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Application of sugarcane bagasse as potentially functional ingredient in cookies formulation: A study on physicochemical, sensory, and texture profile properties

Aplicación del bagazo de caña de azúcar como ingrediente potencialmente funcional en la formulación de galletas: un estudio sobre propiedades fisicoquímicas, sensoriales y de perfil de textura

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Abstract

Sugarcane (*Saccharum officinarum* var. COLPOS CTMEX 05-223) is a crop that is excluded from the sugar industry due to its low juice yield. Its applications are limited to artisanal use during Day of the Dead celebrations as a decorative element for altars. Additionally, during the winter season, it serves as an essential ingredient in the traditional beverage known as "ponche". However, these limited applications have an economic impact on the producers of this crop. In search of increasing its value, the objective of this work was to evaluate the physicochemical and functional properties of sugarcane var. COLPOS CTMEX 05-223 bagasse, added at different concentrations in model cookies, enhancing its use as a functional ingredient. Proximal composition analyzes, as well as functional tests (water and oil retention capacity, swelling index and dietary fiber) were performed on bagasse, also carrying out texture analysis and sensory evaluation of cookies added with bagasse. The results showed that the bagasse appears as a recommended source of dietary fiber, which once added to the cookies in different concentrations (10, 15, 20, 25, and 30%), generated significant changes ($p \leq 0.05$) both in the texture profile of the cookies as well as in their sensory acceptance, evaluated by untrained judges. Based on the above, the sugarcane var. COLPOS CTMEX 05-223 bagasse can be considered a useful ingredient for the preparation of functional foods with specific healthy effects.

Keywords: dietary fiber, functional foods, agro-industrial by-products.

Resumen

La caña de azúcar (*Saccharum officinarum* var. COLPOS CTMEX 05-223) es un cultivo excluido de la industria azucarera debido a su bajo rendimiento de jugo. Las aplicaciones de la caña de azúcar (*Saccharum officinarum* var. COLPOS CTMEX 05-223) están limitadas al uso artesanal durante las celebraciones del Día de Muertos como elemento decorativo en los altares. Además, durante la temporada de invierno, se utiliza como ingrediente esencial en la bebida tradicional conocida como "ponche". Sin embargo, estas aplicaciones limitadas tienen un impacto económico en los productores de este cultivo. En búsqueda de incrementar su valor, el presente trabajo tuvo por objetivo evaluar las propiedades fisicoquímicas y funcionales del bagazo de la caña de azúcar var. COLPOS CTMEX 05-223, posteriormente adicionada a diferentes concentraciones en galletas modelo potencializando su uso como ingrediente funcional. Análisis proximales de composición, así como pruebas funcionales (capacidad de retención de agua y aceite, índice de hinchamiento y fibra dietaria) fueron realizadas al bagazo y a las galletas, sometiendo estas últimas a un análisis de textura y una evaluación sensorial. Los resultados demostraron que el bagazo figura como una recomendable fuente de fibra dietaria, que una vez adicionada a las galletas en diferentes concentraciones (10, 15, 20, 25, y 30%), generó cambios significativos ($p \leq 0.05$) tanto en el perfil de textura de las galletas, como en su aceptación sensorial realizada por jueces no entrenados. Con base en lo anterior, el bagazo de la caña de azúcar var. COLPOS CTMEX 05-223 puede ser considerado un ingrediente útil en la elaboración de alimentos funcionales con efectos saludables específicos.

Palabras clave: fibra dietaria, alimentos funcionales, subproductos agroindustriales.

