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Low cost cassava, peach palm and soy by-products for the nutritional enrichment of cookies: physical, chemical and sensorial characteristics

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Abstract

By-products generated by agro-industries are important alternatives to low cost sources for food enrichment and nutritional components in the human diet, mainly because of their high levels of fiber and protein. The aim of this study was to develop cookies enriched with by-products applying multicomponent mixture experiments (MME) to perform partial replacement of wheat flour by cassava, peach palm and soy bean flour. The maximum level (component proportion = 1) of each variable was 20% (related to total formulation) of the corresponding wheat flour. Flour characteristics, cookie properties and parameters were evaluated. PF had the highest fiber content (32.60 g kg^{-1}), CF got the highest carbohydrate content (78.44 g kg^{-1}) and SF had the highest protein (29.03 g kg^{-1}) and fat (16.14 g kg^{-1}) contents. We have thus established that it is possible to obtain cookies enriched with low cost by-products that have high fiber content and provide sensorial acceptability. A formulation of MME (33.40%CF+33.40%SF+33.40%PF) was the most appropriate one when simultaneous responses to crude fiber and protein contents, besides the hedonic score, were evaluated. The fiber content increased from 1.87 g kg^{-1} (control) to 5.95 g kg^{-1} in enriched cookies. Flours used for enriching cookie production had potential to be utilized as a functional ingredient for food products.

Introduction

Consumers are getting aware of the need to intake food products to improve their health. These products provide them a modern way to follow a healthy lifestyle which differs from the conventional diet. The food industry is facing the challenges to develop a wider variety of nutritionally enriched food products and to release them on the market (Hasler, 1998; Kim *et al.*, 2013; Baiano *et al.*, 2015; Aida *et al.*, 2016; Kumoro *et al.*, 2016; Shah *et al.*, 2016).

Continued development of sustainable and renewable resource technologies is of great importance with respect to environmental concerns (Singh *et al.*, 2012; Villanueva Bermejo *et al.*, 2015), since the significant progress in agribusiness resulted in increased consumption of inputs and consequent increase in the generation of by-products in agro-industrial activities. The use of agro-industrial by-products involves the use of the materials that were previously generated, since the total volume thereof is large (Nonhebel, 2007) and when they are not used, it leads to a raise in the costs of disposal to prevent environmental pollution (Federici *et al.*, 2009; Yang *et al.*, 2016).

The use of food by-products is interesting because most of them are functional component sources; hence, their importance from nutritional and technological points of view (Hernández-Carranza *et al.*, 2015; Kandasamy *et al.*, 2016). The addition of high fiber by-products, as new ingredients, to foods can change the consistency, texture, rheological behaviour and sensorial characteristics of the end products (Dhingra *et al.*, 2012). There is evidence of the role of fiber in the prevention of obesity and various metabolic syndromes. Studies demonstrated the association of obesity or weight gain with high energy consumption and low intake of fruits and vegetables (Davidson and McDonald, 1998).

Cassava (*Manihot esculenta* Crantz) is one of the most important food crops in the tropics. In Brazil, flour and starch are the main industrial products

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obtained from cassava, creating large amounts of solid waste which are destined for feed or deposited in the environment. The bagasse is composed of fibrous matter from the root and part of the starch that could not be extracted during processing (Sriroth *et al*., 2000; Fiorda *et al*., 2013; Fayemi and Ojokoh, 2014; Iwe and Agiriga, 2014). Soy bean (*Glycine max.* Merril) products with high content of protein, isoflavones, omega-3-fatty acid and fiber are potential functional food ingredients. During the production of soy bean hydro soluble extract, a highly important by-product is generated: it contains high levels of proteins and fibers, besides minerals and isoflavones (Redondo-Cuenca *et al.*, 2008). This processed by-product is a potential source of low cost vegetable protein for human consumption (Ma *et al*., 1996; Friedman and Brandon, 2001). On the other hand, peach palm (*Bactris gasipaes* Kunth) has been used for canning products. However, due to the lack of uniformity of the stem structure, high volume of discards can be produced. These by-products are generally discarded or used for animal feed due to their reduced market value derived from undesirable physical integrity (Bolanho, Danesi and Beléia, 2014). Therefore, attempts must be made to explore the value-added application of these by-products and a proposal is the production of flours to be added to bakery products, such as cookies.

