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JABUTICABA PEEL IN THE PRODUCTION OF COOKIES FOR SCHOOL FOOD: TECHNOLOGICAL AND SENSORY ASPECTS

Uso da casca de jabuticaba na produção de *cookies* para a alimentação escolar: aspectos tecnológicos e sensoriais

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ABSTRACT

Jabuticaba (*Myrciaria cauliflora* Berg) is agreatly appreciated fruit with nutritional importance, primarily found in the majority of Brazil. Its peel is a discarded by-product of the Brazilian agroindustry. The objective of this study was to develop cookie formulations with partial replacement of wheat flour (WF) and oat flour (OF) by jabuticaba peel meal (JPF), analyzing the technological aspects of the elaborate cookies and evaluating the acceptance of the selected product. All regression models of the cookies with JPF flour were significant. Cookies with JPF tended to blemish and had smaller thicknesses, greater ISA and IAA, smaller values of breaking strength and decreased color parameters (L*, a* and b*) compared to standard cookies. Cookies made with larger OF fractions had lower values of specific volume. Both the standard and the selected cookies from the cookie desirability test were deemed acceptable among students. This work presents a new possibility to produce cookies based on an agro-industrial co-products, which is interesting for the market for this type of product.

Index terms: *Myrciaria cauliflora* Berg; agro-industrial co-products; mixture design.

RESUMO

A jabuticaba (*Myrciaria cauliflora* Berg) é um fruto muito apreciado, de importância nutricional, encontrado na maior parte do território brasileiro. Sua casca é um subproduto descartado nas agroindústrias brasileiras. Conduziu-se este trabalho com o objetivo de desenvolver formulações de *cookies* com substituições parciais da farinha de trigo (FT) e farinha de aveia (FA) pela farinha de casca de jabuticaba (FCJ), analisar os aspectos tecnológicos dos *cookies* elaborados, além de verificar a aceitação do produto selecionado. Para elaboração do *cookie*, utilizou-se metodologia de superfície de resposta e delineamento de misturas. Todos os modelos de regressão dos *cookies* foram significativos. *Cookies* com FCJ tendem a espessuras menores, maior ISA e IAA, além de possuírem menores valores de força de ruptura e diminuição dos parâmetros de cor (L*, a* e b*), comparados ao padrão. *Cookies* com maiores frações de FA apresentaram maiores valores de volume específico. Tanto o padrão quanto o *cookie* selecionado no teste de desejabilidade foram aceitos por escolares. Neste trabalho apresentou-se uma nova possibilidade de produção de *cookie* à base de um coproduto agroindustrial, sendo interessante do ponto de vista comercial a jabuticaba e ao mercado desse tipo de produto.

Termos para indexação: *Myrciaria cauliflora* Berg; coproduto agroindustrial; delineamento de misturas.

INTRODUCTION

The jabuticaba is native to south-central Brazil, and *Myrciaria cauliflora* (DC) Berg stands out among the currently known species because the fruits are suitable for fresh consumption and for agroindustry (Aschieri; Silva; Cândido, 2009). In Brazil, the residues of fruits and vegetables are generally wasted at all points at the market chain leading up to the final consumer, including the farmers, industry and customer. The foods and their by-products (peels, seeds and bagasse) that are often intended for animal feed could be used as alternative sources of bioactive compounds in foods for human consumption to meet nutritional needs, reducing waste and environmental impact and adding value to these by-products (Melo et al., 2011).

Among the various available alternatives to preventing the inappropriate disposal and waste of these consumable parts that are not typically consumed, their use in the production of flour stands out (Pelissari et al., 2012; Aziz et al., 2012) because they can be applied in formulations such as baked cakes, breads and biscuits (Ajila et al., 2010; Coelho; Wosiacki, 2010; Lopez et al., 2011), increasing their added value.

Cookies are obtained by kneading and baking dough prepared with flour, starches, fermented or not, and other food substances. Their quality is related to the flavor, texture, appearance and other factors, and, in recent years, they have emerged as a product of great commercial interest due to the practicality in their production, marketing and consumption, as well as their long shelf

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life (Perez; Germani, 2007). Therefore, alternatives have emerged for producing nutritionally enriched flours, reflecting the current appeal for healthier eating habits (Fasolin et al., 2007). In this sense, incorporating flour from jabuticaba peels in the preparation of cookies is an alternative contribution to the health of students.