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1 Introduction

According to Food and Agriculture Organization (FAO) of the United Nations, sugarcane (*Saccharum officinarum*) is the most important crop worldwide, with a production of 1.87 billion tons in 2020 (Molina-Cortes *et al*., 2023). Mexico is recognized as the 8th sugarcane producer in the word, reaching an annual production of 5.7 million tons in 2021 (SIAP, 2022). Mexican production of sugarcane is based on the use of those varieties rich in juice, including the CP 72-2086 and MEX 69-290. On the contrary, the varieties with lower juice yield, such as COLPOS CTMEX 05-223, are excluded from sugar industry being identified as a source of agricultural residues. Despite the fact of that sugarcane is considered an efficient source of biomass, its residues such as bagasse represents approximately 30% of the total production. In this context, new alternatives that promote the integral use of the different sugarcane resources (including sugarcane bagasse), have been planned (Vandenberghe *et al*., 2022). Sugarcane bagasse (SCB) is a fibrous residue constituted mainly of cellulose and hemicellulose at concentrations of 40-50% and 25-35%, respectively, while minor concentrations of lignin and natural waxes have also been identified (Mahmud and Anannya 2021). So, SCB can be considered as a source of dietary fibers with potential functional properties.

Dietary fibers are considered edible carbohydrates resistant to the endogenous digestive enzymes, being neither hydrolyzed nor absorbed in the small intestine (Peredo-Lovillo *et al*., 2020). Commonly, dietary fibers are classified in insoluble and soluble fibers (Yin *et al*., 2021). Insoluble dietary fibers include cellulose, hemicellulose, and lignin, with different health claims including the prevention of obesity, colon cancer incidence and atherosclerosis. Through foods, insoluble dietary fibers increase fecal bolus volume, promote peristaltic movements modulating intestinal constipation (Han *et al*., 2023). On the other hand, soluble dietary fibers (i.e., pectin, arabinoxylan, β-glucans, fructo-oligosaccharides, galacto-oligosaccharides, inulin, and xyloglucan), contribute to host well-being through their total or partial fermentation by colonic microbiota, producing health promoting metabolites, especially short chain fatty acids and organic acids (Sun *et al*., 2019; Peredo-Lovillo *et al*., 2020).

Despite the benefits reported for the dietary fibers, their consumption is limited mainly due the modern lifestyle that prompts a recurrent consumption of processed foods and fast food (Beristain *et al*., 2020). In Mexico, dietary fibers consumption ranges between 16 to 18 g/day, being considered less than the minimal recommended amounts for adult men (38 g/day) and women (25 g/day) (Ito *et al*., 2023).

Nowadays, strategies to increase the dietary fibers consumption are being explored. The use of dietary fibers as bioactive ingredients has been indicated as a feasible alternative to obtain new functional foods with desirable health claims. In this sense, cookies emerge as an adequate food matrix to incorporate dietary fibers, since they are one of the most popular bakery products in different socioeconomic groups, with ease and versatility of consumption, larger storage stability, and affordability (Jose *et al*., 2022).

Therefore, the objective of the present study was to use the sugarcane bagasse, obtained in this work from sugarcane *S. officinarum* var. COLPOS CTMEX 05-223, but applicable to another varieties, as a source of dietary fibers to be incorporated in a cookie preparation, in order to increase the consumption of functional foods rich in dietary fibers, and at the same time provide added value to this sub-utilized sugarcane variety through an alternative application in food industry.

2 Materials and methods

2.1 *Obtention of the sugarcane bagasse (SCB)*

Bagasse was obtained from ripe sugarcane (*S. officinarum* var. COLPOS CTMEX 05-223), cultivated in the town El Cuajilote, Veracruz, Mexico (18°45'17.4"N 96°41'48.0"W) at 311 meter above sea level, and harvested during November and December 2021. Sugarcane was washed with top water to remove dust and strange particles (Kamble *et al*., 2021). Later, the bagasse was mechanically pressed in a roller to extract the juice. Once pressed, the bagasse was dried in a rotative drier at 70 ºC for 6 h and grounded in a plate mill (IKA mod. Multidrive B S001, USA) at 20,000 rpm during 5 min. Finally, the particle size of the product obtained from grinding process was homogenized through sieving with a mesh of 0.063 mm aperture.

