Nutrition & Food Science

Preference mappings for gluten-free chocolate cookies: Sensory and physical characteristics

Tatiane Ferreira da Silva, Ana Carolina Conti-Silva,

Received 4 November 2015
Revised 28 January 2016
31 January 2016
Accepted 1 February 2016

Preference mappings for gluten-free chocolate cookies

Sensory and physical characteristics

Tatiane Ferreira da Silva and Ana Carolina Conti-Silva
Department of Food Engineering and Technology,
Sao Paulo State University, São José do Rio Preto, Brazil

Abstract

Purpose – The purpose of this paper was to replace totally the wheat flour for rice flour, whole soy flour and cassava starch in the formulation of chocolate cookies.

Design/methodology/approach – Chocolate cookies with wheat flour, rice flour, whole soy flour and cassava starch were produced, and compared to a commercial chocolate cookie regarding to physical properties and sensory acceptability.

Findings – The chocolate cookie made with rice flour instead of wheat flour was as liked as the cookie with wheat flour, and the greater acceptability scores received by the rice flour cookies correlated with less colour intensity and a lower specific volume thereof. The cookie with cassava starch stood out because of the intensities of its parameters, its more intense colour, and its acceptability scores among the consumers. The cookie with whole soy flour had lower sensory acceptability scores, and the commercial cookie stood out for its high cutting force (instrumental texture).

Originality/value – Celiac consumers desire products with adequate sensory characteristics. This study presents a new gluten-free product, the chocolate cookie made with rice flour, that has the potential to be produced, as this product is as accepted as a cookie made with wheat flour, and even more accepted than a commercial one also made with wheat flour. Therefore, this study offers subsidies for improving the diet of celiac consumers.

Keywords Rice flour, Cassava starch, Sensory acceptability, Texture, Whole soy flour

Paper type Research paper

1. Introduction

Celiac disease is a gluten-sensitive enteropathy characterized by its effects on the mucosa of the small intestine, which results in malabsorption of nutrients. The disease is activated in genetically susceptible individuals by the ingestion of gluten, a protein rich in prolamine, that is found in wheat (gliadin), rye (secalin), barley (hordein) and, occasionally, oats (avenin) (Trefts and Kagnoff, 1981; Kagnoff, 2007). Thus, the clinical spectrum of celiac disease is extensive and includes chronic diarrhoea, weight loss, malnutrition, anaemia, osteoporosis and neurological disorders (Kagnoff, 2007; Sapone *et al.*, 2012). The only scientifically proven treatment for celiac patients is a lifelong adherence to a diet free of gluten. Patients usually improve when they follow a strict dietary treatment, and early diagnosis is important because disturbances and

The authors are grateful for financial support from FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) (grant number 2012/16379-6).

Nutrition & Food Science
Vol. 46 No. 3, 2016
pp. 374-387

0034-6659
DOI 10.1108/NFS-11-2015-0139

complications can be prevented through adherence to dietary therapy (Capriles *et al.*, 2009; Capriles and Arêas, 2013).

Products made from corn, potato, rice, soy, tapioca, arrowroot, amaranth and quinoa can be used as wheat flour substitutes in food products, provided they have not been contaminated with gluten-containing flour during grinding. According to Lamacchia *et al.* (2014), the replacement of the unique technological properties of wheat gluten is the food industry's main task when providing high-quality food without gluten, such as pasta, bread and bakery products, in general. Difficulties arise in terms of structure, loss of starch during cooking and ideal cooking time. The formulation of gluten-free bakery products presents a formidable challenge for cereal technologists: wheat gluten contributes to the formation of a strong protein network, which confers the viscoelastic mass and allows for its use in a wide range of products.

Celiac consumers desire gluten-free products, with accessible price and with better sensory characteristics (Nascimento *et al.*, 2014). Among the products to be evaluated with potential replacements for wheat flour are baked goods, such as cookies. Baked goods represent a popular category of bakery products, and they can provide certain nutritional benefits. From a marketing standpoint, they are popular among people of all age groups and are consumed by nearly all levels of society. This popularity is largely due mainly because of their ready-to-eat packaging, good nutritional quality, availability in different varieties and affordable prices (Laguna *et al.*, 2011; Ishwarya and Prabhasankar, 2013).

