 0.05$) (Table 4). According to Oliveira et al. (2017), these compounds on sorghum flour of brown pericarp and pigmented testa and black pericarp without pigmented testa remain stable for 120 days storage at 4 ºC and 40 ºC.Thus, both studies have shown the storage stability of sorghum phenolic compounds. Nevertheless, those studies evaluated the sorghum flour stability, while the present research hasdemon strated the preservation of total phenolic content on a processed food added sorghum flour during 45 days.

Sorghum cookies showed a higher tannin content than CC ($p \leq 0.05$)(Table 4). Cookie 75 SF, except the first day, showed the highest amount of this compound compared to 50 SF ($p \leq 0.05$) (Table 4). This fact may be related to the BRS 506 sorghum genotype used in the present study, which has pigmented testa, indicating the tannin presence (Awika & Rooney, 2004). According to Moraes et al. (2020), the flour of the BRS 506 genotype has 33.7 mg tannin/g of flour. Therefore, this increases the tannin content on cookies with a higher amount of BRS 506 sorghum flour.

The tannin content of cookies made with flour of sorghum 50 SF and 75 SF increased on storage ($p \leq 0.05$) (Table 4). Similar behavior was reported by Oliveira et al. (2011) which evaluated the tannin content behavior on sorghum grain and flour during six months. The increasing content was associated with the polymerization of flavan-3-ol monomers, which are tannin precursors. Thus, in the present study, the increment in tannin content may be related to the processing and storage time effects on cookies demonstrating that the storage of sorghum food may influence the tannin content.

Except on the 45^{th} day, the anthocyanin content 50 SF did not differ between CC and 75 SF ($p > 0.05$) (Table 4). Meanwhile, 75 SF showed higher anthocyanin content than CC ($p \leq 0.05$) (Table 4). Sorghum flour was the only source of this compound in the recipe. Thus, lower anthocyanin content was expected on cookies CC (Mazur, 2016; Moraes et al., 2015). This result may be related to the fact that the sorghum genotype used in the present research has low anthocyanin content. Therefore, there was no difference between cookies, only a trend of higher content in cookies with a higher proportion of sorghum. Additionally, anthocyanin was measured only with potassium chloride buffer, in pH 1.0, according to modifications for sorghum samples, as Awika et al. (2005) proposed. Thus, anthocyanin content on CC may be overrated. Extracts' absorbance values,

DOI: https://doi.org/10.18512/rbms2022vol21e1247

Table 4. Content of phenolic compounds, tannin, anthocyanin, and antioxidant capacity of cookies made with cornstarch (control) or different proportions of whole sorghum flour during 45 days of storage (genotype BRS 506).

Analysis	CC	50 SF	75SF
Total phenolics			
Day 1	$2.75^{Ba}\pm0.31$	$6.60^{Aa}\pm0.35$	$8.49^{Aa}\pm0.65$
Day 15	$2.03^{Cab}\pm0.19$	$5.58^{Ba}\pm0.07$	$7.37^{Aa}\pm0.18$
Day30	$1.58^{Cb}\pm0.02$	$3.91^{Bb}\pm0.56$	$6.95^{Aa}\pm0.17$
Day 45	$2.11^{Bab}\pm0.19$	$6.14^{Aa}\pm0.08$	$7.73^{Aa}\pm0.66$
Tannins			
Day 1	$0.00^{Ba}\pm0.00$	$2.34^{Ab}\pm0.16$	$2.73^{Ab}\pm0.59$
Day 15	$0.00^{Ca}\pm0.00$	$2.88^{Ba}\pm0.26$	$4.14^{Aa}\pm0.05$
Day 30	$0.00^{Ca}\pm0.00$	$2.53^{Ba}\pm0.09$	$3.80^{Aab}\pm0.20$
Day 45	$0.00^{Ca}\pm0.00$	$3.26^{Ba}\pm0.16$	$4.87^{Aa}\pm0.04$
Anthocyanins			
Day 1	$1.72^{Bb}\pm0.36$	$3.19^{Aba}\pm0.57$	$4.55^{Aa}\pm0.77$
Day 15	$2.56^{Bab}\pm0.30$	$3.79^{Aba}\pm0.26$	$4.88^{Aa}\pm0.81$
Day 30	$1.62^{Bb}\pm0.52$	$2.79^{ABa}\pm0.55$	$3.60^{Aa}\pm0.19$
Day45	$3.35^{Aa}\pm0.32$	$3.98^{Aa}\pm0.38$	$4.55^{Aa}\pm0.09$
DPPH			
Day 1	$7.65^{Bc}\pm0.02$	$9.340^{Ac}\pm0.05$	$9.99^{Ab}\pm0.36$
Day 15	$8.06^{Cb}\pm0.05$	$10.33^{Bb}\pm0.02$	$11.39^{Aa}\pm0.00$
Day 30	$8.86^{Ca}\pm0.12$	$10.90^{Ba}\pm0.07$	$11.61^{Aa}\pm0.12$
Day 45	$8.60^{Ca}\pm0.14$	$10.74^{Bab}\pm0.19$	$11.79^{Aa}\pm0.11$