Lucero et al., (2010) showed that enhancing school meals is extremely important given the health benefits to students and, consequently, the significant improvements in teaching and learning processes. Thus, the mathematical modeling and optimization of food formulations can be an important contributor in the assessment of the nutritional and sensory quality of food for various purposes, in addition to providing researchers with the necessary tools to develop and optimize food products (Dingstad; Westad; Naes, 2004; Ferguson et al., 2006).

In this sense, this work aims to develop a formulation of flour-enriched cookies elaborated with jabuticaba peel substituted for wheat flour and oatmeal, to analyze the technological aspects of both the flour and the prepared cookies, and to perform a sensory analysis of the acceptance of students from a school in the city of Goiânia, Goiás, Brazil.

MATERIAL AND METHODS

Collection of samples

The fruits (50 kg) from different trees were collected for the production of jellies and pulps from the Association of Rural Producers in the Region of Bom Sucesso (APRO-BOM), Nazário, Goiás, Brazil, selected with regards to color, mechanical damage and attack from microorganisms and insects, and were then sanitized for 15 min in a solution of sodium hypochlorite (150 mg L^{-1}). The peels were donated by the association and collected after removing the pulp; they were then refrigerated and taken to the laboratory of Agro-Industrial Waste Utilization of the School of Agronomy, Universidade Federal de Goiás (UFG), to be dehydrated.

Production of jabuticaba peel flour

In the laboratory, jabuticaba peels were dried in an oven (Tecnal-TE 394/3, Piracicaba-SP, Brazil) with forced air circulation at 60 °C until reaching 14% moisture to obtain microbiological stability. The dried peels were ground in a Wiley mill (Marconi model MA630, Piracicaba, Brazil) with sieve analysis in vibrating equipment (Produtest, MOD.T, São Paulo, Brazil) containing seven stacked sieves with openings varying from 1.41 to 0.053 mm and a pan at the bottom (AOAC Method 965-22 (1997)). The dry flour was vacuum packed in low-density polyethylene bags and stored under refrigeration (4±1 °C) until processing.

Mixture design

For the preparation of the cookies, response surface methodology and design of mixtures were used (Barros Neto; Scarminio; Bruns, 2001). The components of the mixture used in this study were jabuticaba peel flour, wheat flour and oatmeal flour. The ingredients in this study were expressed as pseudo-components for the jabuticaba peel flour (Equation 1), oatmeal flour (Equation 2) and wheat flour (Equation 3).

$$X_{JPF} = \frac{C_{JPF} - 0.30}{1 - 0.65} \quad (1)$$

$$X_{OF} = \frac{C_{OF} - 0.15}{1 - 0.65} \quad (2)$$

$$X_{WF} = \frac{C_{WF} - 0.20}{1 - 0.65} \quad (3)$$

where X is the component content in terms of the pseudo-component, C is the actual proportion of the component, JPF is jabuticaba peel flour, OF is oatmeal flour, and WF is wheat flour.

The cookies were prepared and manipulated according to the experimental design shown in Table 1. The order of processing of the experiments was randomized.

The representation of the system of mixtures was constructed using ternary contour diagrams. A polynomial equation was adjusted for each response, estimating the respective coefficients using the canonical models of Scheffé for three components: linear (Equation 4) and quadratic (Equation 5) models. Therefore, regression models with all variables of interest were obtained.

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \quad (4)$$

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 \quad (5)$$

where y is the dependent variable, β is the regression coefficient for each component of the model, x_1 is jabuticaba peel flour, x_2 is oatmeal flour, and x_3 is wheat flour.

Processing of cookies

The formulation used in this test was defined after preliminary tests according to Table 2. A standard cookie with no JPF (control) was prepared for comparison with the desired formulation in the sensory evaluation. The ingredients mixed manually in a container until a homogeneous dough was obtained. The cookies were shaped in a PVC ring (1 cm x 4 cm), placed in a rectangular baking tray (24.5 x 8 x 35.5 cm), smeared with 5 g of soybean oil, and baked in a preheated 180 °C oven for 20 minutes. The procedures were identical for all formulations and were conducted in three replicates.

