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APRIMORANDO A QUALIDADE DE BISCOITOS DE CHOCOLATE COM FARINHA DE FEIJÃO PRETO: EFEITOS DA SUBSTITUIÇÃO PARCIAL DA FARINHA DE TRIGO

ENHANCING CHOCOLATE COOKIE QUALITY WITH BLACK BEAN FLOUR: EFFECTS OF PARTIAL WHEAT FLOUR REPLACEMENT

MEJORA DE LA CALIDAD DE LAS GALLETAS DE CHOCOLATE CON HARINA DE FRIJOL NEGRO: EFECTOS DE LA SUSTITUCIÓN PARCIAL DE LA HARINA DE TRIGO

Bruna Letícia Oliveira Gomes
Bacharela em Ciência e Tecnologia de Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: bruna.leticia1@aluno.ufop.edu.br

Késia Regina Ferreira Santos
Mestranda do Programa de Pós-Graduação em Química
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: kesia.santos@aluno.ufop.edu.br

Ariel Albuquerque Pio
Doutoranda do Programa de Pós-Graduação em Biotecnologia
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: ariel.pio@aluno.ufop.edu.br

Angelina de Sousa Chagas
Mestranda do Programa de Pós-Graduação em Biotecnologia
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: angelina.chagas@aluno.ufop.edu.br

Ana Beatriz de Oliveira Boroni
Discente do curso de Ciência e Tecnologia de Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: ana.bob@aluno.ufop.edu.br

Marina Maximiano de Oliveira Santos
Doutoranda do Programa de Pós-Graduação em Saúde e Nutrição

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Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: marina.maximiano@aluno.ufop.edu.br

Julia Beatriz Fidelis Medeiros
Discente do curso de Ciência e Tecnologia de Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: julia.medeiros@aluno.ufop.edu.br

Fernanda Isabela Moreira
Bacharela em Ciência e Tecnologia de Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: fernanda.isabela@aluno.ufop.edu.br

Samanta de Souza Rezende
Mestranda do Programa de Pós-Graduação em Química
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: samanta.rezende@aluno.ufop.edu.br

Tamires Regina Alves Rodrigues
Discente do curso de Ciência e Tecnologia de Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: tamires.rodrigues@aluno.ufop.edu.br

Reginaldo de Souza Monteiro
Doutorando do Programa de Pós-Graduação em Saúde e Nutrição
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: reginaldo.monteiro@aluno.ufop.edu.br

Samara Oliveira Figueiredo
Discente do curso de Ciência e Tecnologia de Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: samara.figueiredo@aluno.ufop.edu.br

Ana Beatriz Vieira Barbosa
Discente do curso de Ciência e Tecnologia de Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil

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E-mail: ana.bvb@aluno.ufop.edu.br

Paloma Cristina dos Santos
Mestre em Saúde e Nutrição
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: paloma.santos@aluno.ufop.edu.br

Silvia Mendonça Vieira
Doutora em Ciência dos Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: silvia.vieira@ufop.edu.br

Patrícia Aparecida Pimenta Pereira
Doutora em Ciência dos Alimentos
Núcleo de Estudos em Ciências Sensoriais, Universidade Federal de Ouro Preto
Endereço: Ouro Preto, Minas Gerais, Brasil
E-mail: patricia.pereira@ufop.edu.br

Resumo

Este estudo avaliou o efeito da substituição parcial da farinha de trigo por farinha de feijão-preto nas propriedades físicas, físico-químicas e sensoriais de biscoitos de chocolate. Quatro formulações (0%, 30%, 50% e 70% de substituição) foram analisadas quanto à perda de peso, índice de espalhamento, volume, atividade de água, cor, aceitabilidade e atributos sensoriais descritivos. A substituição por farinha de feijão-preto influenciou positivamente diversos parâmetros, reduzindo a perda de peso e a atividade de água, enquanto aumentou o diâmetro e o índice de espalhamento. A cor tornou-se mais escura e menos amarelada com o aumento da substituição. Biscoitos com até 30% de farinha de feijão-preto apresentaram boa aceitação, caracterizada por uma agradável sensação na boca, aparência desejável, cor, espessura e crocância. Esses resultados indicam que a substituição de até 30% da farinha de trigo por farinha de feijão preto é viável para o desenvolvimento de biscoitos com maior potencial nutricional, sem comprometer a qualidade sensorial.

Palavras-chave: Aceitabilidade; farinha de feijão preto; propriedades físicas; propriedades físico-químicas; processamento.

Abstract

This study evaluated the effect of partially replacing wheat flour with black bean flour on the physical, physicochemical, and sensory properties of chocolate cookies. Four formulations (0%, 30%, 50%, and 70% substitution) were analyzed for weight loss, spreading ratio, volume, water

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activity, color, acceptability, and descriptive sensory attributes. Substitution with black bean flour positively influenced several parameters, reducing weight loss and water activity while increasing diameter and spreading ratio. Color became darker and less yellow as substitution increased. Cookies with up to 30% black bean flour showed good acceptance, characterized by a pleasant mouthfeel, desirable appearance, color, thickness, and crunchiness. These results indicate that replacing up to 30% of wheat flour with black bean flour is viable for developing biscuits with greater nutritional potential, without compromising sensory quality.

Keywords: Acceptability; black bean flour; physical properties; physicochemical properties; processing.

Resumen

Este estudio evaluó el efecto de reemplazar parcialmente la harina de trigo con harina de frijol negro en las propiedades físicas, fisicoquímicas y sensoriales de las galletas de chocolate. Se analizaron cuatro formulaciones (0%, 30%, 50% y 70% de sustitución) para pérdida de peso, relación de esparcimiento, volumen, actividad de agua, color, aceptabilidad y atributos sensoriales descriptivos. La sustitución con harina de frijol negro influyó positivamente en varios parámetros, reduciendo la pérdida de peso y la actividad de agua mientras aumentaba el diámetro y la relación de esparcimiento. El color se volvió más oscuro y menos amarillo a medida que aumentaba la sustitución. Las galletas con hasta un 30% de harina de frijol negro mostraron buena aceptación, caracterizada por una agradable sensación en boca, apariencia deseable, color, espesor y textura crujiente. Estos hallazgos indican que es posible sustituir hasta un 30% la harina de trigo por harina de frijol negro para desarrollar galletas con mayor potencial nutricional sin comprometer la calidad sensorial.