Cookies are popular bakery products made of wheat flour whose formulations generally have high calories and low fiber content. With consumers' increasing interest in living a healthy life, many researchers have studied health-promoting cookies by using components with functional properties to replace wheat flour (Chauhan *et al*., 2015; Duta and Culetu, 2015; Park *et al*., 2015).

Furthermore, many studies have investigated the development of cookies with expensive ingredients as substitutes for wheat flour (Chauhan *et al.,* 2015; Duta and Culetu, 2015; Park *et al*., 2015), but the use of by-products, such as cassava, soy bean and peach palm ones, are more interesting because of their low costs and environmental concerns. The aim of this study was to determine the chemical composition, physical properties and sensorial characteristics of enriched cookies produced with blends of cassava (CF), soy bean (SF) and peach palm (PF) by-products in flour form using multicomponent mixture experiments.

Materials and Methods

The process used for obtaining flours from the by-products, as well as the preparation of the cookies, was performed according to Figure 1.

Preparation of samples

The by-products were processed as described by Bolanho, Danesi and Beléia (2014). The peach palm flours were produced from median sheaths and parts of the unused stem, harvested in heart-of-palm farm in Mariluz (Paraná, Brazil) The cassava bagasse and soy bean were harvested in starch and soy industries of Umuarama (Paraná, Brazil). All by-products were dried at 90ºC (MA 035, Marconi, Piracicaba, Brazil) and grounded by a knife mill type Willye Model SL-031, SOLAB (Piracicaba, Brazil). The particle size of the all flours was standardized in 100 mesh and submitted to the analyses (Leoro *et al*., 2010).

The cookies were processed as described by Bolanho *et al*. (2014). The cookies were processed in pilot scale with ingredients from the local commerce, following the basic formulation: 100 g wheat flour, 35 g margarine, 1 egg, 80 g chocolate chips, 45 g brown sugar, 4 mL vanilla extract, 5 g baking powder and enough milk. Components of the formulations were weighed and mixed until complete homogenization. All nine formulations were homogenized, manually modelled in 20 g portions, baked in a pre-heated oven at 180ºC for 20 min and stored in adequate conditions.

Experimental design

The simplex-centroid design for mixtures of three components with two centroid point replications (Table 1) was used for studying the effects of interactions among ingredients on the sensorial quality, protein, fiber content and hardness (instrumentally measured) of cookies. The variables under study were the concentration of CF, PF and SF as partial replacement of wheat flour. The maximum level (component proportion = 1) of each variable was 20% (related to total formulation) of the corresponding wheat flour. Control cookies were prepared without the addition of by-product flour to be used for comparison.

The Scheffé canonic equation (Equation 1) was used for modeling the experimental data:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3 \quad (1)$$

Where: Y is the studied response, β_1 , β_2 , β_3 , β_{12} , β_{13} , β_{23} and β_{123} are the regression parameters and X_1, X_2 and X_3 are the levels of flours in the blends.

Positive values for binary coefficients, β_{ij}, indicate synergistic effects while negative values represent antagonism. Triangular contour plots were generated from the polynomial equations for each property by

Table 1. Experimental design, protein (g kg^{-1}), fiber content (g kg^{-1}), hardness (N), hedonic score (HS) and purchase intent scale (PIS) of fiber-enriched cookies with cassava flour (CF), soy bean flour (SF) and peach palm flour (PF)

	Component proportion[a]			Protein	Fiber	Hardness	HS	PIS
	CF	SF	PF					
1	1	0	0	8.68±0.4	5.33±0.9	24.86±3.9	7.34	4.06
2	0	1	0	10.35±1.0	5.98±1.2	33.14±7.9	7.17	3.76
3	0	0	1	8.85±0.0	7.71±1.1	49.86±7.3	6.62	3.30
4	0.5	0.5	0	9.63±0.3	6.33±0.7	26.32±4.6	6.90	2.93
5	0.5	0	0.5	7.32±0.1	7.65±1.2	41.96±5.2	7.32	3.96
6	0	0.5	0.5	9.63±0.1	7.00±1.5	34.19±6.7	6.58	3.36
7	0.33	0.33	0.33	9.80±0.7	5.87±0.9	37.73±12.4	6.98	3.33
8	0.33	0.33	0.33	9.85±0.1	5.96±0.8	43.54±9.1	6.94	3.63
9	0.33	0.33	0.33	9.35±0.1	6.02±1.3	47.06±11.3	6.94	3.56

