Effect of different levels of green banana flour, chia seeds, sugar, cocoa powder and eggs on textural, physical and sensory properties of chocolate cake

Efeito de diferentes teores de farinha de banana verde, sementes de chia, açúcar, cacau em pó e ovos nas propriedades de textura, físicas e sensoriais de bolo de chocolate

Efecto de diferentes niveles de harina de plátano verde, semillas de chía, azúcar, cacao en polvo y huevos en las propiedades texturales, físicas y sensoriales de torta de chocolate

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Abstract
The development of healthier and tasty chocolate cakes with substitution of traditional ingredients by functional ingredients is still a challenge for the food industry. The aim of this study was to evaluate the physicochemical and sensory characteristics of chocolate cakes made with two different concentrations of green banana flour (GBF) + wheat flour (WF) and hydrated chia + fat, sugar, cocoa powder and eggs by using the Plackett-Burman experimental design (PB12). It was observed that a decrease in WF, GBF and sugar resulted in an increase of water activity, volume and adhesion force. Moreover, an increase in WF, GBF, egg, chia, and sugar resulted in an increase on firmness, elasticity and crust colour. The scanning electron microscopy showed a porous and weak structure for formulations with GBF and chia seeds. The highest scores for the overall acceptability were found for formulations with 75% of GBF in replacement of WF and 50% of chia seeds as fat substitution agent associated with low levels of eggs, sugar and cocoa powder. These results indicate the potential use of chia seeds and GBF in combination to manufacture healthier chocolate cakes.
Keywords: Bakery products; *Theobroma cacao*; Fat replacement; Cake quality.

Resumo
O desenvolvimento de bolos de chocolate mais saudáveis e saborosos com substituição de ingredientes tradicionais por ingredientes funcionais ainda é um desafio para a indústria alimentícia. O objetivo deste estudo foi avaliar as características físico-químicas e sensoriais de bolos de chocolate elaborados com duas diferentes concentrações de farinha de banana verde (GBF) + farinha de trigo (WF) e chia hidratada + gordura, açúcar, cacau em pó e ovos por meio do planejamento experimental de Plackett - Burman (PB12). Observou-se que a diminuição de WF, GBF e açúcar resultou em aumento da atividade de água, volume e força de adesão. Além disso, um aumento em WF, GBF, ovo, chia e açúcar resultou em um aumento na firmeza, elasticidade e cor da crosta. A microscopia eletrônica de varredura mostrou uma estrutura porosa e fraca para as formulações com GBF e sementes de chia. As maiores notas de aceitabilidade global foram encontradas para as formulações com 75% de GBF em substituição ao WF e 50% de sementes de chia como substituto de gordura associado a baixos teores de ovos, açúcar e cacau em pó. Esses

resultados indicam o potencial de utilização de sementes de chia e GBF em combinação para a fabricação de bolos de chocolate mais saudáveis.
Palavras-chave: Produtos de panificação; *Theobroma cacao*; Substituto de gordura; Qualidade do bolo.

Resumen
El desarrollo de tortas de chocolate más saludables y sabrosas con sustitución de ingredientes tradicionales por ingredientes funcionales sigue siendo un desafío para la industria alimentaria. El objetivo de este estudio fue evaluar las características fisicoquímicas y sensoriales de tortas de chocolate elaboradas con dos concentraciones diferentes de harina de plátano verde (GBF) + harina de trigo (WF) y chía hidratada + grasa, azúcar, cacao en polvo y huevo mediante el uso del diseño experimental de Plackett- Burman (PB12). Se observó que una disminución de WF, GBF y azúcar resultó en un aumento de la actividad del agua y de el volumen y de la fuerza de adhesión. Además, un aumento en WF, GBF, huevo, chía y azúcar resultó en un aumento en la firmeza, elasticidad y color de las tortas. La microscopía electrónica de barrido mostró una estructura porosa y débil para formulaciones con GBF y semillas de chía. Los mejores resultados para la aceptabilidad general se encontraron para las formulaciones con 75 % de GBF en sustitución de WF y 50 % de semillas de chía como agente de sustitución de grasa asociado con niveles bajos de huevos, azúcar y cacao en polvo. Estos resultados indican el uso potencial de semillas de chía y GBF en combinación para la fabricación de tortas de chocolate más saludables.
Palabras clave: Productos de panadería; *Theobroma cacao*; Sustitución de grasa; Calidad de torta.

1. Introduction

The lack of a healthy diet is considered the main risk factor for chronic diseases that are responsible for about 65% of deaths worldwide (Lennon et al., 2018; WHO, 2020). The promotion of healthy diet includes to avoid the intake of foods or ingredients with high content of sugar and saturated fats, because their adverse effects on health, including obesity, high cholesterol, higher prevalence of diabetes, coronary and heart diseases (Afshin, et al., 2019; Micha, et al., 2017). Bakery and confectionery, especially cakes, are among the most consumed products worldwide. However, many consumers are seeking for healthier eating, reducing fat and sugar intake in cakes. Although the fat and sugar reduction in cakes is desirable, it can affect the technological and sensory properties of the final product (Fernandes, et al., 2021; Garvey, et al., 2021; Souza, et al., 2018).