Palabras clave: Aceptabilidad; harina de frijol negro; propiedades físicas; propiedades fisicoquímicas; procesamiento.

1. Introduction

Black beans (*Phaseolus vulgaris* L.) have been one of the most important legumes for Latin American and African consumers since prehistoric times due to their high nutritional content, such as carbohydrates, proteins, fiber, vitamins, minerals, and bioactive compounds (Vongsumran et al., 2014; Ferreira et al., 2018). They are sweet-tasting, black, oval-shaped seeds with a small white spot (Meenu et al., 2023). They are a good source of protein, containing most of the essential amino acids, especially lysine, and their protein content is comparable to that of soybeans, meat, eggs, and milk (Jiang et al., 2014). In addition to protein, black beans are also rich in phytochemicals such as saponins, anthocyanins, flavonols, and phenolic acids (Meenu et al., 2023). These phytochemicals are responsible for

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the potent biological activity of black beans, such as antioxidant, antidiabetic, anti-inflammatory, antimutagenic, antiobesity, anticancer, hypercholesterolemia, and reduced risk of coronary heart disease (Anton et al., 2008; Mullins & Arjmandi, 2021).

The techno-functional properties of proteins define their behavior in a food system and depend mainly on the protein structure, its hydration mechanisms for solubility and water or oil retention capacity, rheological characteristics for viscosity and gelation, and its interfacial properties for emulsions and foams (Moure et al., 2006). In addition to these, physicochemical parameters such as temperature, pH, ionic strength, and particle size also influence the techno-functional properties (Martinez-Flores et al., 2006; Kaur et al., 2017).

Cookies are one of the most widely consumed baked products, mainly because of their ready-to-eat nature, diverse types, and relatively low cost (Myers et al., 2023). Ingredients typically used in the production of cookies are flour, fat, sugar, and salt (Maache-Rezzoug et al., 1998). In Western societies, wheat is the primary source of flour for cookies, and as such, most cookies in Western societies are not gluten-free (Myers et al., 2023). To increase their nutritional value, cookies can be prepared with fortified or composite flour (Chauhan et al., 2016). Composite flour has economic value in developing countries because it reduces the burden on imported wheat flour and encourages the use of locally grown crops in flour form (Mamat et al., 2014). Several studies have shown the improved nutritional and sensory values of cookies by incorporating white beans and sesame seeds (Hoojjat & Zabik, 1984), rice and black bean flour (Bassinello et al., 2011), black bean flour (Vongsumran et al., 2014), amaranth (Chauhan et al., 2016), pitaya peel (Ho & Latif, 2016), flaxseed flour (Kaur et al., 2017), and sorghum (Myers et al., 2023). Although previous studies have reported the use of black bean flour or its blends in bakery products, they have mainly focused on proximate composition or instrumental texture, without addressing the combined impact of black bean flour on physicochemical properties, color parameters and sensory acceptance of cookies (Vongsumran et al., 2014; Mariscal-Moreno et al., 2021). In contrast, the present study provides a comprehensive evaluation of chocolate cookies formulated with different substitution levels of wheat flour by black bean flour, emphasizing their technological performance, sensory acceptance and nutritional potential inferred from the characteristics of the raw material. This integrated approach contributes novel insights into the feasibility of developing cookies with added nutritional value using black bean flour as a functional ingredient, thereby expanding its application in bakery formulations. Therefore, the aim of this study was to evaluate the physical, physicochemical and sensory characteristics of chocolate cookies partially replaced by black bean flour at different levels.

2. Methodology

The cookies were prepared and evaluated at the Sensory Analysis Laboratory and the Starchy Products Pilot Plant of the School of Nutrition (ENUT), at the Federal University of Ouro Preto (UFOP). All ingredients were purchased

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from local stores in the city of Ouro Preto, Minas Gerais, Brazil. Several preliminary tests were performed until formulations with promising potential were obtained to be evaluated in this study.

Process for obtaining black bean flour

To prepare the bean flour, the methodology of Frota et al. (2010) was used, with some modifications. The black beans were removed from the packaging and underwent a process to remove impurities such as stones and debris. They were then weighed and washed in running water to eliminate any dirt. Subsequently, the black beans were subjected to maceration in a bean:water ratio of 1:3 (w/v) for 1 hour at room temperature. They were then dried at 200 °C for 30 minutes in an electric oven and ground in an industrial blender for approximately 5 minutes to obtain the flour and sieved using a sieve with a mesh size between 20 and 24 to obtain a flour with standardized particle size..

The black bean flour obtained presented a moisture content of 3.03%, protein content of 18.0%, and iron content of 6.44 mg/100 g. Regarding color parameters, the flour showed a lightness (L) value of 58.96, chroma (C*) of 9.98, and hue angle (h°) of 71.30. These values indicate a low-moisture ingredient with moderate protein content and stable color characteristics, suitable for use in baked products (Manzocco et al., 2020).

Cookie preparation

Table 1 shows the formulations and ingredients used to prepare the cookies.