Technological analyses

The analysis of water activity (Aw) was performed in an Aqua Lab unit (CX-2, Washington, USA). The water absorption index (WAI) and water solubility index (WSI) of the standard cookie and the cookies formulated with JPF were determined according to the methodology of Anderson (1969). Analyses were carried out in triplicate. Instrumental color parameters (L*, a* and b*) were measured with a colorimeter (Color Quest II, Hunter Lab Reston, Canada) according to Paucar-Menacho et al. (2008). Thirty readings were performed on three standard cookies and on three cookies made with jabuticaba peel flour from each experimental point. The specific volume (SV) of the cookies was determined from the displacement of millet seeds in 15 replicates according to the method described by Silva, Silva and Chang (1998).

Determination of the rupture force of the cookies was performed in a texture analyzer (Stable Micro Systems, TA.TX Express, Surrey, England) using a rectangular probe with a Warner-Bratzler steel blade and a reversible blade to cut each cookie in half, which was then placed horizontally on a platform. The pre-test and post-test speed was 10 mm s^{-1}, and the test speed was 2 mm s^{-1}. The distance of the product to the probe was 8 mm. A total of 15 determinations of each formulation was performed on the second day after preparation. The analyzed samples were selected randomly.

Table 1: Design of mixtures to study the effect of jabuticaba peel flour (JPF), oatmeal flour (OF) and wheat flour (WF) on dependent variables in actual proportion and in pseudocomponents, defined by simple design, with $x_1 + x_2 + x_3 = 1$ or 100%.

Experiment	Proportions of ingredients in the ternary mixture					
	In actual concentrations g $(100g)^{-1}$			In pseudocomponent*		
	JPF (c1)	OF (c2)	WF (c3)	JPF (X1)	OF (X2)	WF (X3)
1	0.60	0.15	0.25	0.86	0.00	0.14
2	0.30	0.35	0.35	0.00	0.57	0.43
3	0.60	0.20	0.20	0.86	0.14	0.00
4	0.45	0.35	0.20	0.43	0.57	0.00
5	0.45	0.15	0.40	0.43	0.00	0.57
6	0.30	0.30	0.40	0.00	0.42	0.57
7(1)	0.45	0.25	0.30	0.43	0.285	0.285
7(2)	0.45	0.25	0.30	0.43	0.285	0.285
7(3)	0.45	0.25	0.30	0.43	0.285	0.285

* Source: Statsoft (2004).

Table 2: Actual concentrations of the ingredients used in the formulations of cookies with JPF replacing WF and OF.

Ingredient	Control	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6	Exp. 7 (3 replicates)
WF	140g	75g	105g	60g	60g	120g	120g	90g
JPF	-	180g	90g	180g	135g	135g	90g	135g
OF	160g	45g	105g	60g	105g	45g	90g	75g

Desirability test

From the mathematical models obtained for the Aw, thickness, SV, WAI, WSI, rupture force, L*, a* and b* of the cookies generated in the experimental design and with the aid of the *Response Desirability Profiling* function of the Statistica software (Statsoft, Statistica 7.0, Tulsa, USA), an estimate was made to determine the most desirable cookie formulation for the sensory analysis. A cookie was considered to have the most desirable formulation if it had higher values of SV and rupture force and lower values of L* and WAI.

Validation of the Model

Using the values obtained in the technological analysis, validation tests of the models were carried out by comparing the expected with the observed results using two original replicates and five laboratory replicates. Models with an R^2 lower than 0.83 were discarded.

Microbiological tests of the most desirable JPF and cookie samples for sensory analysis

Microbiological analyses were performed at the Laboratory of Hygiene and Sanitary Control of Food (LACHSA), Faculty of Nutrition (FANUT) (FANUT/UFG) and met the microbiological standards established by RDC Resolution n.12 of the Brazilian National Health Surveillance Agency (ANVISA) of the Ministry of Health. Scores of yeast and molds and coagulase-positive staphylococci were also determined for all samples as hygienic-sanitary indicators of the processing conditions and pathogenicity to complement the evaluation of the proposed microbiological profile. Microbiological analysis followed the procedures described by the American Public Health Association - APHA (2001) and Food and Drug Administration - FDA (2002).

Sensory analysis of standard and most desirable cookies

The subjects able to participate in this study were 100 students aged between 9 and 14 years old of both sexes, with the interest, availability and parental consent to participate in the analysis. This age range was chosen because these individuals are consumers of school meals and the Association of Rural Producers in the Region of Bom Sucesso (APRO-BOM) is a supplier of such products to the municipalities in the region. Analyses involving humans were conducted after approval by the Research Ethics Committee of the UFG under the opinion number 497.446.