The well-known effect of fats is the property of promoting the aeration of the dough, which directly influences the cake volume, due to the formation and stabilization of the foam. The effect provided by the reduction in fat can be offset by the addition of chia mucilage, obtaining a greater specific volume in cakes (Fernandes & Salas-Mellado, 2017). Chia seed shows a high nutritional value with 25% of proteins, 35% of lipids, 79.5% of which are polyunsaturated fatty acids, about 60% as omega 3, and 30% of fibers, being 5.7% insoluble and 24.3% soluble. In addition, it contains minerals, vitamins and natural antioxidants such as tocopherols (238-427 $mg.kg^{-1}$) and polyphenols (Ixtaina, et al., 2015). When in contact with water, the epicarp of chia seeds is hydrated, the cuticle breaks and a mucilage is released on the surface of the seed (Muñoz, et al., 2012). This gel is essentially composed of soluble fibers that contribute to the stability of the structure of food products, in particular, dispersions and emulsions present in desserts, beverages, breads, jellies, mayonnaise, cookies, cereal bars, yogurts and sauces (Mesías, et al., 2015). The chia seeds also have a great capacity to retain water and oil, characteristics that make it a potential additive for baked goods and as a food emulsifier (Olivos-Lugo, et al., 2010). Chia is reported as a fat replacer in cakes in a form of chia gel or mucilage (Fernandes & Salas-Mellado, 2017; Fernandes, et al., 2021; Gallo, et al., 2020) and whole chia flour (Pizarro, et al., 2013).

Green banana flour is studied for wheat flour replacement and fiber enrichment in cakes (Segundo, et al., 2017) and breads (Alcântara, et al., 2020; Khoozani, et al., 2020). The unripe banana fruits have an average of 73.4% of total starch, with 17.5% of resistant starch, which is characterized as dietary fiber. Green banana flour is a source of potassium, phosphorus, magnesium, copper, manganese and zinc, proteins and fibers. The largest amount of resistant starch present in unripe banana flour is type 2 (RS2), which is not digestible in the raw state, due to the high amylose content, but becomes digestible when heated. Its amount can vary from 49 to 57 g/100 g depending on the fruit variety and drying process (Borges, et al., 2009). The use of 20% of green banana flour to replace fat in cakes increased the luminosity, the firmness and the springiness of products (Souza, et al., 2018).

Although the scientific studies mentioned above, there are no studies on the effect of the simultaneous replacement of wheat flour by green banana flour and the substitution of fat by hydrated chia seeds, associated with a proportional substitution of other ingredients such as sugar, cocoa and eggs, in the formulation. Therefore, this study was carried out to evaluate the physicochemical and sensory characteristics of the total replacement of fat by hydrated chia seeds and the partial replacement of wheat flour by green banana flour on the manufacture of cakes. Moreover, a Plackett–Burman experimental design was carried out to study the effect of five different variables (green banana flour/wheat flour, chia/oil, sugar, cocoa powder and eggs) on chocolate cake production.

2. Methodology

2.1 Cake formulations

The following raw materials were purchased at the local market for cakes manufacture: wheat flour (Itaipu, Pinhalzinho, BRA), green banana flour (Linea Verde, Curitiba, BRA), chia seeds (Sabor Verde, Curitiba, BRA), sugar (Alto Alegre, Presidente Prudente, BRA), fresh eggs, fat (Soya, Gaspar, BRA), cocoa powder (Chale do mel, Chapecó, BRA) and baking powder (Royal, Jundiaí, BRA). All formulations in this study were based on the control formulation (CF) described in Table 1.

Table 1 - Layer cake formulation used as a control.

Ingredients (g)	Control Formulation (CF)
Wheat flour	100.0
Sugar	90.0
Milk	95.0
Eggs	78.5
Fat	47.5
Baking powder	4.5

Source: adapted from Segundo et al., (2017).

2.2 Experimental Design

The formulations were based on the Plackett-Burman experimental design (PBD12), with 5 independent variables: X1 = flour (GBF and WF); X2 = chia; X3 = sugar, X4 = cocoa powder and X5 = eggs, in 2 levels and three repetitions of the central point, in a total of 15 experiments (Rodrigues & Iemma, 2014). The addition of baking powder and milk to the formulations was set according to a CF, and the flour blend (GBF and WF) was made according to the experimental design to reach a final weight of 300 grams for all cakes (Table 2).

Table 2 - Experimental design with real and coded values.