The development of gluten-free baked goods remains a technological challenge, largely because of the sensory changes that result from the absence of gluten. Therefore, this study tested the use of rice flour, whole soy flour and cassava starch in total substitution of wheat flour in chocolate cookies, and then investigated their effects on the sensory and physical characteristics of cookies through preference mappings.

2. Materials and methods

2.1 Materials

Rice flour (Urbano), whole soy flour (Jasmine) and cassava starch (Yoki) were used as substitutes for wheat flour for the production of chocolate cookies. The other ingredients used were: wheat flour (Nonita), refined sugar (União), unsalted butter (Aviação), egg (Iwamoto), cocoa powder (Nestlé), vanilla extract (Dr Oetker), baking powder (Royal), salt (Cisne) and baking soda (Kitano). All the ingredients were purchased from a local market.

A chocolate-flavoured commercial cookie was also purchased from the local market to be compared to the cookies made for the study. The list of ingredients of this cookie included organic wheat flour enriched with iron and folic acid, organic sugar, organic palm oil, organic cocoa, invert sugar, salt, chemical leavening (ammonium bicarbonate and sodium bicarbonate) and natural vanilla aroma.

2.2 Analysis of the chemical composition of gluten-free flours

The rice flour, whole soy flour and cassava starch used were characterized regarding to chemical composition, as following: moisture content based on evaporation at 105°C, protein content using the micro-Kjeldahl method, lipid content using the extraction method by Soxhlet with petroleum ether and ash by incineration in a muffle furnace at 550°C (AOAC, 1990) and fibre content using the enzymatic–gravimetric method described by Prosky *et al.* (1988), using total dietary fibre assay kit (No. TDF100A-1KT, Sigma-Aldrich, USA). The available carbohydrates were calculated as the difference between 100 and the sum of moisture, protein, lipid, ash and total dietary fibre content. All analyses were performed in triplicate with the exception of the fibre analysis, which was performed in duplicate.

2.3 Chocolate cookie production

The standard formulation with wheat flour was produced using the following ingredients: wheat flour (450 g), refined sugar (270 g), unsalted butter (150 g), eggs (150 g), cocoa powder (135 g), vanilla extract (15 mL), baking powder (15 g), salt (8.1 g) and sodium bicarbonate (4.5 g). The butter, sugar and vanilla extract were mixed in a planetary mixer for 2 min. The eggs were added and the dough was mixed for 2 min. The wheat flour, cocoa powder, baking powder, salt and baking soda were added, and the dough was mixed for another 2 min. The dough was rolled out using an electric dough roller (Vithory, model V. 300, Brazil), until it was 5- to 7-mm thick. It was then cut into cylindrical units using an appropriate mould, which was approximately 3.3 cm in diameter. The moulded cookies were placed in pans lined with parchment paper and placed in a Pasiani oven (Classic Model Turbo 240, Brazil) without preheating at 150°C for 8 min. The cookies were cooled at room temperature for approximately 40 min with no air current, and 30 cookies were vacuum packed (Vacuum Sealer 200B, Selovac, Brazil) in each polyethylene plastic bag (35-cm long, 25-cm wide and 0.16-cm thick) and stored in plastic boxes at room temperature.

Initially, the simplex-centroid design for ternary mixtures was used to evaluate the effects of the interaction between the rice flour, whole soy flour and cassava starch in terms of the following dependent variables: sensory acceptability (appearance, aroma, texture, flavour and overall acceptance) and physical parameters (colour, instrumental texture, specific volume, and expansion factor). Therefore, all of the wheat flour used in the original recipe (450 g) was replaced by rice flour, whole soy flour and cassava starch alone, and it was also replaced in other assays with a mix of two flours and in additional assays with a mixture containing three different proportions of the flours. The results showed that the three components (rice flour, whole soy flour and cassava starch) influenced all dependent variables, in all models, only when used individually. Thus, gluten-free chocolate cookies were produced by completely replacing the wheat flour with each of three flours (one in each batch). The gluten-free cookies were produced using the standard formulation, with identical ingredient quantities and processing conditions.