The acceptability test was applied using a 5-point facial hedonic scale in which the appearance, texture, flavor and odor were evaluated according to a randomized block design, in which each panelist represented a block. The third point in the scale was considered as the limit of acceptance of the cookie formulations.

Statistical analysis

The results of the physical and sensory analyses (acceptance) were evaluated by analysis of variance (ANOVA) at a significance level of 5%. For the analysis of WSI, a level of significance of 10% was used. The technological analyses of the cookies were evaluated using response surface graphs. Statistica software version 7.0 (Statsoft, 2004) was used to obtain the experimental design and data analysis and to construct the graphics.

RESULTS AND DISCUSSION

Mixture design and technological characteristics

The jabuticaba peel flour obtained in this study, as well as the wheat and oatmeal flours, were fine-grained (80 mesh). According to Hoseney and Rogers (1990), the particle size distribution influences the ability of flour to absorb water, and smaller particles absorb proportionately more water more rapidly than larger ones. In this sense, it is possible to infer that the cookies in this study absorb water uniformly, depending on the textural properties of the flour used.

According to Table 3, all the regression models of cookies with jabuticaba peel were significant; the Aw, thickness, SV, WAI, rupture force, L*, a* and b* were significant at 5%, and the WSI was significant at 10%. In addition, the regression models had coefficients of determination (R^2) greater than 83%, except for the thickness, for which the coefficient of determination (R^2) was greater than 67%. Therefore, all models were considered predictive.

Analysis of Figure 1A verifies that the highest values of Aw (close to 0.48) were found in formulations with 0.30 to 0.60 g (100 g)$^{-1}$ JPF (Table 1), with 0.15 to 0.35 g (100 g)$^{-1}$ OF and 0.25 to 0.33 g (100 g)$^{-1}$ WF. Lower Aw (close to 0.38) values were found in cookies with JPF formulations ranging from 0.44 to 0.53 g (100 g)$^{-1}$, with OF between 0.27 and 0.35 g (100 g)$^{-1}$ and WF between 0.20 and 0.21 g (100 g)$^{-1}$.

Table 3: Adjusted polynomial models, significance level (p), lack of fit (LF) and coefficient of determination (R^2) for the physical properties of cookies with JPF as a function of pseudo-components of JPF (x_1), OF (x_2) and WF (x_3).

Variable	Adjusted models	LF	P	R^2
Aw	$y = 0.431x_1 + 0.357x_2 + 0.219x_3 + 0.475x_1x_3 + 0.69\ x_2x_3$	0.00069	0.03398	0.8894
Thickness	$y = 1.165x_1 + 1.39x_2 + 1.315x_3$	0.06452	0.03457	0.6742
SV	$y = 1{,}51x_1 + 1{,}44x_2 + 1{,}86x_3 – 0{,}84x_1x_3 – 1{,}34x_2x_3$	0.00467	0.02351	0.9086
WAI	$y = 1.00x_1 + 0.78x_2 – 1.38x_3 – 4.62x_1x_3 + 5.47x_2x_3$	0.54437	0.00130	0.9790
WSI	$y = 40.28x_1 + 37.63x_2 + 102.66x_3 – 136.76x_1x_3 – 168.13x_2x_3$	0.90829	0.07159	0.8363
Rupture force	$y = 1561x_1 + 51121x_2 + 76579x_3 - 109526x_1x_3 – 223763x_2x_3$	0.02711	0.01795	0.9205
L*	$y = 40.58x_1 + 52.22x_2 + 44.87x_3 – 9.83x_1x_2 – 19.31x_2x_3$	0.70146	0.00450	0.9607
a*	$y = 1.63x_1 + 3.97x_2 + 3.22x_3 – 3.87x_2x_3$	0.96551	0.00139	0.9453
b*	$y = 0.86x_1 + 11.40x_2 + 2.63x_3 – 11.44x_1x_2 – 14.71x_2x_3$	0.50192	0.00685	0.9514

Madrona and Almeida (2010) found mean Aw values of 0.36 in cookies made with okara and oatmeal, which is 6% and 2% lower than the maximum and minimum values, respectively, of Aw found in cookies with jabuticaba peel in this study. Vieira et al., (2010), studying sweet biscuits made with 15% cassava starch as a substitute for wheat flour, found Aw values of 0.31, which is 11% and 7% lower than the maximum and minimum values, respectively, of Aw found in cookies with jabuticaba peel in the present study.