Formulations	**X1 (GBF+WF)**	**X2 (Chia+Fat)**	**X3 (Sugar)**	**X4 (Cocoa powder)**	**X5 (Egg)**	**X1 GBF+WF(g)**	**X2 Chia+fat(g)**	**X3 Sugar (g)**	**X4 Cocoa powder(g)**	**X5 Egg (g)**	**Ingredients mix (g)**	**Flour mix (g)**
1	1 (75/25)	-1 (50/50)	1 (95)	-1 (8)	-1 (75)	54.21	36.15	68.67	5.79	54.30	219.12	80.88
2	1 (75/25)	1 (100/0)	-1 (85)	1 (12)	-1 (75)	54.21	72.29	61.44	8.67	54.30	250.91	49.09
3	-1 (50/50)	1 (100/0)	1 (95)	-1 (8)	1 (85)	36.15	72.29	68.67	5.79	61.44	244.34	55.66
4	1 (75/25)	-1 (50/50)	1 (95)	1 (12)	-1 (75)	54.21	36.15	68.67	8.67	54.3	222.00	78.00
5	1 (75/25)	1 (100/0)	-1 (85)	1 (12)	1 (85)	72.27	72.29	61.44	8.67	61.44	276.11	23.89
6	1 (75/25)	1 (100/0)	1 (95)	-1 (8)	1 (85)	54.21	72.29	68.67	5.79	61.44	262.40	37.60
7	-1 (50/50)	1 (100/0)	1 (95)	1 (12)	-1 (75)	36.21	72.29	68.67	8.67	54.30	240.14	59.86
8	-1 (50/50)	-1 (50/50)	1 (95)	1 (12)	1 (85)	36.15	36.15	68.67	8.67	61.44	211.08	88.92
9	-1 (50/50)	-1 (50/50)	-1 (85)	1 (12)	1 (85)	36.15	36.15	61.44	8.67	61.44	203.85	96.15
10	1 (75/25)	-1 (50/50)	-1 (85)	-1 (8)	1 (85)	54.21	36.15	61.44	5.79	61.44	219.03	80.97
11	-1 (50/50)	1 (100/0)	-1 (85)	-1 (8)	-1 (75)	36.15	72.29	61.44	5.79	54.30	229.97	70.03
12	-1 (50/50)	-1 (50/50)	-1 (85)	-1 (8)	-1 (75)	36.15	36.15	61.44	5.79	54.30	193.83	106.17
13	0 (62.5/37.5)	0 (75/25)	0 (90)	0 (10)	0 (80)	45.18	54.22	65.06	7.23	57.83	229.52	70.48
14	0 (62.5/37.5)	0 (75/25)	0 (90)	0 (10)	0 (80)	45.18	54.22	65.06	7.23	57.83	229.52	70.48
15	0 (62.5/37.5)	0 (75/25)	0 (90)	0 (10)	0 (80)	45.18	54.22	65.06	7.23	57.83	229.52	70.48

Formulations 1 to 15: Plackett-Burman experimental design (PB) with a total of 15 experiments. X1 to X5: 5 independent variables, at 2 levels (+1 and -1), plus two repetitions of the central point (0). GBF: green banana flour. WF: wheat flour. Ingredients mix: total sum of the ingredients of the formulation. Flour mix: GBF and WF blend, according to the experimental design to reach a final weight of 300 grams for all cakes. Source: Authors.

2.3 Physicochemical characterization of the cakes

The samples were evaluated for water activity in AquaLabPre® (Decagon Devices, Pullman, USA) apparatus, according to the manufacturer's instructions. The specific volume of the cakes was determined by AACCI method 10-05.01 (2016) by the millet seed displacement and expressed as cm^3/g. The pH was determined by dispersing 10 g sample in 100 mL distilled water and measured in a pHmeter (ION, model pHB 500, Chicago, USA). The moisture content was determined by the method 931.04 (AOAC, 2016). All analyses were performed in triplicate.

The texture was measured according to the method 74-10.02 AACCI (2016) in a texture analyzer (Brookfield, model CT3, Virginia, USA) with 2.5 cm^3 samples, 1 cm away from the ends. The texture parameters were 40% compression, using an acrylic cylinder of 20 mm in diameter and a speed of 2.0 $mm.s^{-1}$. The crust colour was assessed by the colour parameters L*, a*, and b* in a colorimeter (Hunter Lab, model Mini Scan EZ, Virginia, USA), by direct readings in three different regions from a cut of the central portion of the cake, and the crumb colour was measured at 2 cm from the center of the cake, according to the manufacturer's instructions (Bodart, de Peñaranda, Deneyer, & Flamant, 2008).

2.4 Microstructure analysis using SEM

The formulation CF and the samples F4, F9, F10, that showed texture parameters closest to the control formulation, were examined using scanning electron microscopy (SEM). Freeze-dried samples were fractured and coated with gold. The microstructures were observed in a SEM stage using a JSM6701F scanning electron microscope (JEOL, Japan) with an accelerating voltage of 10-15 kV.