[a] Coded values CF + SF + PF = 1. Results are expressed as mean ± standard deviation.

the software Statistica. For the optimization of the cookie formulations, we applied the technique of the desirability function (high content) (Derringer and Suich, 1980) and simultaneous responses of independent variables crude fiber and protein contents and hedonic score.

Analyses of the response variables

The chemical composition of by-product flours and cookies (moisture, ash, protein, crude fiber and fat) were determined by standard procedures and carbohydrates were calculated by difference (Merril and Watt, 1973; Horwitz, 1997).

A MiniScan XE-Plus spectrophotometer was used for measuring the L^*, a^*, and b^* values of the top surface of 10 cookies (n=10). Lower L^* values indicate a darker color on the surface. The degree of redness or greenness is based on parameter a^*, i. e., positive values denote redness whereas negative values indicate greenness. The b^* values indicate yellowness or blueness; positive values represent yellow while negative values represent blue. Standard white and black tiles were used for calibrating the color measurement instrument (Khouryieh and Aramouni, 2012).

Hardness was investigated by textural measurement, as described by Mildner-Szkudlarz *et al.* (2013), with a Brookfield-CT3 Texture Analyzer. The parameters used for determining the cut force were: pre-test speed, 2 mm s^{-1}; test speed, 5 mm s^{-1}. The trigger force limit was 0.07 Newton (N) and distance of 8.0 mm. Ten determinations were performed for each formulation in samples selected at random and the results were expressed in N.

The water activity analysis was determined according to Khouryieh and Aramouri (2012) by Aquala-Decagon. Cookies were crushed into small pieces and a representative sample was placed into plastic cups and measured, one at a time. All the analyses mentioned were performed in triplicate.

An untrained test panel in an adequate number (n = 30) was recruited in the university; participants had to be between 19-60 years of age and willing to participate. On the evaluation form, the panelists were instructed to evaluate the appearance, aroma, taste, texture, overall acceptability and purchase intent scale, as well as their overall impression of a freshly prepared cookie of each formulation served monadically in odorless plastic plates to prevent any bias. A 9-point categorical hedonic scale was anchored by "dislike extremely" and "like extremely" whereas a 5-point scale was anchored by "I certainly would not buy it" and "I certainly would buy it" (Meilgaard *et al*., 1991). The project was approved by the Permanent Committee for Ethics in Research Involving Human Beings, at the Maringá State University (CAAE no. 0398.0.093.000-10, Report nº 621/2010).

Cookie formulations were submitted to microbiological analyses in relation to coliforms at 45ºC, Positive Staphylococcus coagulase (Lancette and Bennett, 2001), Salmonella (Andrews *et al.*, 2001) and Bacillus cereus (Bennett and Belay, 2001).

Statistical analyses

Analysis of variance and the means test (Tukey's

Table 2. Approximate composition and physical characteristics of control cookies and cookies enriched with cassava flour (CF), soy bean flour (SF) and peach palm flour (PF)

Characteristics	Control cookie	Enriched cookie
Moisture (g kg^{-1})	5.67±0.1^b	7.88±0.2^a
Protein (g kg^{-1})	9.26±0.2^a	9.66±0.2^a
Fat (g kg^{-1})	24.57±0.4^a	24.68±0.2^a
Ash (g kg^{-1})	1.92±0.1^a	1.87±0.1^b
Carbohydrate (g kg^{-1})	58.2	55.26±0.3
Crude fiber (g kg^{-1})	1.87±0.8^b	5.95±0.1^a
Energy [kcal]	491.02	481.84
Hardness (N)	25.44^b±7.6	40.58^a±6.8
Aw	0.678^a±0.0	0.672^a±0.6
L*	55.72^a±2.1	55.16^a±1.2
a*	10.78^a±0.4	11.43^a±1.0
b*	31.50^a±1.4	31.14^a±1.0

Averages followed by the same letter in the line are not different by t-test ($p<0.05$). Results are expressed as mean ± standard deviation.

test and t-test) were performed by the statistical software Statistica for Windows 7.1. Level of significance was set at $p<0.05$ for the null hypothesis.