2.2 *Physicochemical characterization of SCB*

Physicochemical characterization of bagasse was based on the AOAC methods including ash (AOAC 923.03), moisture (AOAC 23.003:2003), proteins (AOAC 2001.11), lipids (AOAC 920.39C), and fiber (AOAC 978.10) analysis.

2.2.1 *Carbohydrate composition of SCB fiber*

Kurscheer and Hoffer cellulose was quantified according to the methodology proposed by Siva *et al*. (2021). Holocellulose was quantified following the procedure described in the ASTM D-1104 guideline. Lignin content was evaluated through acid hydrolysis method proposed by Kumar *et al*. (2020). Difference between the holocellulose and cellulose contents was considered as hemicellulose concentration in SCB.

Table 1. Formulations used for the elaboration of cookies added with sugarcane bagasse.

Component	Control	C10	C15	C20	C25	C30
Bagasse	0 g	16.5 g	24.75 g	33 g	41.25 g	49.5 g
Wheat flour	165 g	148.5 g	140. 25 g	132 g	123.75 g	115.5 g
Sucrose	65 g	65 g	65 g	65 g	65 g	65 g
Egg	50 g	50 g	50 g	50 g	50 g	50 g
Cinnamon	3 g	3 g	3 g	3 g	3 g	3 g
Vanilla (ethanolic extract)	5 mL	5 mL	5 mL	5 mL	5 mL	5 mL
Butter	90 g	90 g	90 g	90 g	90 g	90 g

C10, C15, C20, C25, and C30: Cookies added with 10, 15, 20, 25, 30% sugarcane bagasse, respectively. Cookie without addition of sugarcane bagasse were considered as control.

2.3 Functional properties of SCB

2.3.1 Water retention capacity (WRC)

WRC was determined according the methodology described by Klaassen and Trindade (2020), with slight modifications. Bagasse (0.5 g) was mixed with 6 mL of distilled water and heated in a water bath at 30 ºC for 30 min under constant agitation. After heating, the mixture was centrifugated for 15 min at 3,500 x g, and the supernatant dried at 150 ºC for 4 h in an air stove. The solids present in the supernatant were weighed and the WRC was calculated according to the Equation 1:

$$WRC = \frac{\text{Solids in supernatant (g)}}{\text{Bagasse sample (g)}} \quad (1)$$

2.3.2 Lipids absorption index (LAI)

LAI was evaluated according the methodology proposed by Torres González *et al*. (2016), slightly modified. Bagasse (0.5 g) was mixed with 3 mL vegetable oil, and then stirred in a vortex by 5 min. Later, the mixture was left to stand for 30 min at 25 ºC before being centrifuged under the same previously described conditions. The supernatant weight was measured, and LAI was calculated using the Equation 2:

$$LAI = \frac{\text{Absorbed oil (g)}}{\text{Sugarcane bagasse sample (g)}} \quad (2)$$

2.3.3 Swelling power (SP)

14 mL of an aqueous bagasse solution (1% w/v) were heated in a water bath at 60 ºC for 30 min. Subsequently, the mixture was centrifuged at 4,000 x g for 15 min and the supernatant was dried in an air stove at 105 ºC for 4 h. Once dried, the solids in supernatant as well as the pellet were weighed using an analytical balance. The SP was calculated using the Equation 3 (Anchundia *et al*., 2016; Salgado-Delgado *et al*., 2022):

$$\text{SP} = \frac{\text{Pellet (g)}}{\text{Sugarcane bagasse sample (g)} - \text{Dried supernatant (g)}} \quad (3)$$

2.4 Formulation of cookies added with SCB

Based on the design and procedure conditions proposed by Korese *et al*. (2021), five formulations of cookies containing 10, 15, 20, 25 and 30% bagasse were elaborated. Also, Table 1 shows the other ingredients used in cookie's formulation. Cookies without bagasse addition were considered as controls. All the cookies formulations as well as the control sample were considered for the following analysis.