CC: cornstarch cookie (control); 50 SF: Cookies of 50 g of whole sorghum flour /100g total flour (whole sorghum flour + corn starch);75 SF: Cookies of whole sorghum flour 75 g/100 g total flour (whole sorghum flour + corn starch) and 100 SF: Cookies of whole sorghum flour 100 g/100g total flour (whole sorghum flour + corn starch). Data are expressed as the mean ± standard deviation. Means followed by the same capital letters in line do not differ from each other according to the Tukey test at 5% probability ($p\leq0.05$).Means followed by the same lowercase letters on the column do not differ from each other according to the Tukey test at 5% probability ($p\leq0.05$).Total phenolic is expressed as mg of equivalent gallic acid/1g sample; tannins are expressed as mg of equivalent catechin/1g of the sample; anthocyanins are expressed as mg/1g of a sample; antioxidant capacity (DPPH) is expressed as percentage (%).

measured by the differential pH method proposed by Fuleki and Francis (1968), should also be subtracted from the absorbance of extracts diluted in sodium acetate buffer, pH 4. Furthermore, studies to measure the extract absorbance on both buffers are needed.

There was no difference in anthocyanin content between 50 SF and 75 SF during 45 days of storage (Table 4) ($p \leq 0.05$). Oliveira et al. (2017) showed that anthocyanin content of brown sorghum with tannin and black sorghum without tannin remained stable for 120 days, at 4 and 40 ºC.The authors highlighted the tannin stability and the possibility of storing it at room temperature without any losses. That stability may be attributed to the chemical structure of the 3-deoxyanthocyanins. Most common in sorghum grain, these anthocyanins do not have an oxygen molecule in the C-3 position. This molecular lack differentiates the 3-deoxyanthocyanins from others, and it is more stable than that found in fruits and vegetables (Awika & Rooney, 2004). While Oliveira et al. (2017) reported anthocyanin stability on sorghum flour as in the present study. It demonstrates that sorghum food may keep the flour properties, regarding anthocyanin, even after storage.

The sorghum flour cookies showed total phenolic, tannins, and anthocyanins contents higher than the maize control (CC). This result was predictable since the higher phenolic content in sorghum influences the food antioxidant capacity (Martino et al., 2012; Moraes et al., 2015). Like tannin behavior, antioxidant capacity was higher on sorghum cookies ($p \leq 0.05$) (Table 4). Except on the 1st day, the 75 SF showed higher antioxidant capacity than 50 SF ($p \leq 0.05$)(Table 4).The higher the amount of sorghum flour used, the higher the phenolic content, leading to increased antioxidant capacity due to the straight correlation between phenolic, such as tannins, and the antioxidant capacity (Moraes et al., 2015). On the last day of storage, the antioxidant capacity was higher than on the 1st day ($p \leq 0.05$) (Table 4). This result may be due to the higher tannin content in sorghum cookies at the end of storage once positively correlated (Moraes et al., 2015). Atonfack et al. (2019) reported increased sunflower butter antioxidant capacity after 24 days of storage. A raised hypothesis is related to the soluble phenols released by acidulants present in the ingredients, such as the margarine. Therefore, the rise in tannin polymerization associated with the butter and margarine phenols release may increase the sorghum cookie's antioxidant capacity.

Conclusions

Whole sorghum flour added to cookies showed technological and sensory features similar to the control cookies. The new products were accepted by consumers, especially those added with 50 g or 75 g of sorghum flour. The sorghum flour improved the nutritional and functional properties of formulations. Sorghum cookies maintained the total phenolic content for 45 days of storage, associated with increased antioxidant capacity, particularly for those added with 50 g or 75 g of sorghum flour on the day 45th. These outcomes indicate whole sorghum flour as an option for the food industry to attempt new products with nutritional properties and potential health benefits. A new study is suggested to develop these cookies, reduced-fat and sugar-free, intended for a specific consumer audience.

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