The concept of Aw is highly valued in studies on changes in foods because it is directly related to the growth and metabolic activity of microorganisms and hydrolytic reactions. According to Ordonez et al., (2005), foods with an Aw lower than 0.60 are microbiologically stable because Aw is considered limiting for the growth of microorganisms. Even with Aw percentages higher than in previous studies on cookies, the Aw of the cookies made with jabuticaba peel flour were below the recommended limit for the development of microorganisms. Aw levels below 0.6 can retard the growth of microorganisms, also reducing the activity of spoilage reactions and favoring a long shelf life of foods (Ordonez et al., 2005).

In Figure 1B, the highest thicknesses of the cookies (close to 1.38 cm) were found in formulations with JPF ranging from 0.30 to 0.34 g (100 g)$^{-1}$ (Table 1), with OF between 0.30 and 0.35 g (100 g)$^{-1}$ and WF from 0.31 to 0.40 g (100 g)$^{-1}$. In contrast, the lowest thicknesses (close to 1.18 cm) were found in formulations with JPF ranging from 0.57 to 0.60 g (100 g)$^{-1}$, with OF between 0.15 and 0.21 g (100 g)$^{-1}$ and WF from 0.20 to 0.28 g (100 g)$^{-1}$.

The cookies prepared with higher percentages of JPF had smaller thickness than the formulations with higher proportions of OF and WF because JPF has a high content of dietary fiber (15.25%) (Ferreira et al., 2012). Perez and Germani (2007) justified that flours with a high fiber content tend to retain more water due to the hydrophilic characteristics of the fiber.

Analysis of Figure 1C verifies that cookies with the highest SV values (close to 1.8 cm) were those with a JPF content ranging from 0.43 to 0.60 g (100 g)$^{-1}$ (Table 1), with OF from 0.15 to 0.28 g (100 g)$^{-1}$ and WF between 0.20 and 0.47 g (100 g)$^{-1}$. However, cookies with the lowest SV values (approximately 1.3 cm) were those with JPF varying between 0.30 and 0.32 g (100 g)$^{-1}$, with WF from 0.34 to 0.35 g (100 g)$^{-1}$ and WF between 0.33 and 0.36 g (100 g)$^{-1}$.

The SV of the cookies is affected by several factors, such as the quality of the ingredients used in the preparation of the dough, especially the flour and processing conditions (Moura et al., 2010). Cookies produced with larger fractions of WF had lower values of SV. This can be explained by the higher water retention capacity resulting from the presence of soluble dietary fiber in OF (6.8%) (Ada, 1999). However, the SV values found in cookies with JPF are in agreement with those found by Gutkoski, Nodari and Jacobsen Neto (2003) in their study on sugar-snap cookies elaborated with WF from three cultivars; these authors found SV values ranging from 1.15 to 1.41. Assis et al. (2009) studied cookies prepared with different fractions of pumpkin seed and obtained SV values between 1.00 and 1.36.

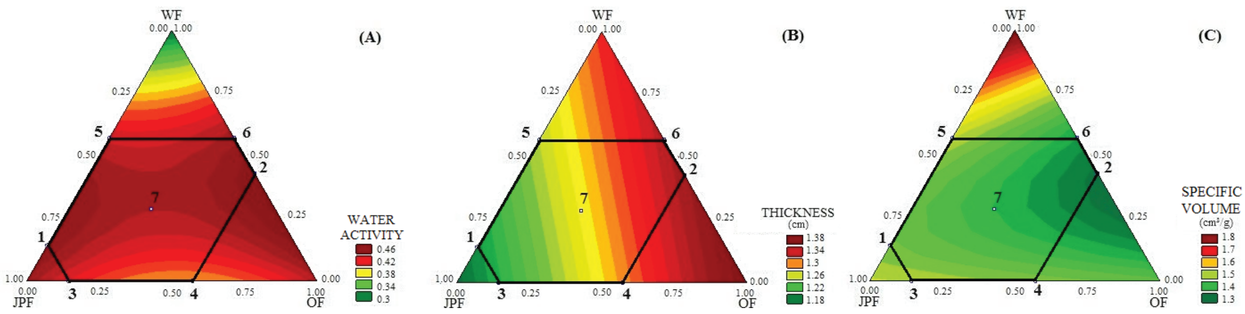

Figure 1: Water Activity (Aw) (A), thickness (B) and Specific Volume (SV) (C) of the cookies with JPF. Response surface generated by the experimental model (in terms of pseudocomponents). The area delimited between points 1 and 6 shows the region analyzed experimentally.