Table 1 - Formulations of chocolate cookies prepared with different levels of black bean flour

Ingredients (%)	Formulations (%)			
	0	30	50	70
Wheat flour	37.67	26.37	18.84	11.30
Black bean flour	-	11.30	18.84	26.37
Unsalted butter	10.46	10.46	10.46	10.46
Milk chocolate	15.70	15.70	15.70	15.70
Brown sugar	25.11	25.11	25.11	25.11
Eggs	10.46	10.46	10.46	10.46
Baking powder	0.31	0.31	0.31	0.31
Vanilla flavour	0.29	0.29	0.29	0.29

The cookies were prepared according to the methodology of Clerici et al. (2013), with modifications. The flours were combined according to the established percentage (Table 1), and the butter was incorporated with the fingertips until obtaining a moist, crumbly texture. Then, the eggs, sugar, baking powder, and vanilla flavour were added, mixing again until obtaining a homogeneous dough. Finally, the chocolate was delicately incorporated into the dough. The dough was divided into 35 g portions (according to each formulation) and refrigerated for a minimum period of 120 minutes. Subsequently, the cookies were baked in a

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conventional oven preheated to 180 °C for approximately 25 minutes. The cookies were allowed to rest for 24 h at room temperature (approximately 25 °C) in airtight containers before performing the analyses.

Physical and physicochemical evaluation of cookies

Five cookies per formulation were used for all physical and physicochemical determinations. The height of the cookies was defined as the vertical dimension measured at the central point of each individual cookie using a digital caliper (Hércules et al., 2024). The diameter was measured at the base of the cookie, considering the largest value obtained among perpendicular measurements, according to Pizzinatto et al. (1993). Cookie thickness was determined by the stacking method, in which four cookies were stacked and measured, and the procedure was repeated four times, with the mean value used for Analysis (Ho & Latif, 2016). This approach was adopted due to the irregular surface of the cookies, which limits direct thickness measurement on individual units.

Weight loss was determined by the difference between the weights before and after baking (Hércules et al., 2024). The spreading ratio factor was determined by dividing the diameter by the height, according to the methodology of Zambrano et al. (2002). The apparent volume of the cookies was defined by the millet seed displacement method. The millet seeds were poured into a graduated cylinder up to a certain volume. The sample was inserted into the cylinder until it was completely covered by the millet seeds, and the displaced volume was recorded. The specific volume was determined by dividing the apparent volume by the weight of the sample, according to Pizzinatto et al. (1993).

The direct determination of water activity was performed using a Raesung Model WA-60A water activity meter (Raesung, Guangdong, China) at a temperature of 25 °C. Pieces of the biscuits (approximately 2 g) were uniformly placed in plastic cells and allowed to equilibrate within the free space of the sealed chamber. The reading was then recorded when equilibrium was reached (Ho & Latif, 2016).

The color of the cookies was determined according to L* [lightness (L = 100; white and L = 0; black], a* [green (−) to red (+) chromaticity] and b* [blue (−) to yellow (+) chromaticity] using a Konica Minolta CR-400 color meter, working at D65 (daylight) and using CIELab standards. The colorimeter was calibrated prior to analysis using the Konica Minolta white calibration plate (Frost et al., 2011).

Sensory evaluation of cookies

The study was conducted at the Food Sensory Analysis Laboratory with authorization and approval from the Research Ethics Committee of the Federal University of Ouro Preto, under registration (CAEE 59327422.3.0000.5150). A total of 131 volunteers (26% men, 73% women, and 1% did not declare) participated in the sensory evaluation, recruited from among students, professors, administrative technicians, employees, and visitors of the Federal University of Ouro Preto, 89% of whom were between 18 and 27 years old. A limitation of this study is related to the representativeness of the sensory panel. The sensory evaluation was conducted in a university setting, which resulted in a predominance of young participants associated with the academic environment. Although this demographic profile may

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limit the extrapolation of the results to other population groups, it is partially aligned with the target consumers of cookie and snack-type products, which are commonly consumed by younger individuals (Platta et al., 2025). Nevertheless, the results should be interpreted within the context of the evaluated sample, and future studies including a more heterogeneous consumer panel are recommended.

The cookies were cut in half (~17 g per sample) and offered to the panelists in a monadic sequential presentation on odorless plastic plates coded with three-digit random numbers at room temperature and served in a randomized and counterbalanced order across participants to minimize order and carryover effects. As only four formulations were evaluated, sensory fatigue was minimized . Water was provided to the panelists to cleanse their palates between samples (Wakeling & Macfie, 1995). An acceptance test was performed on the attributes of appearance, aroma, taste, and texture using a 9-point structured hedonic scale (1 = extremely disliked to 9 = extremely liked). In addition, purchase intention was assessed using the attitude scale (1 = certainly would not buy to 5 = certainly would buy). The Stone & Sidel (1993) methodology was used to perform the acceptance test and purchase intention.

The Just-About-Right (JAR) scale was used to assess the actual suitability of five sensory attributes (chocolate cookie color, sweetness, flavor intensity, bitter taste and crunchiness) using a 9-point structured hedonic scale (Cadot et al., 2010). The midpoint denotes the point where the sensory attribute is almost right (JAR), that is, assumed to be ideal (Moskowitz, 2001).

Furthermore, the pleasant sensation in the mouth of each cookie sample was evaluated using a 9-point structured hedonic scale (1 = extremely unpleasant to 9 = extremely pleasant) (Stone & Sidel, 1993).

In addition, the sensory profiles of the chocolate cookies were evaluated using the CATA (Check-All-That-Apply) method (Jaeger et al., 2020). The CATA evaluation consisted of checklists for 34 attributes. The attributes consisted of appearance (6 attributes), aroma (7 attributes), flavor (9 attributes), and texture (12 attributes). The complete CATA attribute is presented in Table 2. The selection of attributes was based on previous literature on sensory characteristics of cookies (Silva & Conti-Silva, 2016; Ervina, 2023) and through a focus group composed of members of the Center for Studies in Sensory Sciences (NECISEN).