2.4 Sensory acceptability of chocolate cookies

The sensory analysis was performed at the Sensory Analysis Laboratory, Department of Food Engineering and Technology, in the Institute of Biosciences, Literature and Exact Sciences, at Sao Paulo State University. Individual booths illuminated with white light were used. This study was approved by the Research Ethics Committee of the institution (Decision 149.493).

Any student, staff and professor were recruited to the sensory analysis, composing an untrained sensory panel. First, a questionnaire was given to characterize the consumers (age and sex), the extent to which they like cookies, their preference in respect to cookies and their cookie consumption frequency. Next, the formulations were evaluated for sensory acceptability using the nine-point hedonic scale which ranges from "dislike extremely" to "like extremely" (Meilgaard *et al.*, 2007). The attributes were evaluated in the following order: appearance, aroma, texture, flavour and overall acceptability. We also asked the consumers about their intention to purchase the cookies based on a five-point scale, which ranged from "I would certainly not buy this" to "I would certainly buy this".

The test was performed with 92 consumers, and the samples were randomized and evaluated in a monadic manner, complete and balanced block (MacFie and Bratchell, 1989). Consumers received a sample of each cookie, which was presented in a napkin encoded with three random digits.

2.5 Physical analysis of chocolate cookies

The colour of ten random cookies was analysed using a Hunterlab colourimeter, ColorFlex 45/0 model (USA) and the Spectra Magic Nx program (CM-S100W version 2.03.0006, USA), as well as with an illuminant D65 and a 10° observer. The CIE-L*a*b* was used (luminosity = L*, a* = red/green, b* = yellow/blue) and the chroma value (C*) and hue (h) were also obtained.

The instrumental texture was evaluated using a TA.XT Plus Texture Analyser (Stable Micro Systems, England) and the Texture Exponent 32 software (Stable Micro Systems, England). Ten random cookie samples were compressed until they broke completely. The maximum force obtained was defined as the cutting force of the cookies. Two probes were used:

(1) a three-point bending probe with a distance of 3.0 cm between the axles and a test speed of 1.0 $mm.s^{-1}$ (Laguna *et al.*, 2012); and

(2) a Warner-Bratzler probe with a guillotine, with a test speed of 1.0 $mm.s^{-1}$.

The specific volume ($cm^3.g^{-1}$) was measured in ten random samples. It was defined as the ratio between the apparent volume (determined by millet seed displacement) and the weight after the cookies were baked (AACC, 2000a).

The diameter and thickness of ten random cookie samples were measured using a digital calliper (Digimess IP54) before and after baking. The expansion factor was defined as FE = (diameter/thickness of the cookie after baking)/(diameter/thickness of the cookie before baking) (AACC, 2000b).

2.6 Statistical analyses

The average sensory analysis scores ($n = 92$) were compared using analysis of variance followed by Tukey's test. The average physical parameter scores ($n = 10$) were compared using the Kruskal–Wallis test (non-parametric ANOVA), followed by Dunn's test. The Pearson correlation was applied to the individual consumer scores to evaluate the correlation between the sensory attributes and overall acceptance of each cookie. A correlation coefficient above 0.70 indicates very strong correlation (Leighton *et al.*, 2010). A significance level of 5 per cent was adopted.

Internal preference mappings were constructed using cluster analysis, followed by multidimensional scaling. Cookie samples were placed in the columns (variables), and the individual consumer scores were placed in the rows (cases). First, a cluster analysis that considered the Euclidean distance as the measure of distance and a single linkage as the rule of amalgamation were applied to the individual data from each consumer, and the midpoint of the largest increment was considered to separate the groups. The hierarchical cluster analysis generated a matrix containing the number of subjects grouped. The smaller the distance between them, closer their similarity and relationship. The aim of the division process is to unify groups so that the variation within these groups does not increase drastically, and so that the resulting groups are as homogeneous as possible (Härdle and Simar, 2012). The resulting matrix of the cluster analysis was then used in the multidimensional scaling analysis. This analysis is a multivariate technique based on proximity between objects, subjects or stimuli, and it is used to produce a spatial representation of these items (Hair *et al.*, 2006). The graphs resulting from multidimensional scaling are considered internal preference mappings. Finally, multidimensional scaling can be measured by stress value, and a value below 0.05 indicates that the data are well behaved and fit to the model. The use of this multivariate analysis is therefore suitable for evaluating the data (Johnson and Wichern, 1992; Kruskal and Wish, 1978). Stress values obtained in this work were ≤0.01.