2.5 Sensory analysis

A sensory evaluation (approved by Ethical Committee in Research Involving Human Beings – CESPH/UDESC, Protocol nº CAAE: 59997016.0.0000.0118/2016) was performed by 53 volunteers, including 11 men and 42 women, with an average of 22 years old. All untrained volunteers were students and workers of Santa Catarina State University – UDESC and usual consumers of cakes. Cakes were divided into pieces of 3 cm^3 and disposed at white plastic plates coded with three-digit code numbers and presented to each volunteer in a randomized order. A cup of water was also provided. Cakes were evaluated based on consumer acceptance by the evaluation of their appearance, colour, texture, taste and overall acceptability. This evaluation was performed using a hedonic scale of 9 points ranging from "dislike extremely" (1 score) to "like extremely" (9 score). The volunteers also answered three questions about: the frequency, the consumption pattern and the intention of purchasing the product. All cake samples were evaluated within 24 hours after baking. Only the cake formulations F4, F9 and F10 were selected for sensory analysis because they showed texture parameters closer to the control CF.

2.6 Statistical analysis

The formulations were prepared according to the Placket and Burman experimental design and the analysis were carried out in triplicate. Analysis of variance (ANOVA) followed by Tukey's test were carried out using Protimiza Experimental Design software (Protimiza, Campinas, Brazil) with statistical significance set at 10% ($P<0.10$) and considering 90% confidence levels, and with statistical significance set at 5% ($P<0.05$) and considering 95% confidence levels.

3. Results and Discussion

Table 3 shows the results of water activity, volume, moisture and texture parameters of cake formulations. According the Plackett-Burman experimental design (PB12), the WF/GBF, chia/oil, sugar and egg concentration were the main parameters that influence the characteristics of cake formulations.

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Table 3 - Water activity, volume, moisture and texture parameters of cake formulations.

Formulation	Aw	Volume (cm³/g)	Moisture (%)	Firmness (N)	Adhesiveness (N)	Elasticity (mm)	Chewiness
F1	0.903 ± <0.001 ^{e}	2.34 ± 0.11 ^{ab}	64.58 ± 0.03 ^{a}	32.20 ± 6.62 ^{b}	0.20 ± 0.12 ^{a}	12.30 ± 3.10 ^{bc}	186.03 ± 4.82 ^{a}
F2	0.908 ± <0.001 ^{de}	2.13 ± 0.12 ^{bc}	60.60 ± 0.02 ^{ab}	51.62 ± 4.67 ^{a}	0.20 ± 0.07 ^{a}	13.28 ± 3.20 ^{abc}	185.06 ± 0.50 ^{a}
F3	0.952 ± 0.010 ^{bc}	1.20 ± 0.15 ^{e}	61.74 ± 0.01 ^{ab}	14.49 ± 2.39 ^{cd}	0.10 ± 0.05 ^{bc}	13.05 ± 3.40 ^{ab}	100.47 ± 0.88 ^{c}
F4	0.922 ± 0.014 ^{d}	1.65 ± 0.43 ^{de}	66.23 ± 0.01 ^{a}	16.92 ± 2.09 ^{c}	0.22 ± 0.04 ^{a}	12.23 ± 3.09 ^{c}	105.06 ± 1.26 ^{b}
F5	0.953 ± 0.006 ^{bc}	1.80 ± 0.26 ^{cd}	45.31 ± <0.01 ^{d}	16.89 ± 2.98 ^{c}	0.10 ± 0.07 ^{bcd}	14.72 ± 2.92 ^{bc}	100.06 ± 0.24 ^{c}
F6	0.944 ± 0.003 ^{bc}	1.71 ± 0.18 ^{cde}	49.45 ± 0.01 ^{de}	10.89 ± 1.00 ^{de}	0.20 ± 0.05 ^{a}	12.74 ± 0.23 ^{abc}	98.44 ± 1.46 ^{cd}
F7	0.948 ± 0.008 ^{bc}	2.00 ± 0.03 ^{cd}	54.28 ± 0.01 ^{bc}	10.11 ± 1.16 ^{de}	0.05 ± 0.23 ^{bcde}	13.53 ± 3.44 ^{ab}	94.48 ± 2.12 ^{d}
F8	0.942± 0.004 ^{c}	1.58 ± 0.29 ^{cde}	54.07 ± 0.02 ^{bc}	6.62 ± 0.97 ^{ef}	0.05 ± 0.03 ^{bcd}	11.07 ± 3.05 ^{c}	95.79 ± 1.04 ^{d}
F9	0.950 ± 0.005 ^{bc}	3.16 ± 0.08 ^{a}	54.36 ± 0.02 ^{bc}	6.45 ± 0.54 ^{ef}	0.01 ± 0.03 ^{e}	14.24 ± 1.82 ^{a}	95.41 ± 1.19 ^{d}
F10	0.948 ± 0.001 ^{bc}	2.10 ± 0.15 ^{bcd}	49.92 ± 0.01 ^{cd}	8.92 ± 1.32 ^{d}	0.05 ± 0.05 ^{cde}	13.35 ± 0.70 ^{ab}	97.15 ± 0.76 ^{cd}
F11	0.969 ± 0.001 ^{a}	3.05 ± 0.12 ^{a}	49.92 ± <0.01 ^{cd}	10.42 ± 2.33 ^{de}	0.05 ± 0.03 ^{cde}	13.55 ± 1.65 ^{ab}	97.00 ± 1.17 ^{cd}
F12	0.972 ± 0.001 ^{a}	2.64 ± 0.25 ^{ab}	39.83 ± <0.01 ^{e}	9.13 ± 2.05 ^{d}	0.04 ± 0.02 ^{de}	13.24 ± 0.37 ^{ab}	95.30 ± 1.46 ^{d}
F13	0.960 ± 0.002 ^{ab}	2.58 ± 0.31 ^{b}	48.56 ± 0.01 ^{de}	8.78 ± 1.00 ^{d}	0.10 ± 0.01 ^{b}	12.73 ± 0.55 ^{abc}	53.00 ± 3.90 ^{e}
F14	0.956 ± 0.002 ^{abc}	1.97 ± 0.12 ^{cd}	49.36 ± 0.01 ^{cde}	7.89 ± 1.23 ^{de}	0.10 ± 0.01 ^{b}	12.71 ± 0.89 ^{abc}	54.70 ± 3.17 ^{e}
F15	0.960 ± 0.003 ^{abc}	2.11 ± 0.09 ^{bcd}	49.22 ± 0.01 ^{cde}	8.65 ± 1.54 ^{d}	0.10 ± 0.01 ^{b}	12.78 ± 0.98 ^{abc}	53.60 ± 4.01 ^{e}
CF	0.942 ± <0.001 ^{c}	2.62 ± 0.25 ^{ab}	25.59 ± 0.02 ^{f}	2.75 ± 0.29 ^{e}	0.05 ± 0.07 ^{cde}	12.97 ± 0.38 ^{ab}	24.30 ± 2.72 ^{f}