Table 2 - CATA Attributes

Appearance	Aroma	Taste	Texture
Characteristic cookie appearance	Characteristic chocolate cookie aroma	Characteristic taste of chocolate cookies	Characteristic cookie texture
Presence of particles	Sweet aroma	Strange taste	Pleasant thickness
Pleasant color	Pleasant aroma	Sweet taste	Unpleasant thickness
Unpleasant color	Unpleasant aroma	Residual bitterness	Unpleasant texture

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Characteristic cookie format	Bean aroma	Pleasant taste	Pleasant texture
Cookie thickness	Almond aroma	Unpleasant taste	Crunchiness
	Burning aroma	Chocolate taste	Residual particles
		Bean taste	Hardness
		Almond taste	Softness
			Chewiness
			Sandyness
			Crumbly texture

Experimental design and evaluation of results

The experimental design followed a completely randomized design (CRD). Each formulation was produced in a single processing batch on the same day under controlled conditions. For physical, physicochemical and color analyses, five cookies per formulation were considered as analytical units. Sensory evaluation was conducted with 131 consumers, who evaluated all formulations using a monadic sequential presentation under controlled conditions. Statistical analyses were performed considering the analytical units (cookies) within each formulation, and results were expressed as mean ± standard deviation. The use of a single processing batch per formulation characterizes this study as an exploratory product development assessment.

Data on physical parameters, water activity, color, acceptance and purchase intention were evaluated by analysis of variance (ANOVA), and mean comparisons were performed using the Tukey test ($p \leq 0.05$) with Sisvar software (Ferreira, 2014).

To analyze the data obtained using the Just-About-Right (JAR) scale, two complementary approaches were applied. First, the percentage of consumers who evaluated each of the five sensory attributes (chocolate cookie color, sweetness, flavor intensity, bitter taste, and crunchiness) at each point of the JAR scale was calculated, as proposed by Morais et al. (2014). This approach allows the identification of attributes perceived as less than ideal, ideal, or more than ideal by the consumers. Second, the methodology proposed by Calixto et al. (2020) was adopted, in which JAR attribute scores are statistically described using central tendency parameters and graphically represented through box-and-whiskers plots. This approach provides a descriptive overview of attribute perception and dispersion without inferring causal effects on overall liking.

The mouthfeel data were analyzed through regression analysis in Excel software.

The CATA data were analyzed using SPSS software, with which the Cochran's Q test was performed to identify significant differences between the cookies for each of the descriptors. Furthermore, a sensory map was generated from a Correspondence Analysis to visualize the distribution of significant attributes according to the samples in SensoMaker software version 1.6 (Pinheiro et al., 2013).

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3. Results and discussion

Physical and physicochemical evaluation of cookies

The average values of the physical parameters, water activity, and color characteristics of cookies and chocolate with partial replacement of wheat flour by black bean flour are presented in Table 3, with significant differences being observed in practically all parameters ($p \leq 0.05$), with the exception of apparent and specific volumes, where the samples did not differ from each other ($p > 0.05$).

Table 3 - Physical parameters, water activity, and color characteristics of chocolate cookies with partial replacement of wheat flour by black bean flour.

Parameters	Cookie samples			
	Control	**30%**	**50%**	**70%**
Height (mm)	52.00 ± 0.53 d	56.07 ± 0.84 c	68.50 ± 0.92 a	60.33 ± 0.82 b
Diameter (mm)	51.33 ± 0.35 c	57.85 ± 1.68 b	67.93 ± 0.91 a	59.80 ± 0.86 b
Thickness (mm)	25.17 ± 0.55 a	21.73 ± 1.08 b	17.56 ± 0.86 d	19.84 ± 0.30 c
Weight loss (%)	1.27 ± 0.13 b	1.25 ± 0.65 b	1.52 ± 0.38 b	2.37 ± 0.22 a
Spread ratio	0.99 ± 0.01 b	1.03 ± 0.04 a	0.99 ± 0.00 b	0.99 ± 0.01 b
Apparent volume (cm^3)	80.00 ± 0.00 a	80.00 ± 0.00 a	80.00 ± 0.00 a	80.00 ± 0.00 a
Specific volume (cm^3/g)	2.37 ± 0.01 a	2.36 ± 0.07 a	2.37 ± 0.03 a	2.44 ± 0.02 a
Water activity (a_w)	0.69 ± 0.05 a	0.59 ± 0.00 b	0.54 ± 0.01 b	0.54 ± 0.02 b
Luminosity (L*)	17.48 ± 0.50 b	19.52 ± 0.36 a	11.10 ± 0.32 d	15.90 ± 0.49 c
Redness (a*)	6.50 ± 0.31 b	7.10 ± 0.32 ab	8.00 ± 1.18 a	7.20 ± 0.49 ab
Yellowness (b*)	18.72 ± 0.65 a	15.48 ± 2.23 b	15.90 ± 0.55 b	12.70 ± 0.94 c

Note: n = 5 cookies per formulation (single processing batch). Mean ± standard deviation. Means followed by the same letter, in the line, do not differ statistically from each other using the Tukey Test at 5% significance.

According to Boz (2019), during the baking of bakery products, such as cookies, structural, physicochemical, and sensory changes occur. These changes will reflect on the digestibility of the product and sensory acceptance by consumers (Mohsen et al., 2009).

Statistical differences were found in all cookies in relation to height, with the cookie with 50% black bean flour having the highest mean value (Table 3). Height is an important parameter for the cookie industry (Hércules et al., 2024), since, according to Mauro et al. (2010), it allows the elaboration of a thicker product when compared to the standard.

Cookies with 0% substitution (control) had a smaller diameter and greater thickness (Table 3). The results obtained in the present study are in agreement with

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those reported by Leon et al. (1996) and Ho & Latif (2016), who stated that the diameter value has an inverse correlation with the protein content. The gluten protein in wheat flour plays a vital role in the formation of a web-like structure during dough heating, and this structure is important for its irreversible expansion (Leon et al., 1996). In addition, Miller et al. (1997) stated that protein content influences cookie dough viscosity, since the formation of a continuous gluten web increases viscosity and interrupts the flow of the cookie dough. Thus, replacing wheat flour with black bean flour resulted in a lower amount of gluten, modifying the rheological behavior of the dough. Although gluten reduction limits the formation of an elastic network, the presence of non-gluten proteins and dietary fiber from black bean flour can increase dough consistency and restrict lateral flow during baking (Ho & Latif, 2016). This behavior contributed to changes in cookie diameter and thickness.