Results and Discussion

The approximate composition of CF, PF and SF showed different profiles with significant differences ($p<0.05$) among moisture (5.48, 9.73 and 4.42 g kg^{-1}), protein (1.16, 3.97 and 29.03 g kg^{-1}), fat (7.42, 3.83 and 16.14 g kg^{-1}), crude fiber (6.20, 32.60 and 14.88 g kg^{-1}), ash (1.20, 3.80 and 0.55 g kg^{-1}) and carbohydrate contents (78.44, 40.47 and 34.98 g kg^{-1}), besides energy value (384.42, 234.63 and 401.30 g kg^{-1}). PF had the highest fiber content (32.60 g kg^{-1}), CF got the highest carbohydrate content (78.44 g kg^{-1}) while SF had the highest protein (29.03 g kg^{-1}) and fat (16.14 g kg^{-1}) contents (data are shown in the appendix).

The experimental design resulted in nine formulations of the enriched cookies under analysis (Table 1). Data on the evaluation of various experiments carried out with the three components (CF, PF and SF) enabled the mathematical modelling and the analysis of each component addition regarding the desirable characteristics (response variables) of the enriched cookies. Based on these models, deeper knowledge of the influence of each factor on the responses could be achieved. All models, Eq. 2, Eq. 3, Eq. 4 and Eq. 5 were significant ($p<0.05$). The adjusted coefficients of determination R^2adj varied between 50 and 97% and aimed to consider the equations appropriate for prediction purposes. Most models were essentially linear equations. Thus, no binary combination was significant, except for the hedonic score (Eq. 6).

$$Protein = 8.47\,CF + 10.73\,SF + 8.61\,PF \tag{2}$$

$$Crude\ fiber = 5.62CF + 5.87SF + 7.79PF \tag{3}$$

$$Hardness = 28.7\,CF + 32.3\,SF + 51.9\,PF \tag{4}$$

$$Hedonic\ score = 7.3CF + 7.2SF + 6.6PF - 1.3CF.SF + 1.5CF.PF - 1.1SF.PF \tag{5}$$

$$Purchase\ intent\ score = 4.2\,CF + 3.7\,SF + 3.4\,PF - 3.4\,CF.SF \tag{6}$$

All results of CF, PF and SF found by this study were higher than values of wheat flour, except carbohydrates. Protein content of SF was threefold the one of wheat flour (Zucco *et al.*, 2011). In by-product flour, low protein content is commonly found, as in cassava flour (1.16 g kg^{-1}). Consequently, in the enriched cookies, soy bean flour is also responsible for the highest protein content (Figure 2A). It may be observed in the high coefficient of PF found by the regression model (Eq. 2, R^2_{adj} 50.64%, p= 0.05). Soy products are excellent sources of protein in food and feed (Friedman and Brandon, 2001) and are associated with significant decreases in serum cholesterol and LDL cholesterol concentrations (Anderson *et al.*, 1995). Crude fiber content was 32.60, 14.88 and 6.30 g kg^{-1} in PF, SF and CF, respectively. All by-product flours evaluated by this study had higher crude fiber content than wheat flour and mango by-product flour (Zucco *et al.*, 2011; Abdul Aziz *et al.*, 2012). The