2.5 Physicochemical characterization of cookies added with SCB

The cookies formulations were physicochemical characterized according to the previously described methodologies (Section 2.2).

2.5.1 Total dietary fiber in cookies added with SCB

Total dietary fiber was determined according to the AOAC 2011.25 method, using the enzymatic kit TDF100A-1 (Sigma-Aldrich, USA). As preliminary step, bagasse was degreased, and its particle size adjusted to 0.45 mm using a sieve (# 40, 400 μm aperture). Two 600 mL flasks were used to carried out the enzymatic reactions. Each flask contained 1 g of bagasse, 50 mL of phosphate buffer solution (pH 6.0), and 100 μL of thermostable amylase. Mixtures were incubated at 90 ºC (in a water bath) for 15 min with intermittent stirring. Once the incubation time is over, the mixtures were cooled up to 25 ºC and pH was adjusted to 7.5 using 0.275 N NaOH. Then, 5 mg of protease were added to each flask which were again incubated at 60 ºC for 30 min. After this time, the mixtures were cooled at 25 ºC and the pH adjusted to 4.5 with 0.325 N HCl. Amyloglucosidase was added and enzymatic reaction was promoted by heating at 60 ºC for 30 min. Finally, 200 mL of 95% ethanol were added, and samples rested 12 h at room temperature protected from light.

The content of each flask was separately filtered using two Gooch crucibles, which contained a celite layer of known weight (W1). The material retained in the celite layer was purified by performing three consecutive washes, firstly using 60 mL of ethanol (78% v/v), 20 mL of ethanol (95% v/v), and finally 20 mL of pure acetone. The washed residues were air dried at 105 ºC for 12 h, and the final weight was registered (W2).

One Gooch crucible was used for protein determination (P), and the second crucible was calcinated at 525 ºC for 5 h, registering the ash content in grams (A). Total dietary fiber was calculated with the Equation 4:

$$\% \text{ Total dietary fiber} = \frac{R - P - A - B}{S} \times 100 \qquad (4)$$

Where R is the dry residue weight (W2-W1), P is the protein weight in the crucible, A is the ash weight in the crucible, B is the sample blank, and S is the sample weight (0.5 g of degreased bagasse).

2.6 *Texture profile analysis (TPA)*

TPA of all cookies formulations were obtained using a texturometer (Brookfield mod. CT3, MA, USA), using the methodology proposed by Ribeiro *et al*. (2020), with the following operation parameters. Starter speed of 2 mm/s, and a final speed (after cookie fracture) of 10 mm/s with a trigger force of 0.24 N. Hardness and fracturability were evaluated for each cookie sample and compared to the control (Korese *et al*., 2021).

2.7 *Sensorial evaluation*

To perform the sensorial evaluation of all cookies formulations, instructions previously described by Paucar-Menacho *et al*. (2016), were followed with slight modifications. No trained judges (100) evaluated the sensorial attributes of color, flavor, consistency, and aroma of cookies, through a nine-points hedonic scale, in which 1 corresponded to "I dislike it very much" and 9 corresponded to "I like it very much". At the beginning of sensorial analysis, all the no-trained judges were informed about the cookies composition, and all of them provide their consent to participate in the sensory test.

2.8 *Statistical analysis*

Analysis of variance (ANOVA) was performed on the resulting data, followed by a Tukey's test with a significance level of 5% ($p \leq 0.05$) and the confidence intervals were calculated from means of triplicates with a confidence level of 95%, using the statistical software Minitab 18 (Minitab Inc. State College, USA). Excel version 16.71 (Microsoft, NM, USA) was used to design the graphs.

Table 2. Physicochemical characterization of bagasse from sugarcane var. COLPOS CTMEX 05-223.