The dimensional values observed in the present study, particularly height and thickness, are higher than those commonly reported for conventional cookies (Pereira et al., 2013). This behavior can be attributed to the formulation characteristics, especially the higher protein and fiber content provided by black bean flour, which reduces dough extensibility and limits lateral spreading during baking. Consequently, the cookies exhibited a more compact and thicker structure, which explains the spread ratio values close to 1. Similar effects have been reported for cookies formulated with legume or high-protein flours, in which increased dough consistency and reduced gluten network formation result in limited spreading and greater thickness (Maache-Rezzoug et al., 1998; Vratanina & Zabik, 1978; Hércules et al., 2024).

For weight loss, a statistically significant difference was found only in relation to cookies with 70% black bean flour, with this sample showing the highest loss (Table 3).

It was observed that cookies with 30% replacement of wheat flour with black bean flour had a higher spread ratio ($p \leq 0.05$) (Table 3). The spread ratio is a measure of cookie quality (Mudgil et al., 2017). For better cookies, a higher spreading ratio is desirable (Barak et al., 2013).

It was found that cookies made with black bean flour did not differ from each other in terms of aw, presenting lower values compared to the control. The difference in aw observed with the replacement of wheat flour is probably due to the lower water retention capacity of black bean flour. According to Zoulias et al. (2002), cookies should demonstrate low aw values, as this property affects shelf life. According to Ribeiro & Seravalli (2007), water activity values below 0.6 do not favor microbial growth. Therefore, the control cookie is more susceptible to microbiological changes than cookies made with black bean flour.

The color parameters L* and a* did not show any consistent trend for the experimental cookies (Table 3). Cookies with 30% replacement had significantly higher L* values compared to the others. The cookie with 70% black bean flour was significantly ($p \leq 0.05$) darker than the cookie with 30% black bean flour, which may indicate that cookies become darker with increasing substitution of wheat flour for black bean flour. According to Hércules et al. (2024), L* values below 50 represent darker colors; therefore, all cookies in the present study fall into this classification. Vratanina & Zabik (1978) noted a decrease in L* values for sugar cookies with

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increasing substitution with red and white bran. Furthermore, Chevallier et al. (2000) suggested that protein content was negatively correlated with cookie lightness, indicating that the Maillard reaction played the main role in color formation, thus suggesting that increasing the replacement of wheat flour with black bean flour made cookies darker because black bean flour has a higher protein content (14.28%) (unpublished data) than wheat flour (9.8%) (Boen et al., 2007).

The a* value of cookies without replacement (control) was lower, showing no difference in relation to cookies with 30% and 70% black bean flour.

The replacement of 70% wheat flour with black bean flour resulted in lower b* values ($p \leq 0.05$) (Table 3). This result may be due to the degradation of unstable yellow compounds during the baking of cookies (Lian & Chong, 2015), since black bean flour had a higher b* value (14.06) (unpublished data).

Sensory evaluation of cookies

The average sensory scores of chocolate cookies with partial replacement of wheat flour by black bean flour are shown in Table 4.

Table 4 - Average acceptance and purchase intention values of chocolate cookies made with partial replacement of wheat flour by black bean flour

Cookie Samples	Appearance	Aroma	Taste	Texture	Purchase Intention
Control	7.91 ± 1.51 a	7.38 ± 1.74 b	7.37 ± 1.76 b	7.01 ± 1.92 a	3.64 ± 1.16 a
30%	7.85 ± 1.33 a	7.76 ± 1.50 a	7.71 ± 1.45 a	7.35 ± 1.92 a	3.79 ± 1.12 a
50%	6.72 ± 1.76 b	7.43 ± 1.59 b	7.24 ± 1.56 b	6.77 ± 1.79 b	3.50 ± 1.19 a
70%	6.37 ± 2.02 c	7.24 ± 1.76 b	6.84 ± 1.76 c	6.53 ± 2.05 b	3.08 ± 1.17 b

Note: n=131. Mean ± standard deviation. Means followed by the same letter, in the line, do not differ statistically from each other using the Tukey Test at 5% significance.

It was observed that all samples presented high acceptability values, with scores between 6.37 (I liked it slightly) and 7.91 (I liked it very much) and purchase intention between 3.08 (I don't know if I would buy it) and 3.79 (I would probably buy it). Replacing wheat flour with up to 50% black bean flour did not affect the sensory properties when compared to the control (0% substitution) (Table 4).

In general, the tasters rated the cookie with 30% black bean flour as having greater acceptance and purchase intention in relation to the other samples, being considered superior to the control. These results are in agreement with several studies on the replacement of wheat flour with alternative flours, such as those by Gambus et al. (2003), Chauhan et al. (2016), and Kaur et al. (2017), who evaluated the effect of partially replacing wheat flour with a mixture of flaxseed flour, matri flour, and cowpea flour, with amaranth flour and flaxseed flour in cookies, respectively. In addition, the lower values for appearance, taste, and purchase intention of the sample with 70% replacement may be due to the bitter taste of the bean flour, in addition to promoting greater darkening (Mohsen et al., 2009).

Table 5 shows the percentages of the ideal scale by formulation. The ideal

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scale was used to evaluate the color of the chocolate cookie, sweetness, flavor intensity, bitter taste, and crunchiness of the chocolate cookies made with partial replacement of wheat flour by bean flour to determine how much each formulation varied or approached the ideal level for this product.