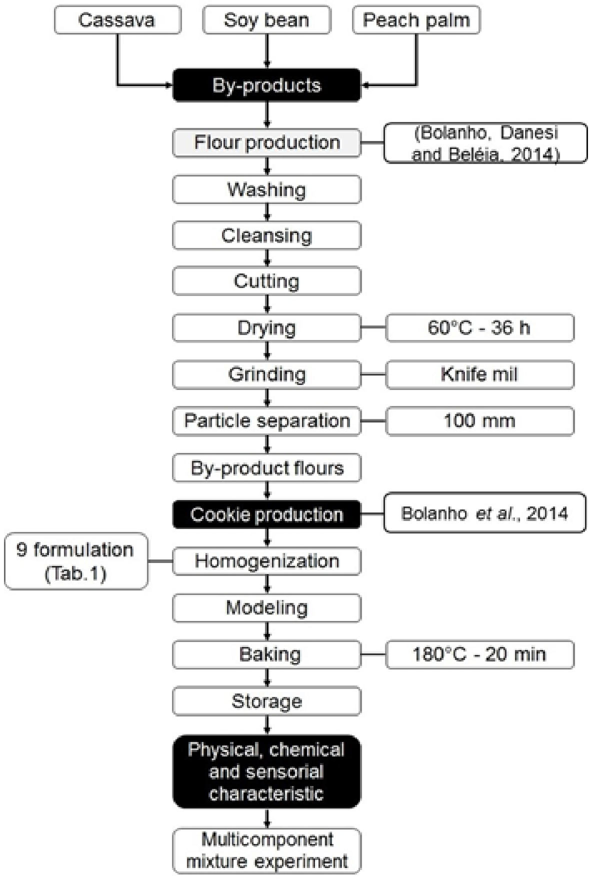

Figure 1. Schematic diagram of the process used for obtaining flour from by-products and cookie preparation

crude fiber content of the enriched cookies ranged from 6 to 7.6 g kg^{-1}, which was consistent with the crude fiber content found in the flours (Figure 2B). Equation 3 (R^2adj 50.76%, p=0.05) revealed that PF was the most important variable (highest coefficient) regarding crude fiber in enriched cookies. It corroborates the fact that PF is the by-product flour that contains more crude fiber by comparison with CF and SF.

The crude fiber analysis is based on acid and alkaline hydrolysis and it does not estimate water soluble compounds. Therefore, values found by this methodology were generally lower than the ones obtained by dietary fiber tests which promote an enzymatic hydrolysis of non-fiber compounds (Bolanho *et al.*, 2014). Furthermore, the US Food and Drug Administration allows foods to be labelled as 'a good source of fiber' or 'high fiber' if they contain more than 2.5 g or 5.0 g dietary fiber per serving, respectively (Jin *et al.,* 1994). Although the dietary fiber content of the samples was not determined, values obtained by the crude fiber analysis showed that the consumption of 100 g cookies of all formulations evaluated by this study would be considered a good source of fiber. Some physiologic effects exerted by fiber ingestion are laxation, increase in faecal bulk and decrease in cholesterol and blood glucose (Davidson and McDonald, 1998). It is important since fiber intake has been decreasing and causing considerable eating disorders. Consequently, the development of products with high fiber content can minimize such problems and encourage a healthy lifestyle (Tharanathan and Mahadevamma, 2003).

Therefore, alternative sources of fiber bring great advantages to the food industry because they contribute to the enrichment of products and prevent waste by enabling full use of raw materials (Elleuch *et al.*, 2011; Dhingra *et al.*, 2012; Khouryieh and Aramouni, 2012; Kim *et al*., 2013).

The incorporation of by-product flours into cookies reduced moisture loss of baked cookies. It could be readily correlated to the enhanced water retention derived from high fiber content, due to the chemical structure of the added fiber and dependence on the particle size and porosity of the material of the flour (Kim *et al.,* 2013; Mildner-Szkudlarz *et al.*, 2013). Thus, moisture loss can contribute to increase cookie hardness.

Textural property is one important parameter to evaluate the quality of cookies. Their hardness was significantly affected when by-product flours were incorporated. PF was the most important ingredient which increased fiber content and hardness (Eq. 4, R^2adj 51%, p=0.04) (3C) of enriched cookies. Its addition caused the lowest values of hedonic score (Eq. 5, Figure 2D) and purchase intent (Eq. 6, Figure 2E). On the other hand, CF had the lowest effect (low coefficient) on fiber content and hardness of cookies. These data supplemented results found by Kohajdová *et al.* (2011) when they produced cookies with 5, 10 and 15% of orange and lemon fiber and verified that general acceptance was inversely proportional to the amount of fiber added to the dough. Cookie hardness partially results from the development of a gluten network with water molecules to form its structure. Increase in fiber content in the cookie dough modifies these characteristics (Taylor *et al*., 2008).