In Figure 2A, the highest values of WAI (close to 1 g gel.g^{-1}) were observed in JPF formulations ranging from 0.30 to 0.60 g (100 g)$^{-1}$ (Table 1), with OF between 0.15 and 0.35 g (100 g)$^{-1}$ and WF from 0.24 to 0.35 g (100 g)$^{-1}$. In contrast, lower values of WAI (0.5 to 1 g gel.g^{-1}) were found in formulations with JPF ranging from 0.30 to 0.45 g (100 g)$^{-1}$, with OF between 0.15 and 0.31 g (100 g)$^{-1}$ and WF from 0.39 to 0.40 g (100 g)$^{-1}$. The WAI is related to the availability of hydrophilic groups (-OH) to bind to water molecules and to the gel forming capacity of starch molecules. Cookies produced with higher percentages of JPF tend to absorb more water because they have high levels of dietary fiber (15.25%) (Ferreira et al., 2012). Perez and Germani (2007) justified that flour with a high fiber content tends to retain more water due to the hydrophilic characteristics of the fiber.

Camargo, Leonel and Mischan (2008), in a study with biscuits extruded from sour cassava starch with fiber, obtained WAI values of 4.8 to 11.9 g gel.g^{-1}. The WAI of the cookies with JPF in this study were 91.6% lower than the values found in the biscuits extruded from sour cassava starch because the gelatinized starch granules absorb water and swell at room temperature. However, increasing the degree of gelatinization also increases the starch fragmentation, thereby decreasing the water absorption (Borba; Sarmento; Leonel, 2005; Carvalho et al., 2002).

Analysis of Figure 2B verifies that the highest values of WSI (close to 80%) were found in formulations with JPF ranging from 0.41 to 0.60 g (100 g)$^{-1}$, with OF between 0.15 and 0.35 g (100 g)$^{-1}$ and WF from 0.20 to 0.40 g (100 g)$^{-1}$. The lowest WSI values (close to 30%) were in the formulations with JPF ranging from 0.30 to 0.37 g (100 g)$^{-1}$, with OF between 0.33 and 0.35 g (100 g)$^{-1}$ and WF from 0.29 to 0.35 g (100 g)$^{-1}$.

The WSI is related to the amount of soluble solids present in a dried sample and can be used to verify the intensity of the heat treatment, depending on the gelatinization, dextrinization and consequent solubilization of starch among the other components in the raw material, such as protein, fat and fiber (Moura et al., 2010). Camargo, Leonel and Mischan (2008) studied the production of extruded biscuits of cassava starch with fiber and obtained WSI values ranging from 23.17 to 29.23%. The lowest WSI values of the cookies with JPF corresponded to the highest WSI value of extruded biscuits composed of sour cassava starch with fiber. The water solubility of cookies in the present study can be explained by the presence of fiber in the JPF and OF (Leite-Legatti et al., 2012; Ada, 1999) and the presence of starch in the WF (Nascimento; Wang, 2013). The concentrations of the different flours in the cookies determine a higher or lower solubility in water. However, in this study, formulations with higher percentages of JPF and WF tended to be more water-soluble. This increased solubility is attributed to the dispersion of the amylose and amylopectin molecules as a result of gelatinization when conditions are milder and to the formation of low-molecular-weight compounds when conditions are harsher (Colonna et al., 1984).

From Figure 2C, the highest values of rupture force (close to 70000 N) were found in formulations with JPF ranging from 0.43 to 0.47 g (100 g)$^{-1}$ (Table 1), with OF from 0.35 to 0.47 g (100 g)$^{-1}$ and WF from 0.20 to 0.22 g (100 g)$^{-1}$. The lowest rupture force values (30000 N) were found in formulations with JPF ranging from 0.56 to 0.60 g (100 g)$^{-1}$, with OF between 0.15 and 0.16 g (100 g)$^{-1}$ and WF from 0.24 to 0.29 g (100 g)$^{-1}$.