F1 to F15: cake formulations with different concentrations of WF, GBF, cocoa powder, hydrated chia and eggs. CF: control formulation, without the addition of GBF, cocoa powder and hydrated chia. Results were expressed as mean ± standard deviation (n = 3) and for the texture analyses (n = 5). Means followed by different letters in the same column are significantly different according to the Tukey's test ($P<0.05$). Source: Authors.

The water activity for formulations F1, F2, F4 was lower and for F11, F12 and F13 was higher than the obtained for CF (P< 0.05). PB12 experimental design showed a negative effect (P< 0.1) for flour mix, WF and GBF blend. It was observed that the lower flour mix concentration resulted in higher water activity of cakes due to the increase in the hydrated chia and egg contents, as observed for formulation F11 (Table 3).

The formulations F1, F4 and F6 containing the higher sugar contents showed a lower water activity (Table 3), probably due to the intermolecular bonds between sugar and water, which reduces the amount of free water (Fernandes & Salas-Mellado, 2017). A lower water activity (< 0.90) is generally desirable because is directly related to food preservation, although a high (> 0.90) water activity can increase microbial growth, such as bacteria, yeasts and molds (Jin, Tang, & Sablani, 2019).

It was observed a reduction (P< 0.05) on the volume for formulations F3, F4, F5, F6, F7, F8 and F14 when compared to the CF, probably due to the presence of GBF which influences the low development of the gluten structure (Alcântara, et al., 2020). Sugar negatively affected (P< 0.1) the volume of the formulations (Table 3), and the lower volume was observed for the formulations F3 and F4, both containing the higher sugar levels. The formulations F9 and F11 exhibited the highest volume, both containing the lower flour and sugar contents. García, et al., (2014) reported that the reduction of sugar increased the dough elasticity. Sugar also controls the dough viscosity by limiting the amount of free water during cooking. The reduction of the available water raises the starch gelatinization temperature and increases the denaturation temperature of the egg white protein, so sugar reduction can interfere in the cake volume (Milner, et al., 2020).

A significant increase (P< 0.05) in the moisture content was also observed for formulations F1, F2, F3 and F4 probably due to the addition of higher hydrated chia levels (Table 3). Although, there was no effect (P< 0.1) for moisture levels of the formulations. The moisture content ranged from 25.59% to 66.23% for the CF and the formulation F4, respectively (Table 3). The low moisture content of the CF is due to the absence of hydrated chia and the presence of conventional soybean oil. The formulation F4 presented a higher moisture, possibly due to the sugar content that increases the water retention, reduces evaporation during baking and increases the moisture content of the final product (Lee et al., 2020). Oliveira et al. (2015) studied the substitution of 10, 20, and 30% wheat flour by green banana flour in bread formulations and found moisture values ranging from 39.89 to 40.67%, in agreement with the values found in the present study (Table 3). According to the authors, the high moisture content may be due to the high protein, starch composition and low lipids level. Moreover, the hydrophilic characteristics of these parameters can improve the water absorption capacity and increase the moisture content of the final product.