CF contributed to enhance the hedonic score in the sensorial analysis. Negative coefficients corresponding to the interactions between CF and SF and between SF and PF indicated antagonistic effects while there was positive coefficient corresponding to the interaction between CF and PF (Eq. 5, R^2_{adj} 97.98%, p=0.00). It shows that both interactions between CF and SF and between SF and PF decreased the hedonic score whereas the interaction between CF and PF increased the hedonic score. As shown in Figure 2C and Figure 2D, the hedonic score (Eq. 6, R^2adj 66.10%, p=0.01) and purchase intent scale were more positively affected by CF. Therefore,

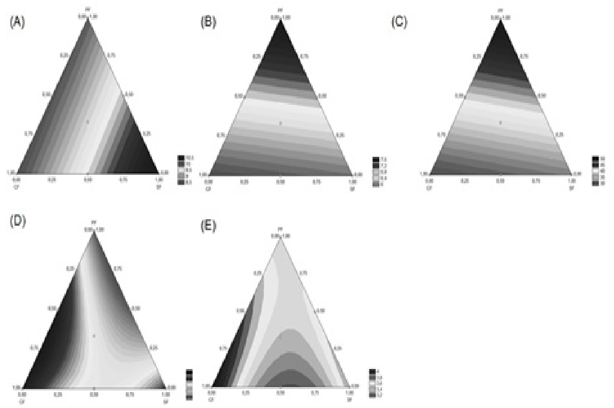

Figure 2. Contour plot for (A) protein and (B) crude fiber content [g kg^{-1}], (C) hardness [N], (D) hedonic score and (E) purchase intent of enriched cookies produced with blends of cassava flour (CF), soy bean flour (SF) and peach palm flour (PF).

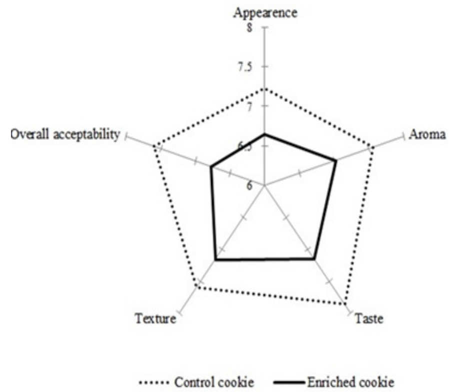

Figure 3. Diagram of average sensory ratings for control and enriched cookies

CF seems to improve sensorial acceptability and purchase intent of enriched cookies.

MME technique was successfully applied to evaluate the effect of different factors on the most important quality parameters of enriched cookies. By using this technique, we found a formulation with equal parts of by-product flour (33.40% CF + 33.40% SF + 33.40% PF). It was found appropriate when simultaneous responses (crude fiber and protein contents and hedonic score) were combined for optimization. To verify changes caused to the by-product cookies, this formulation was compared to the one of the control cookies.

Comparative results of control and enriched cookies are shown in Table 2 and Figure 3. In this study, we found significant differences ($p<0.05$) between moisture and fiber contents of control and enriched cookies. As mentioned before, both attributes can contribute to the significant difference ($p<0.05$) in texture between control and enriched cookies.

Mechanical properties of cookies are important quality attributes as they have direct impact on sensorial perception and, thereby, important implications for consumers' acceptance of such products (Booth *et al.*, 2003). In this study, hardness of enriched cookies was higher than the one of control cookies. This factor can be a major contributor to reduce the sensorial acceptability of enriched cookies by comparison with control cookies. Kim *et al.* (2013) observed that the addition of 15% pre-harvest dropped apples to cookies strengthened the structure of the cookie dough and increased the resistance to deformation by comparison with the addition of 5% pre-harvest dropped apples. Mildner-Szkudlarz *et al.* (2013) studied cookies to which 10, 20 and 30% of linseed flour had been added; they found evidence of the fact that color and texture directly influenced sensorial analysis. Besides, the addition of 20% of linseed flour showed an overall feeling in the sensorial analysis.