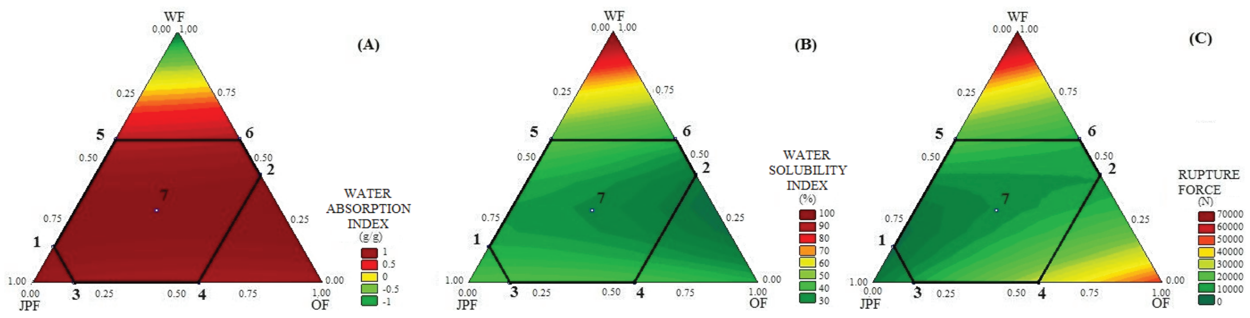

Figure 2: water absorption index (WAI) (A), water solubility index (WSI) (B) and rupture force (C) of the cookies with JPF. Response surface generated by the experimental model (in terms of pseudocomponents). The area delimited between points 1 and 6 shows the region analyzed experimentally.

Formulations with higher percentages of JPF had a significantly lower rupture force. In a study on the physical characteristics of biscuits with soy flour and oat bran, Mareti, Grossmann and Benassi (2010) found rupture force values of 3000 N. Differences in rupture force are related to the level of substitution of JPF by WF and OF and also to the other ingredients and their proportions. McWatter et al., (2003) studied the physical and sensory characteristics of biscuits containing a mixture of fonio (variant of millet) and cowpea flours and attributed the tougher texture in the cookies to the increased protein content and its interaction during the preparation of the dough and baking. The results of this study can be explained by the high fiber content of JPF (Legatti-Leite et al., 2012). Perez and Germani (2007) explained that flour with a high fiber content tended to retain more water due to its hydrophilic characteristics. This could have generated a more humid and consequently softer cookie. Figure 3 shows the color analysis performed on the JPF cookies of this experiment.

Similar to the L* value, a* and b* also decreased with increasing percentages of JPF in the formulations. This same tendency was also reported by Ajila et al. (2010). This can be explained by the fact that the jabuticaba peels have enzymes such as polyphenol oxidase (Daiuto et al., 2010) and are rich in polyphenols, (Leite-Legatti et al., 2012) which are a substrate for this enzyme (Ajila; Bhat; Rao, 2007). In this sense, these values decreased due to enzymatic browning.

Desirability test

From the experimental models of the instrumental parameters SV, rupture force, L* and WAI, the desirability test was carried out to define the final formulation of the cookie. The results of the desirability test indicated that the most desirable formulation for the cookie was a mixture of 0.45 g (100 g)$^{-1}$ JPF, 0.35 g (100 g)$^{-1}$ OF and 0.20 g (100 g)$^{-1}$ WF, which corresponds to experimental point 4 (Table 1).

Model validation

The models were validated by comparing the observed with the expected results of Aw, SV, WAI, WSI, rupture force, L*, a* and b* (Table 4) and taking into account only values with an R^2 above 0.83. Regarding texture, the predicted model corroborated the analytically determined values, i.e., a cookie containing jabuticaba peel flour with technological characteristics close to those predicted by the models was obtained, with percent variations of 8.74% for Aw, 3.33% for SV, 9.6% for WAI, 5.68% for WSI, 6.2% for rupture force, 3.9% for L*, 10.9% for a* and 6.9% for b*.

The equated values (Table 2) were calculated based on the equations derived from the statistical coefficients of the mixture design for the attributes listed in Table 4. The differences between the analyzed and calculated values are related to the experimental error and the determination coefficient equations.

Microbiological tests of the most desirable JPF and cookie samples for sensory analysis

According to the results, the jabuticaba peel flour, the standard cookie and the most desirable cookie with JPF presented microbiological characteristics suitable for consumption because their values were below the maximum level permitted by Brazilian law.