A significant increase ($P< 0.05$) in firmness was observed for all formulations in relation to the CF probably due to lower WF concentration, lower gluten level and weakness of the protein structure of the cake formulations (Segundo, et al., 2017; Andrade et al., 2018). A positive effect ($P< 0.1$) was observed for the flour mix and a negative effect ($P< 0.1$) for the egg, indicating that the low wheat flour content and the high egg content can decrease the firmness, as can be observed for formulations F3, F8 and F9, which contains the lower wheat flour and the higher egg levels (Table 3). Souza, et al., (2018) found firmness values of 6.6 N for the control formulation and 9.4 N for the formulation with 25% fat substitution and 20% sugar reduction, indicating an increase in firmness with the decrease of the sugar level. Segundo, et al., (2017) studied the replacement of WF by GBF in cake and brownie, and found an increase in firmness of the formulations, confirming the findings of the present study.

The formulations F1, F2, F4, F6, F13, F14 and F15 showed a significant difference ($P< 0.05$) in the adhesion force when compared to the CF. There was a negative effect ($P< 0.1$) for the variable egg (PB12), that shows that an increase in adhesion force is associated to the decrease of egg content. A positive effect ($P< 0.1$) of the variables mix flour and sugar (PB12) was observed, as a higher level of these ingredients also increases the adhesion force. The formulations F1 to F6 presented a higher adhesion force when compared to the CF due to its higher wheat flour, chia seeds and sugar contents (Table 3). The adhesion force corresponds to the force required to remove the material that adheres to the mouth during chewing and the lower adhesion force is favorable to the easy chewing (Wang, et al., 2012).

The elasticity showed positive effect ($P< 0.1$) for variable chia and negative effect for variable sugar (PB12), indicating an increase in elasticity with the increase in chia level and the reduction of sugar in the formulations. This effect is desirable since elasticity is the degree to which a product returns to its original shape after compression between the tongue and teeth (Agama-Acevedo, et al., 2012). The formulation F5 showed a higher elasticity due to its higher hydrated chia and lower sugar levels (Table 3). None of the independent variables (PB12) showed a significant effect ($P< 0.1$) on the chewability. However, all formulations were significantly different ($P< 0.05$) for chewability when compared to CF (Table 3). The results showed that the addition of GBF and the reduction of WF provided greater energy required for swallowing the sample.

3.1 Crust and crumb cake colour

All samples differed statistically ($P< 0.05$) from the CF for the colour parameters L, a* and b* due to the absence of dark-coloured ingredients, GBF and cocoa powder, in CF sample (Table 4)).

Table 4 - Crust and crumb colour of cake formulations.

Formulations	**Crust**			**Crumb**		
	L*	a*	b*	L*	a*	b*
F1	21.63 ± 0.92 def	4.72 ± 0.53 f	6.26 ± 0.74 hi	25.42 ± 2.36 bc	5.51 ± 0.50 d	10.14 ± 0.86 gh
F2	23.13 ± 0.13 cd	5.32 ± 0.70 def	7.23 ± 0.41 ghi	20.63 ± 0.27 e	4.43 ± 0.27 d	6.83 ± 0.33 h
F3	25.22 ± 0.74 bc	5.42 ± 0.65 de	9.68 ± 1.07 e	24.90 ± 0.74 bc	5.48 ± 0.16 d	10.05 ± 0.47 hfg
F4	22.23 ± 1.10 cde	4.67 ± 0.96 def	5.93 ± 0.49 i	22.68 ± 1.19 cde	5.70 ± 0.27 cd	9.60 ± 0.68 gh
F5	25.97 ± 1.04 b	6.28 ± 0.29 d	9.21 ± 0.45 ef	22.09 ± 0.54 cde	5.67 ± 0.20 cd	9.64 ± 0.41 gh
F6	24.84 ± 0.55 bc	4.08 ± 0.12 f	6.11 ± 0.18 hi	22.09 ± 0.99 de	5.36 ± 0.20 d	9.79 ± 0.36 gh
F7	16.62 ± 0.75 j	11.27 ± 0.41 b	17.67 ± 1.10 c	10.95 ± 3.20 g	13.96 ± 1.75 a	16.76 ± 1.57 cd
F8	13.69 ± 2.29 j	8.77 ± 0.74 b	13.27 ± 0.61 d	13.07 ± 1.69 f	14.98 ± 1.10 a	22.32 ± 2.57 b
F9	19.44 ± 0.65 gh	12.44 ± 0.31 b	8.47 ± 0.36 efg	22.30 ± 0.73 de	5.61 ± 0.23 cd	6.83 ± 0.14 h
F10	21.84 ± 0.46 efg	4.65 ± 0.31 ef	6.70 ± 0.32 hi	23.57 ± 0.51 cd	5.45 ± 0.25 cd	10.12 ± 0.14 gh
F11	19.32 ± 0.88 h	11.56 ± 0.79 b	23.27 ± 0.55 b	18.30 ± 2.10 f	14.54 ± 1.19 a	21.91 ± 2.60 c
F12	24.47 ± 1.06 bd	11.75 ± 0.54 b	22.27 ± 0.68 b	14.86 ± 0.51 f	14.13 ± 0.67 a	25.84 ± 0.81 b
F13	22.08 ± 0.87 def	4.82 ± 0.73 ef	7.64 ± 0.99 fghi	26.76 ± 1.12 b	7.3 ± 0.34 bc	13.72 ± 0.76 ef
F14	20.59 ± 0.90 fgh	4.90 ± 0.98 def	7.72 ± 0.90 fgh	27.18 ± 0.98 bd	9.03 ± 0.45 b	15.98 ± 0.98 ef
F15	21.34 ± 1.05 efg	4.54 ± 0.66 f	6.80 ± 0.91 hi	23.72 ± 1.76 c	6.19 ± 0. 76 cd	12.51 ± 0.78 eg
CF	35.47 ± 2.55 a	18.25 ± 0.74 a	37.77 ± 1.32 a	39.41 ± 3.57 a	13.23 ± 0.51 a	38.91 ± 3.57 a