Table 5 - Evaluation of the ideals of each characteristic of chocolate cookies made with partial substitution of wheat flour for black bean flour

F	C	Percentage of the ideal scale by formulation								
		EL	ML	MoL	SL	I	SM	MoM	MM	EM
Co	Chocolate cookie color	0.76	4.58	6.11	13.74	64.89	6.11	0.76	1.53	1.53
	Sweetness	0.00	3.82	6.11	16.79	47.33	12.98	8.40	2.29	2.29
	Flavor intensity	0.00	5.34	9.92	16.03	49.62	12.98	3.05	2.29	0.76
	Bitter taste	0.00	7.63	4.58	6.87	61.07	9.92	3.05	3.82	3.05
	Crunchiness	0.00	2.29	2.29	12.98	31.30	13.74	14.50	12.21	10.69
30%	Chocolate cookie color	0.00	0.76	3.82	16.79	53.44	13.74	7.63	3.05	0.76
	Sweetness	0.76	0.76	8.40	16.79	54.20	12.21	4.58	2.29	0.00
	Flavor intensity	0.00	2.29	6.87	21.37	48.85	12.21	5.34	2.29	0.76
	Bitter taste	0.76	5.34	7.63	6.11	58.02	14.50	5.34	1.53	0.76
	Crunchiness	0.76	0.00	4.58	11.45	41.22	18.32	11.45	7.63	4.58
50%	Chocolate cookie color	0.00	3.05	9.92	10.69	39.69	14.50	11.45	6.11	4.58
	Sweetness	0.76	2.29	3.82	16.03	47.33	11.45	8.40	6.87	3.05
	Flavor intensity	0.00	3.05	6.11	16.03	45.04	19.08	8.40	0.76	1.53
	Bitter taste	1.53	4.58	6.87	9.16	50.38	17.56	6.87	1.53	1.53
	Crunchiness	0.76	1.53	3.82	12.21	38.17	18.32	12.98	7.63	4.58
70%	Chocolate cookie color	0.00	6.11	6.87	13.74	25.19	11.45	21.37	7.63	7.63
	Sweetness	0.00	1.53	8.40	21.37	41.98	13.74	9.16	3.82	0.00
	Flavor intensity	0.76	3.05	12.21	17.56	32.82	17.56	9.16	5.34	1.53
	Bitter taste	0.76	5.34	2.29	6.11	51.91	16.03	10.69	3.82	3.05
	Crunchiness	5.34	8.40	17.56	22.14	22.90	12.98	8.40	2.29	0.00

F: Formulations; C: Characteristics; Co: Control; EL: Extremely less; ML: Much less; MoL: Moderately less; SL: Slightly less; I: Ideal; SM: Slightly more; MoM: Moderately more; MM: Much more; EM: Extremely more

The results of the ideal scale test (Table 5) indicated that, overall, all formulations presented the highest percentages of responses at the ideal level for chocolate cookie color, sweetness, flavor intensity, bitter taste, and crunchiness. An exception was observed for the crunchiness attribute of the cookie formulated with 70% substitution of wheat flour by black bean flour, which showed a higher proportion of responses below the ideal level, indicating a perception of reduced crunchiness.

According to Tesfaye et al. (2010), basic descriptive statistics and graphical tools, such as percentile plots and box-and-whiskers plots, provide an exploratory

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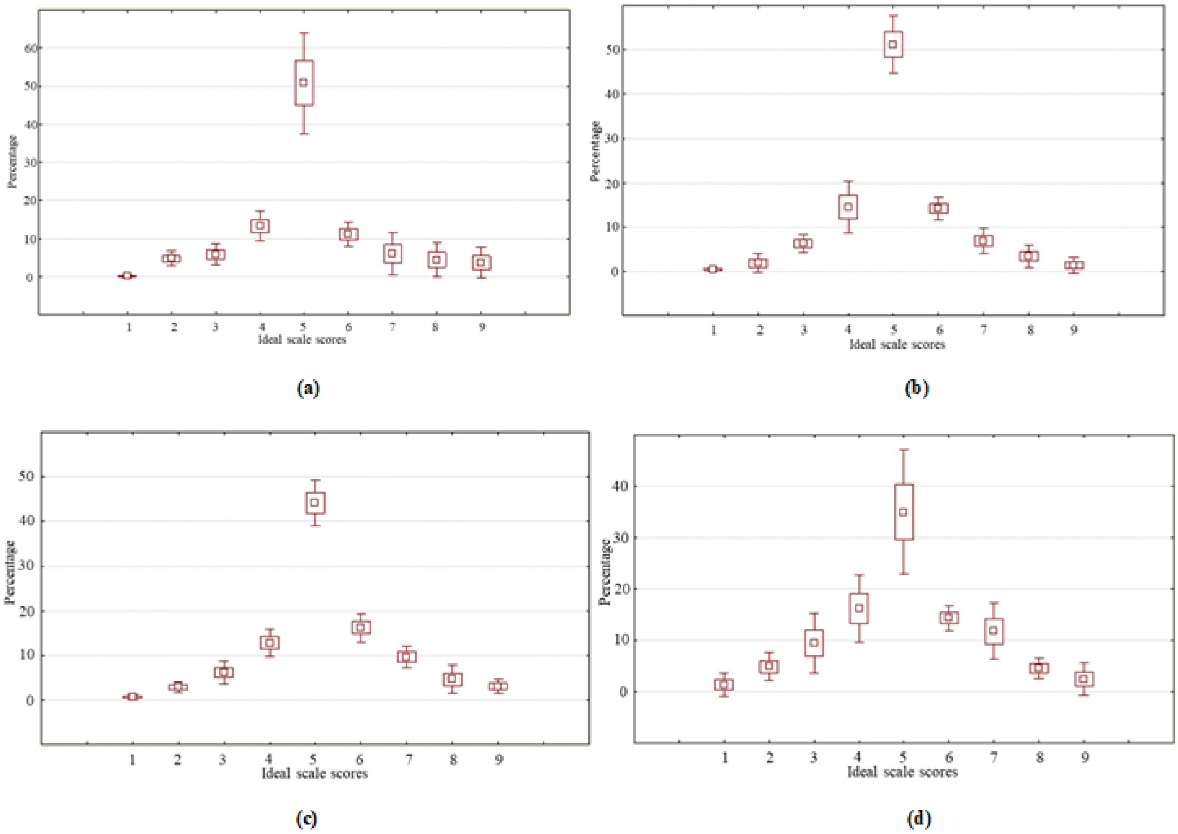
overview of sensory data and allow the identification of attributes that may contribute to perceived differences among samples. Since the ideal scale data were non-normally distributed, JAR scores were described using box-and-whiskers plots (Figure 1).