The color of cookies plays a major role in the consumer's perception and acceptability of the product. There was no significant difference between L^*, a^* and b^* values for control and enriched cookies. L^* values are indicators of the lightness of the samples. Maillard browning reactions are responsible for producing darker cookies (Taylor *et al.*, 2008). Values of a^* and b^* found by this study were similar to those found by Davidov-Pardo *et al.* (2012) for cookies containing grape seed. However, in this study, we found lower L^* value than the one observed by those authors, a fact that shows coolie browning.

Sensorial aspects and consumer acceptance have to be considered during the development of new products. In the sensorial analysis (Figure 3), differences between control and enriched cookies regarding appearance, aroma, overall acceptability, taste and texture attributes were perceived.

Enriched cookies had lower values than control cookies, which were evaluated in all attributes by the hedonic scale in this study. The value, which was between 6 and 7, corresponds to "I liked it slightly - I liked it moderately". Thus, cookies are a good source of fiber enrichment to human food because they mask whole products that are normally slightly rejected by most consumers (Lemes *et al.*, 2012).

Despite getting lower values in the sensorial acceptance, low cost by-products enriched with high fiber content are an alternative to make this type of product popular and available as a healthy product.

However, the addition of by-products may generate flavor issues, i.e., some problems may be large enough to require added flavor-masking alternatives in the formulation. It may lead to the development of a blend of specific masking materials that, if used in precise combination, helps minimize that problem (Lucera *et al*., 2012).

Microbiological analyses demonstrated that control and enriched cookies were made in appropriate conditions, in accordance with parameters, which are considered safe for consumption, issued by the current Brazilian legislation (Anvisa, 2001). Both control and enriched cookies had the lowest level of Positive Staphylococcus coagulase (<10 CFU/g) and Coliforms at 45ºC (0.4 x 10^1 MPN/g). Furthermore, cookies evaluated by this study had no Salmonella (in 25 g sample). Water activity (Table 2) found by this study (0.600) reduces the possibility of microbial reproduction and corroborates microbiological results. This parameter, associated with high baking temperature, high percentage of sugar and the packaging system that protects the product from moisture, light and oxygen, acts as a barrier to provide stability to the cookies during storage (Zoulias *et al*., 2000). Similar results were reported for cookies with *S. platensis* by studies carried out by our research group (Bolanho *et al*., 2014). Krüger *et al*. (2003) conducted the same microbiological control in cookies and found no microbiological contamination, a fact that emphasizes that the temperature used for baking is sufficient to inactivate microorganisms.

Enriched cookies had less energy than control cookies, thus, enhancing their potential in food technology (Table 2). Consumers have currently been more interested in low-calorie products due to increasing emphasis on health issues.

Innovation in food products and investigation of alternative raw materials to reduce production cost are important to cookie manufacturers (Baltsavias *et al*., 1999). By-products used by this study are generated in large quantities by the food industry and the resulting by-product flour represents technological and nutritional potential. Therefore, availability of sources of fiber and protein at a competitive cost for incorporation into food products enables to take advantage of such materials. Thus, soy bean and peach palm by-products can be a good partial replacement for wheat flour. Furthermore, complete replacement of wheat flour by by-products could aim at the development of gluten-free cookies for the gluten intolerant and represent a good alternative since the celiac disease is a chronic inflammatory disorder in genetically susceptible subjects, characterized by damage on the small intestinal mucosa caused by gluten (Catassi and Fasano, 2008; Pelegrini and Agostoni, 2015).

Conclusion

The multicomponent mixture experiments allowed the choice of an enriched cookie formulation based on results obtained from the variables under study. Partial substitution (20%) of wheat flour by cassava, soy bean and peach palm flours (33.40% CF + 33.40% SF + 33.40% PF) increased protein and fiber contents in the enriched cookies (5.95 and 1.87 g kg^{-1}), by comparison with control cookies. This formulation has a lower score in the sensorial evaluation, but it is considered acceptable by consumers.

The increase in fiber content in the formulations under testing increased the hardness required to rupture the enriched cookies and decreased the sensorial acceptability. Therefore, the development of cookies with cassava, peach palm and soy bean by-products in flour forms can offer broad opportunities to the food industry to produce a wide variety of fibre and protein enhanced products. In bakery products, the application of these by-products that are generally discarded or used in animal feed encourages the full use of raw materials of vegetable origin.

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