Results are expressed as mean ± standard deviation of five determinations (n = 5). Means followed by different letters in the same column are significantly different according to the Tukey's test ($P<0.05$). F1 to F15: Cake formulations with different concentrations of wheat flour, green banana flour, cocoa powder, hydrated chia, and eggs. CF: control formulation without the addition of green banana flour, cocoa powder, and hydrated chia. Source: Authors.

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The crust colour of the cakes showed a positive effect ($P < 0.1$) for all variables (PB12) except for chia seeds and cocoa powder with a lower value for the variable flour, which affects the crust colour due to its dark colouration. Andrade, et al., (2018), investigated the replacement of 10, 15 and 20% wheat flour by green banana flour in whole wheat pan bread and found L, a* and b* values of 59.49, 12.82 and 30.77, respectively, for the crust of the control formulation which is close to the results found at the present study (Table 4). The author pointed out that the green banana flour contributed to the pan bread colour, reducing the a* and b* values, which means a reduction of chromaticity to red and to yellow, respectively. Fernandes & Salas-Mellado, (2017), studied cake formulations and observed that an increase in chia concentration resulted in a decrease in the luminosity of the crust.

The crumb colour (Table 4) is influenced by wheat flour. As lower is the flour particle size, brighter is the product colour. The luminosity of the product decreased significantly ($P < 0.05$) for all for formulations when compared to the CF. The colour coordinate a* reduced significantly ($P < 0.05$) for most formulations when compared to CF, except for the formulations F7, F8, F11 and F12, which has a high a* value, with a tendency for red tonality. The colour coordinate b* decreased significantly ($P < 0.05$) when compared to CF sample and a positive b* value indicates yellow tone (Savlak, et al., 2016). The crumb colour of the cakes had no effect ($P < 0.1$) for all variables (PB12). Souza, et al., (2018) used green banana puree (GBP) to replace fat and sugar in cakes and reported a 50% increase in yellow colour of the cakes with the increase in the amount of GBP. The addition of GBF reduced the a* and b* values, which means a decrease in the tendency to red and yellow colours, respectively.

3.2 Cakes microstructure

The control CF, without addition of GBF, chia seeds and cocoa powder, showed a cohesive, smooth, elastic, homogeneous, more uniform and continuous structure. The cakes with addition of GBF in substitution of WF and chia seeds in total substitution of lipids (F4, F9 and F10) showed an increase in porosity, larger and irregular gas cells and also small fissures in the cake structure (Fig. 1). The presence of high fiber content, as it is observed in GBF and in chia seeds, can modify the gluten network and disrupt the gas cell retention in cakes as also reported by previous studies (Andrade, et al., 2018; Segundo, et al., 2017).