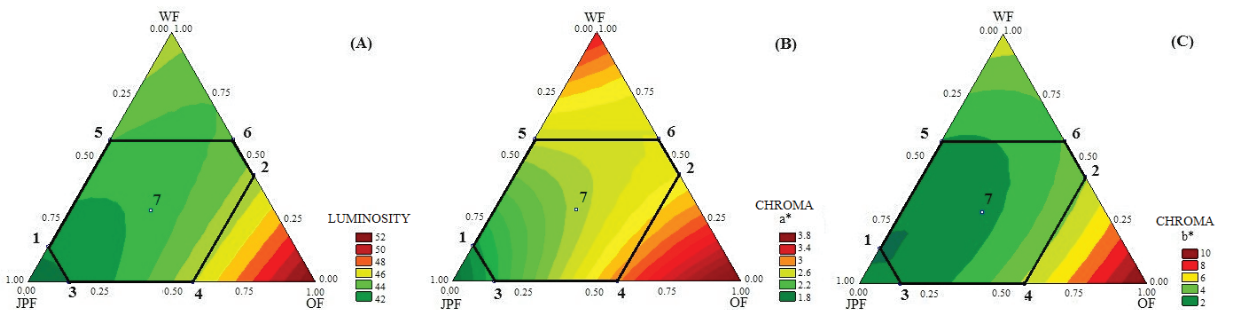

Figure 3: Luminosity (A), chroma a* (B) and chroma b* (C) of the cookies with jabuticaba peel. Response surface generated by experimental model (in terms of pseudocomponents). The area delimited between points 1 and 6 shows the region analyzed experimentally.

Table 4: Observed and expected results of Aw, thickness, SV, WAI, WSI, rupture force, L*, a* and b*, for the cookie formulation with JPF according to the predicted models.

Parameter	Observed	R^2	Expected
Aw	0.389	0.8894	0.355
SV	1.470	0.9086	1.421
WAI	0.875	0.979	0.791
WSI	38.769	0.8363	36.567
Rupture Force	29810.2	0.9205	27981.9
L*	44.805	0.9607	43.049
a*	2.964	0.9453	2.641
b*	4.064	0.9514	3.784

Sensory analysis of cookies

In the sensory analysis, results were obtained regarding the acceptance of the product in the categories of appearance, texture, flavor and odor. For the standard cookie, the scores obtained for the parameters of appearance, texture, flavor and odor were 3.88, 3.99, 4.14 and 3.52, respectively. In the cookie containing JPF, the scores obtained for the same parameters were 3.62, 3.52, 3.06 and 3.46, respectively. For all parameters, the scores for the standard cookie were higher than those obtained for the cookie with JPF. Adding a larger amount of vanilla essence to the formulation is suggested to improve the sensory scores because it interferes with the flavor and odor, which were the lowest scores of the cookie prepared with JPF. However, according to the pre-defined methodology, the product would be considered accepted if it obtained scores greater than or equal to 3 (indifferent). In this sense, both cookies were accepted by the children.

The sensory analysis in the present study with cookies containing JPF corroborates that conducted by Ferreira et al., (2012), replacing 10% of WF with JPF. These authors obtained a cookie with good physical properties, and, based on their acceptance test, they obtained scores of 3.68, 2.95 and 4.21 for appearance, flavor and texture, respectively. In this study, the appearance and texture were also the main features positively influencing the acceptance of cookies. The flavor score determined in this study was 3.5% higher than that in the cited work. These data can be considered excellent because the cookies of the present study were prepared with 45% substitution of WF and OF by JPF, whereas the former had only 10% substitution of WF by JPF. Given this difference and the presence of dietary fiber and bioactive compounds in JPF (Legatti-Leite et al., 2012), the importance of eating these biscuits in school meals should be emphasized because of the health benefits and consequent significant improvements in teaching and learning (Lucero et al., 2010). The major nutritional contributions of the cookies with jabuticaba peels are related to their fiber content, which was 127% higher than the standard cookie, and their calorific value, which was 11% lower than the standard cookie (unpublished data).

Furthermore, further use of flours elaborated from agro-industrial co-products should continue to be investigated to develop food formulations in general because they contribute to the use of regional products, enhance the development of alternative foods and value the preservation and sustainable development in the native areas of Cerrado and the Atlantic Forest.

CONCLUSIONS

The results presented in this study indicate that JPF is a raw material with good technological qualities, thus being an alternative for use in cookies without a loss of physical and sensory qualities of the product. Moreover, this is a new possibility to produce cookies based on an agro-industrial co-products, which is interesting from a commercial standpoint due to aspects related to the sustainability of the jabuticaba processing industry and the market for this type of product.

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