Component	% (dry basis)
Moisture	8.64 ± 0.08
Ashes	1.30 ± 0.07
Protein	0.89 ± 0.13
Lipids	0.86 ± 0.04
Whole fiber	83.05 ± 1.30
Constituted by:	
Cellulose	13.81 ± 0.90
Hemicellulose	49.17 ± 1.11
Holocellulose	36.94 ± 0.51
Lignin	29.44 ± 1.42

Results are expressed as the mean of triplicates ± standard deviation.

3 Results and discussions

3.1 *Physicochemical characterization of SCB*

Results of physicochemical characterization of SCB are presented in Table 2. According to the moisture content (8.64%), it is possible to suggest that bagasse may exert a prolongated stability, since the low moisture content avoids the fungal growth facilitating its use in food industry. Ashes content (1.30%) was higher than bagasse from other sugarcane varieties such as CUBA 1051-73 and CENICAÑA 8592, which showed ashes content of 0.75 and 0.68%, respectively (Cubeña-Morán and Loor-Chávez, 2016). It is widely known that minerals in SCB are dependent of soil conditions in which crop in cultivated, so the mineral concentration may vary from season to season. Proteins (0.89%) and lipids (0.86%) were the minor components in SCB, being expected results considering the vegetable origin of SCB.

Fiber content of SCB was 83.05%, being recognized as the main component of bagasse. Likewise, fiber components were quantified showing a cellulose content (13.81%) significantly lower ($p \leq 0.05$) than 29.80 and 24.78% of cellulose contained in MEX 83-481 and MEX 69-290 sugarcane varieties, respectively (Aranda *et al*., 2004). Conversely, hemicellulose content (49.17%) seems to be higher than other hemicellulose contents reported in sugarcane varieties such as MEX 83-481, with 29.80% hemicellulose. Also, lignin content (29.44%) was higher to other sugarcane varieties including CC 8592 and ECU-01, which reported 7.10 and 7.80% of lignin, respectively (Aranda *et al*., 2004). These differences in fiber components are specific for each sugarcane variety, thus, can be considered quality parameter to differ several varieties of sugarcane exploited in each geographical region.

Table 3. Physicochemical analysis of cookies added with sugarcane bagasse.

Component	Control	C10	C15	C20	C25	C30
Moisture (%)	3.02 ± 0.25a	3.40 ± 0.35a	3.46 ± 0.30a	3.42 ± 0.41a	3.61 ± 0.22a	3.47 ± 0.44a
Ashes (%)	1.06 ± 0.21c	1.57 ± 0.26bc	1.63 ± 0.25ab	1.73 ± 0.15ab	1.76 ± 0.20ab	2.06 ± 0.15a
Protein (%)	14.24 ± 0.15a	11.41 ± 0.25b	11.22 ± 0.10b	10.89 ± 0.15bc	10.88 ± 0.15bc	10.47 ± 0.19c
Lipids (%)	22.3 ± 2.06a	21.74 ± 0.8a	20.91 ± 3.81a	20.24 ± 2.94a	19.58 ± 2.39a	19.44 ± 0.92a
Dietary fiber (%)	0.42 ± 0.03a	4.36 ± 0.15b	5.46 ± 0.32c	8.31 ± 0.44d	8.72 ± 0.43e	10.99 ± 0.14f
Sugars* (%)	58.71	57.60	56.62	55.79	54.34	52.89

* Sugars were estimated as the remained fraction of 100% - % of the other components.

C10, C15, C20, C25, and C30: Cookies added with 10, 15, 20, 25, 30% sugarcane bagasse, respectively. Cookie without addition of sugarcane bagasse were considered as control. Different letters in the same row indicate significant difference ($p \leq 0.05$) between cookies formulations.