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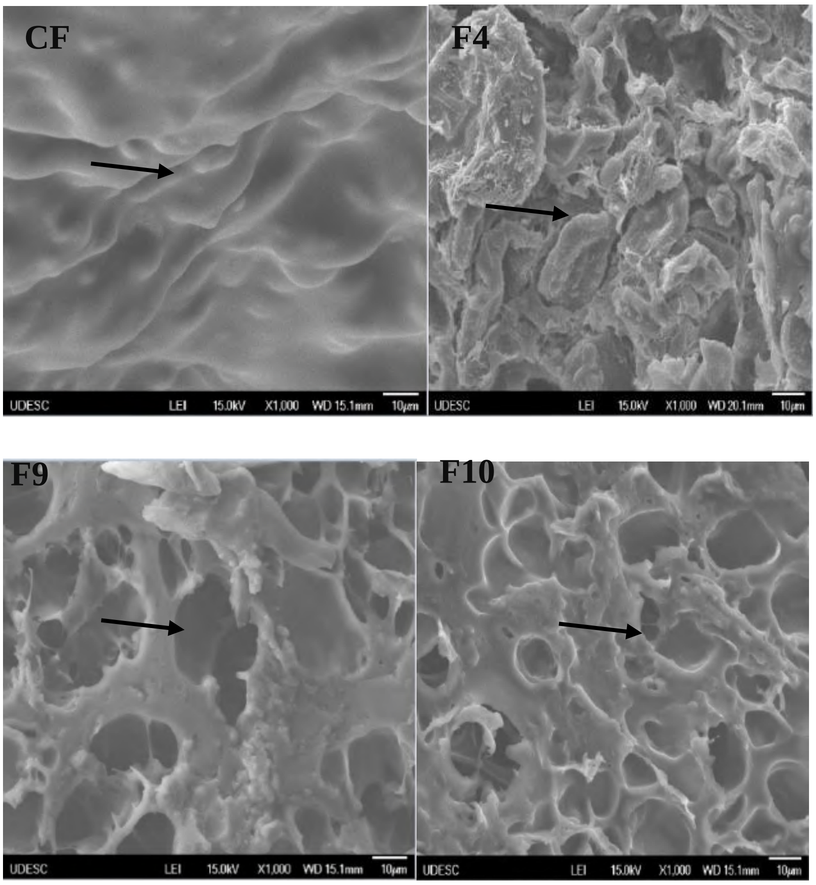
Figure 1 - Microstructure of cake samples.



GBF: green banana flour and WF: wheat flour, CF: control formulation without addition of GBF, cocoa powder and chia seeds; F4 and F10: cakes with 75% of GBF; F9: cakes with 50% of GBF; F4, F9 and F10: total substitution of lipids by hydrated chia seeds. Magnification of 1000x. Source: Authors.

3.3 Sensory evaluation

The cake formulations (F4, F9 and F10) with textural characteristics very close to the control CF were selected for sensory evaluation. Sample F10 showed the best score for taste, colour and appearance in relation to the CF and the F4 and F9 samples. The results showed that the inclusion of GBF in replacement of the wheat flour at levels of 50% and 75% and the use of chia seeds in a total substitution of fat resulted in cakes with sensory acceptability and there was no significant difference ($P < 0.05$) among the evaluated formulations (Table 5). These results can improve the benefits of use green banana flour in different products as also demonstrated by Souza, et al., (2018).

Table 5 - Sensory scores for taste, colour, texture, appearance and overall acceptance on a 9-point hedonic scale of cakes with green banana flour and chia seeds.

Samples	Taste	Colour	Texture	Appearance	Overall acceptance
F4	6.11±1.70 [a]	7.13±1.50 [a]	7.09±1.80 [a]	7.02±1.20 [a]	7.13±1.70 [a]
F9	6.92±1.30 [a]	7.09±1.40 [a]	7.08±1.60 [a]	6.98±1.60 [a]	7.00±1.30 [a]
F10	8.00 ±1.30 [a]	8.00±1.50 [a]	7.00 ±1.20 [a]	8.00 ±1.10 [a]	7.00 ±1.00 [a]
CF	7.06±1.10 [a]	7.34±1.10 [a]	7.60±1.00 [a]	7.19±1.00 [a]	7.25±1.00 [a]

Results are expressed as mean ± standard deviation. Means followed by different letters in the same column are significantly different according to Tukey's test (P<0.05). GBF: green banana flour; WF: wheat flour; F4 and F10: cakes with 75% of GBF; F9: cakes with 50% of GBF; F4, F9 and F10: 50% substitution of lipids by hydrated chia seeds; CF: control formulation without addition of GBF, cocoa powder and chia seeds. Source: Authors.

4. Conclusion

GBF and hydrated chia can be used simultaneously to improve the functional and nutritional properties of cakes with few changes on physicochemical properties. The addition of WF, GBF and sugar to the formulations resulted in water activity, volume and adhesion force with a negative effect, indicating that a decrease in the amount of these ingredients can improve technological parameters. The firmness, elasticity and crust colour showed a positive effect for WF, GBF, egg, chia, and sugar, indicating that a higher concentration of these ingredients can improve the texture and the colour parameters studied. The scanning electron microscopy showed porosity and irregular air spaces in formulations with GBF and chia seeds. There was a high consumer acceptance for the formulations with replacement of wheat flour of up to 75% of GBF and 50% of fat substitution by chia seeds in the presence of 85% of sugar, 85% of eggs and 8% of cocoa powder. These findings indicate that the increase of green banana flour and chia seeds levels associated with a reduction on sugar, eggs and cocoa powder ingredients level, were feasible for use in the manufacture of healthier chocolate cakes with desired technological properties and sensory quality. The simultaneous use of green banana flour and chia seeds as ingredients in the same product can also be helpful for the food industry to develop cakes and bakery products with better nutritional characteristics.

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Declaration of interest statement

There is no conflict of interest in this work.

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