As shown in Figure 1, all cookie formulations exhibited a symmetrical distribution of responses, with median values located at or near the ideal level. A tendency toward a lower proportion of ideal responses was observed as the level of black bean flour increased, whereas the formulation containing 30% black bean flour showed a response pattern similar to that of the control.

Figure 1 - Box-and-stick plot indicating the scores assigned to all the characteristics on the horizontal axis by the percentages of the consumers' ratings, vertical axis. (a) Control; (b) 30%; (c) 50%; and (d) 70%



The average scores for pleasant sensation in the mouth were between 5.8 (indifferent/slightly pleasant) and 6.76 (slightly pleasant/moderately pleasant) (Figure 2).

Figure 2 - Average scores for pleasant sensation in the mouth of cookies made with partial replacement of wheat flour by black bean flour

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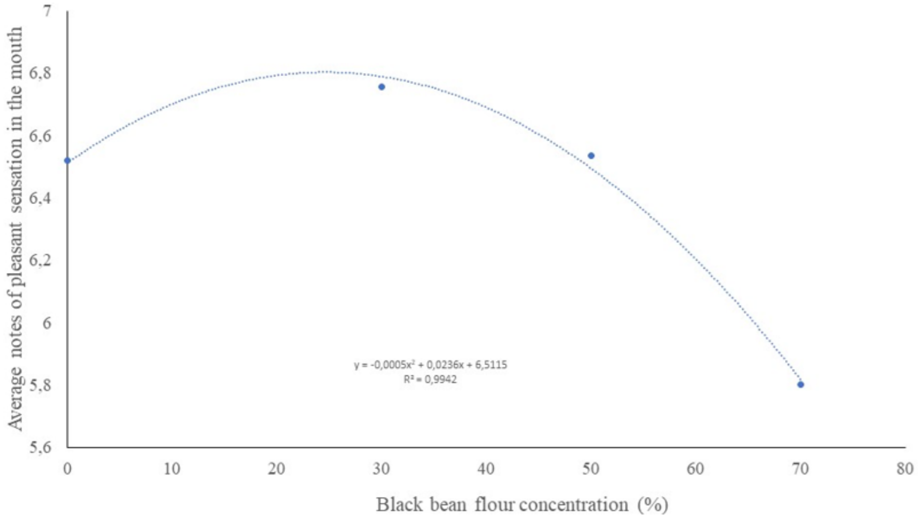

It is clear that after 30% replacement of wheat flour with black bean flour, the pleasant sensation in the mouth decreased. According to Mauro et al. (2010), the main criteria for accepting foods enriched with dietary fiber are good processing behavior, good stability and appearance, and satisfaction with the aroma, color, texture, and sensation left by the food in the mouth. In view of this, it can be inferred that the cookie with a replacement of up to 30% of wheat flour with black bean flour provides a pleasant sensation in the mouth.

The CATA questionnaire was used to portray the profile of the cookies (Table 6). According to Cairano et al. (2021), the description of the products by the CATA analysis is very close to that obtained by the descriptive analysis with trained evaluators; therefore, its use is viable.

Table 6 - Frequency of sensory descriptors using the check-all-that-apply (CATA) method for chocolate cookies made with partial replacement of wheat flour by black bean flour.

Sensory Descriptors	**0%**	**30%**	**50%**	**70%**	***p-value***
Appearance					
Characteristic cookie appearance	97.71 a	96.95 ab	94.66 ab	91.60 b	0.037
Presence of particles	80.15 b	89.31 ab	93.89 a	91.6 a	0.000
Pleasant color	98.47 a	98.47 a	97.71 ab	93.89 b	0.022
Unpleasant color	25.19 c	33.59 c	47.33 b	59.54 a	0.000
Characteristic cookie format	98.47 a	98.47 a	96.95 a	98.47 a	0.392
Cookie thickness	99.24 a	100 a	99.24 a	98.47 a	0.494
Aroma					
Characteristic chocolate cookie aroma	94.66 a	98.47 a	99.24 a	96.95 a	0.060
Sweet aroma	97.71 a	98.47 a	100 a	96.95 a	0.207
Pleasant aroma	96.95 a	97.71 a	95.42 a	98.47 a	0.442
Unpleasant aroma	25.95 a	27.48 a	26.72 a	32.82 a	0.322