3.2 Functional properties of SCB

SCB reached a WRC of 4.58 ± 0.10 g of water/g of sample, which was higher to the WRC showed by the "Chontaduro" (*Bactris gasipaes*) flour, whose WRC was 3.93 g of water/ g of sample (Dussán-Sarria *et al*., 2019). The water retention capacity is influenced by several factors, such as the abundance of free hydroxyl groups in the chemical structure, which promote the formation of hydrogen bonds with water molecules. Additionally, particle porosity, particle size, and pH levels also play a significant role in determining the WRC (Alpizar-Reyes *et al*., 2022). Hence, based on the WRC obtained for SCB in the present study, the potential use of SCB as a food additive to improve rheological properties in food products can be suggested (Cerda-Mejía *et al*., 2017).

Likewise, other functional properties evaluated for the SCB such as LAI and SP showed positive and desirable results. For example, SCB showed a LAI of 4.44 ± 0.17 g of lipids/g of sample, which resulted higher than other agricultural residues derived from the flour extraction process from legumes such as *Lupinus mutabilis* (1.18 g/g) and *Cajanus cajan* (2.4 g/g). Lipids absorption can be considered a desirable functionality of the ingredients added to food products where lipids addition is essential, and lipid fugacity should be controlled. Hence, the use of SCB as ingredient could be a solution for the control and maintenance of original sensorial characteristics of lipid-rich food product (Vegas *et al*., 2017). According to the SP value (6.11±0.1 g/g), SCB can be considered as an additive with reduce SP, compared to the SP of other agricultural residue such as apple pomace (16.16 g/g), that is used as a natural source of pectic substances used as food additive in jell, jams and syrups (Rana *et al*., 2015). The SP of natural fibers is influenced by the presence and concentration of both soluble fibers and starches, which are not found in SCB. So, SCB can be used as a gelling agent that improves textural properties in specific food products.

3.3 Physicochemical characterization of cookies added with SCB

Results of the physicochemical characterization of cookies added with SCB are presented in Table 3. Moisture content did not show significant difference ($p \leq 0.05$) between cookies added with SCB and control, ranging from 3.02 to 3.61% dry basis. This moisture content is considered adequate for cookies, contributing to their characteristic texture and prolongated storage stability (Najjar *et al*., 2022).

Ashes content increased as the SCB content increased in the cookie formulation. Ashes content in the control sample (1.06 ± 0.21 %) and in the cookies formulation samples were significantly different, being the C30 the sample with the higher content of ashes (2.06 ± 0.15 %). Such difference is given by the ashes content of SCB (1.30 ± 0.07 %) added to the cookies formulation. The maximum ashes content reported for cookies added with SCB was similar to the reported by Benítez *et al*., (2017), for cookies added with flaxseed flour with an ashes content of 2.66 %. A higher ash content suggests a significant amount of minerals present in the bagasse, such as calcium, magnesium, and iron (Esua *et al*., 2016: Oladunjoye *et al*., 2021). This can contribute beneficially to the nutritional quality of cookies, which in turn is beneficial for all types of populations.

Interestingly, the protein content decrease as the SCB concentration increases in the cookies formulation, however C10, C15, C20, and C25 samples did not show significant difference to each other, but when compared to Control and C30 samples, significant difference ($p \leq 0.05$) was observed. These differences may be due to the substitution of wheat flour in cookies formulation for SCB. This substitution decreases the wheat flour in cookies and thus, the protein content that it contributes to the product. Consequently, the protein content in all samples, including control, demonstrated a decreasing trend as follows: Control > C10 > C15 > C20 > C25 > C30. As expected, carbohydrates exhibit the highest composition in the different formulations, including the control, because wheat is the main ingredient in cookie formulation and contains a significant amount of carbohydrates. Additionally, the addition of sucrose contributes to this result. This behavior has been reported in various cookies formulated using fruit by-products (Oladunjoye *et al*., 2021; De Toledo *et al*., 2019). On the other hand, the dietary fiber contents increased in cookies as the content of SCB increased in the formulations. All the samples, including control, were significantly different ($p \leq 0.05$), being the control the sample with the lower dietary

Table 4. Texture parameters of cookies added with sugarcane bagasse.