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Bean aroma	22.9 b	29.01 a	21.37 b	30.53 a	0.032
Almond aroma	66.41 a	72.52 a	73.28 a	70.23 a	0.396
Burning aroma	45.80 a	39.69 a	41.98 a	46.56 a	0.374
Taste					
Characteristic taste of chocolate cookies	96.95 a	99.24 a	95.42 a	97.71 a	0.129
Strange taste	43.51 b	38.93 b	48.09 ab	58.02 a	0.001
Sweet taste	98.47 a	98.47 a	99.24 a	96.95 a	0.438
Residual bitterness	47.33 a	45.04 a	48.85 a	56.49 a	0.118
Pleasant taste	98.47 a	98.47 a	96.95 a	96.18 a	0.557
Unpleasant taste	25.95 b	29.01 b	31.3 ab	41.98 a	0.001
Chocolate taste	95.42 a	98.47 a	95.42 a	93.13 a	0.133
Bean taste	20.61 b	30.53 ab	31.3 a	32.82 a	0.005
Almond taste	70.23 a	75.57 a	71.76 a	74.05 a	0.558
Texture					
Characteristic cookie texture	96.95 a	98.47 a	94.66 a	95.42 a	0.147
Pleasant thickness	100.00 a	99.24 a	93.13 b	97.71 ab	0.001
Unpleasant thickness	28.24 b	29.77 b	42.75 a	35.11 ab	0.005
Unpleasant texture	35.11 b	40.46 ab	46.56 ab	49.62 a	0.013
Pleasant texture	93.89 a	95.42 a	93.89 a	93.89 a	0.934
Crunchiness	96.95 ab	100.00 a	96.95 ab	93.13 b	0.019
Residual particles	76.34 b	90.08 a	89.31 a	90.08 a	0.000
Hardness	93.89 a	93.89 a	88.55 a	87.02 a	0.078
Softness	83.21 b	94.66 a	93.13 a	96.18 a	0.000
Chewiness	99.24 a	97.71 a	100.00 a	98.47 a	0.284
Sandyness	81.68 b	91.60 a	92.37 a	93.89 a	0.000
Crumbly texture	85.50 a	81.68 a	88.55 a	85.50 a	0.339

Note: The same letter within the same row is not significantly different by Cochran's Q test ($p \leq 0.05$)

It was observed that there was consistency between the affective tests and the CATA (Table 6). The Cochran's Q test allowed us to visualize how consumers discriminated cookies by attributes. Most positive attributes, such as characteristic cookie appearance, pleasant color, pleasant thickness, and crunchiness, characterized cookies with 0% and 30% substitution, while those considered negative, such as presence of particles, unpleasant color, strange and unpleasant flavor, unpleasant thickness, and residual particles, characterized cookies with 50% and 70% substitution. Cannas et al. (2020) reported that the use of alternative flours promotes a more characteristic flavor in cookies.

Correspondence analysis (CA) is a multivariate graphical technique specifically designed to analyze categorical variables, and its value is most evident when applied to nominal variables (Xu et al., 2024). Figure 3 shows the results of the cookie formulations evaluated using CA, with one and two dimensions

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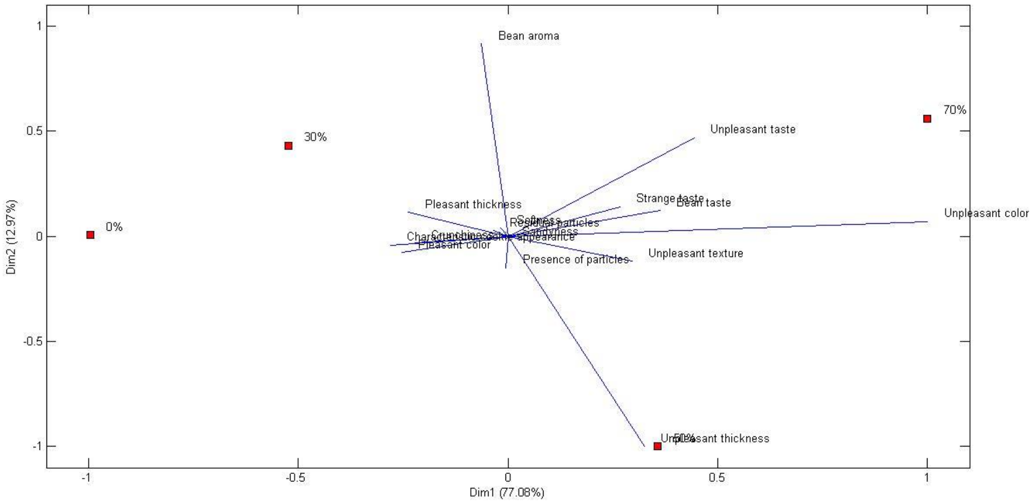
accounting for 77.08% and 12.97% of the total variance, respectively, and a cumulative variance contribution of 90.05%.

Cookies with 0% and 30% were positively correlated with “pleasant thickness,” “pleasant color,” and “characteristic cookie appearance” (Figure 3). The CATA results showed that consumers preferred the control cookies and those with 30% substitution.

Figure 3 - Correspondence analysis of significant CATA attributes for chocolate cookies made with partial replacement of wheat flour by black bean flour



5. Conclusion

This study evaluated the partial replacement of wheat flour with black bean flour in chocolate cookies as a strategy to enhance their nutritional potential while maintaining technological and sensory quality. The incorporation of black bean flour was associated with changes in physical and sensory characteristics of the cookies, including lower weight loss and water activity, as well as adequate dimensional properties and satisfactory consumer sensory perception.

Black bean flour influenced cookie color parameters, and an increase in substitution levels was accompanied by a tendency toward a lower proportion of responses classified as ideal in the sensory evaluation. Nevertheless, cookies formulated with up to 30% replacement of wheat flour showed consumer acceptance comparable to the control, being characterized by favorable sensory attributes such as appearance, color, thickness, and perceived crunchiness.

Overall, the partial replacement of wheat flour with up to 30% black bean flour represents a technologically viable alternative for chocolate cookie production and shows potential to contribute to improved nutritional quality, in line with current consumer interest in products containing added functional ingredients. Future studies should further investigate shelf life, storage conditions, and nutritional composition to support the application of black bean flour in bakery products.

A limitation of this study is that each formulation was produced in a single

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processing batch, which does not allow the evaluation of batch-to-batch variability. In addition, instrumental texture measurements were not performed; therefore, interpretations related to texture and crunchiness are based exclusively on consumer sensory perception. Nevertheless, the objective of the study was to compare different levels of wheat flour substitution under identical processing conditions, ensuring internal consistency. Future studies should include independent processing replicates and instrumental texture analyses to strengthen statistical inference and provide a more comprehensive evaluation of product texture.

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