Texture parameter	Control	C10	C15	C20	C25	C30
Hardness (N)	44.8±0.65c	46.36±1.78c	61.62±4.24b	65.06±1.29b	72.41±3.74a	72.14±2.85a
Fracturability (N)	40.43±3.81a	43.46±1.58a	43.65±4.27a	44.06±1.29a	43.16±2.36a	44.14±4.90a

C10, C15, C20, C25, and C30: Cookies added with 10, 15, 20, 25, 30% sugarcane bagasse, respectively. Cookie without addition of sugarcane bagasse were considered as control. Different letters in the same row indicate significant difference (p≤0.05) between cookies formulations.

fiber content, since no SCB was added (Table 3). Compared to previous reports, dietary fiber content in cookies added with SCB is higher to those reported for cookies added with pea and soybean flours, which reached 0.7 and 6.7%, respectively. Also, Mesta and Miñope (2018), reported lower dietary fiber content of 0.85% in cookies added with pineapple fiber. These results support the idea of use agricultural residues or subproducts from agricultural industry, such as SCB, firstly to increase the dietary fiber consumption, and secondly as potentially functional ingredient for the elaboration of food products that have a positively impact in consumers health, mainly through the control and modulation of glycemic index, as well as exerting a hypocholesterolemic effect (Delgado-Nieblas *et al*., 2021).

3.4 Texture profile analysis (TPA)

3.4.1 Hardness

Acceptability of cookies by consumers is directly based on their texture attributes, related to their freshness and quality (Myers *et al*., 2022). Values of texture analysis of the cookies added with SCB and control are presented in Table 4. As with dietary fiber content, cookie hardness value increased as fiber content increased in formulation. Significantly differences ($p \leq 0.05$) in cookie hardness were observed between control (44.8 ± 0.65 N) and C15, C20, C25 and C30 samples. Likewise, C25 and C30 formulations showed the higher hardness values (72.41 ± 3.74 and 72.14 ± 2.85 N, respectively), being significantly different ($p \leq 0.05$) to the other cookies formulations. There are various explanations regarding the formation of the structure that determines the texture of cookies, which in turn influences their hardness and fracturability. One of these explanations is based on the melting of sugar present in the cookie dough during the baking process, resulting in the formation of protein aggregates and lipid bridges (Chevallier *et al*., 2002). These components become embedded in a vitreous sugar matrix after cooling, contributing to the final structure and texture of the cookie. On the other hand, it has been reported that the texture of cookies made with wheat flour is attributed to the cooled sugar crystallization and starch gelatinization (Gallagher *et al*., 2004). These processes also contribute to the formation of the structure and texture of the cookie. Additionally, some studies attribute the texture of cookies solely to sugar recrystallization, without considering the influence of other factors such as proteins and lipids present in the dough (Xu *et al*., 2020: Myers *et al*., 2023). In addition to the factors mentioned above, the hardness, as well as moisture content, can be affected by the SCB addition in cookies formulation, which provides rigidity to the baked product (Panghal *et al*., 2018).

3.4.2 Fracturability

Fracturability is defined as the resistance showed by a food product just before splitting into two segments; and is closely related to its hardness (Hussain *et al*., 2020). This research evaluated the fracturability of cookies added with SCB, and derived of this addition, the cookies showed a gradual increase in fracturability according to the increase of SCB concentration in each cookie formulation. Nevertheless, significative differences between cookies formulations were not observed (Table 4). In comparison to previous studies, the cookies added with SCB demonstrated intermediate resistant to fracture with a maximum resisting force ranging 43.16-44.14 N. Meanwhile cookies added with flaxseed, showed higher resistance to fracture (80.83 N), cookies added with soybean demonstrated lower fracturability values (0.010-0.012 N) (Kaur *et al*., 2019; Yang *et al*., 2022).

Both fracturability and hardness of cookies are dependent of multiple factors, including particle size of ingredients, type of baking, additional ingredients (SCB), cookie morphology. These factors alter the moisture content and then modulates texture parameters, specifically fracturability, which is negatively correlated to the texture parameters of final product (Korese *et al*., 2021).

3.5 Sensorial evaluation

Sensory quality is the ultimate measure of a new product quality and success. Sensorial attributes of cookies added with SCB (color, flavor, consistency, and aroma), were evaluated and results are illustrated in Figure 1. As shown, the higher scores in color (7.02), flavor (7.02), aroma (7.10), and texture (7.13) were reported in the C30 samples, while control sample obtained lower scores in flavor (5.92), aroma (6.45), and texture (4.91) attributes. C10 was the only sample of cookies added with SCB with lower score in color attribute (6.49). These results suggest that the incorporation of SCB in cookies formulation improve their sensorial attributes, highlighting its use an ingredient that also contribute to the development of food products rich in dietary fiber, with potential functional properties and

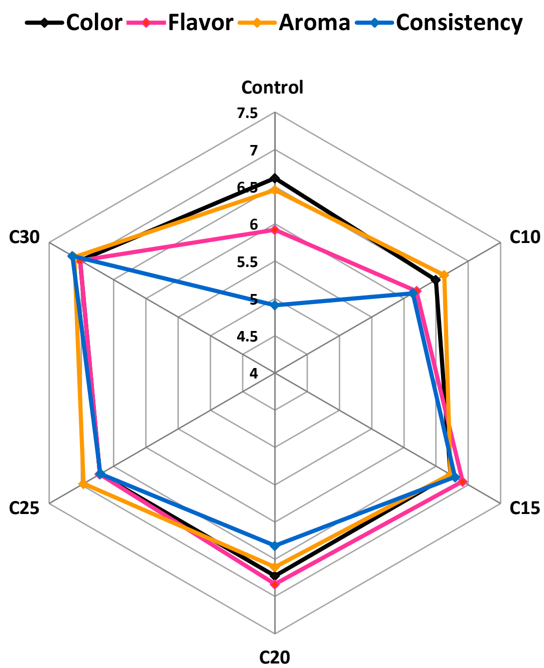

Fig. 1. Sensorial evaluation of cookies added with sugarcane bagasse. C10, C15, C20, C25, and C30 are the cookies added with 10, 15, 20, 25, and 30% sugarcane bagasse, respectively. Cookie without addition of sugarcane bagasse were considered as control.

sensorial accepted by the consumers. Finally, cookies added with SCB can be considered an alternative to increase the consumption of food products rich in dietary fiber, with acceptable sensory attributes and functional properties of interest for human health.

Conclusions

Based on the results obtained, it can be concluded that the addition of SCB into the cookies formulations does not significantly affect the moisture content of cookies, make them adequate for consumption, with a possible longer stability and desirable quality. On the other side, SCB addition negatively affects the protein content in cookies, while ashes and dietary fiber contents increased in concordance with the SCB concentration in cookies. Texture properties analysis demonstrated that the inclusion of SCB in cookies elaboration does not affect the hardness and fracturability of product, maintaining the characteristic texture for cookies. Furthermore, sensory analysis demonstrated that cookies with SCB had higher scores in color, aroma, flavor, and consistency, in comparison with the control sample. Based on the previous results, the formulation substituted with 30% SCB (C30) proved to be the most suitable for cookie formulation, as it does not affect their sensory and textural properties and provides the highest amount of dietary fiber. Finally, the present study can be considered as one of the first attempts to use agricultural residues, derived from sugar industry, as functional ingredients in the elaboration of bakery products with specific health claims and desirable texture and sensory properties. The authors consider the cookies added with SCB a promising alternative to produce nutritive food products with specific functional properties and health claims, although the inclusion of fiber from SCB in other food products should be investigated, focusing on extending its application as new functional ingredient. Furthermore, these data can be applied to the utilization of sugarcane bagasse from different varieties, thereby contributing to the valorization of agro-industrial by-products.

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