External preference mapping was constructed using principal component analysis. The sensory and physical means were placed in columns (variables), and the different cookies were placed in rows (cases). The data were standardized in the columns before analysis. The principal component analysis was performed with a correlation matrix and without rotation factors. An explained variation above 70 per cent for the first two principal components indicates a strong correlation between variables, and also indicates that the principal component analysis is an appropriate multivariate analysis to be applied to the data (Mardia *et al.*, 1979). In this way, two factors were extracted, considering that the first two eigenvalues explained more than 70 per cent of the data variation. All the statistical analyses were performed using Statistica 10.0 software (StatSoft Inc., USA).

3. Results and discussion

3.1 Chemical composition of the gluten-free flours

The chemical composition of the gluten-free flours (Table I) was found to be similar to the values reported on the labels. The whole soy flour is distinguished by high contents of proteins, lipids, ash and dietary fibres, while the rice flour and cassava starch have high available carbohydrate content.

Table I.
Mean scores (SD) of chemical composition of gluten-free flours ($n = 3$; $n = 2$ for fibres)

g/100g fresh weight of edible food	Rice flour	Whole soy flour	Cassava starch
Moisture	11.8 (0.02)	8.1 (0.13)	12.9 (0.02)
Proteins	6.2 (0.09)	36.3 (0.07)	0.03 (0.01)
Lipids	1.1 (0.07)	21.5 (0.20)	0.5 (0.08)
Ash	0.4 (0.00)	5.0 (0.03)	0.1 (0.03)
Total dietary fibre[a]	3.9	20.9	1.1
insoluble fibre	1.9 (0.11)	15.6 (0.11)	0.03 (0.10)
soluble fibre	2.0 (0.65)	5.4 (0.06)	1.1 (0.32)
Available carbohydrates[b]	76.6	8.2	85.4

Notes: [a] Sum of insoluble fibre and soluble fibre; [b] resulting in 100 – (moisture + protein + lipid + ash + total dietary fibre)

3.2 Sensory acceptability of chocolate cookies

Approximately 91 per cent of the consumers who participated in the sensory analysis were between 18 and 28 years of age, and the majority were women (73 per cent). In all, 78 per cent of the consumers reported that they like cookies very much, 18 per cent like moderately and 4 per cent like slightly. All of the consumers reported that they consume cookies: 49 per cent once a week to daily, 34 per cent every two weeks and 17 per cent rarely. The kinds of cookies that they reported to prefer were as follows: 53 per cent prefer traditional chocolate cookies with chocolate chips, 36 per cent prefer chocolate cookies, 15 per cent prefer traditional cookies and 18 per cent prefer whole wheat cookies (in this question, consumers were allowed to choose as many types of cookies as necessary to represent their preference).

The cookie made with rice flour had the same acceptability as the cookie with wheat flour and as the commercial cookie for all sensory attributes and overall acceptability (Table II). The cookie with cassava starch received lower scores for its appearance than the cookies with wheat flour and the commercial cookies, and it also received lower scores for its aroma than the commercial cookie did. Most of the cookie formulations were well liked (the average score was above 6 for all attributes and overall acceptability) except for the formulation made with whole soy flour, as it received lower scores than the other samples for almost all attributes (some averages below 5). The cookie with whole soy flour was also considered to be rejected, because consumers reported less intent of purchase than they did for the other cookies.

The cluster analysis for acceptability based on aroma [Figure 1(a)] resulted in three groups: one group that included the cookies with rice flour, with wheat flour and with cassava starch, plus two more groups: one with the commercial cookie and the other with the whole soy flour cookie. For the acceptability based on appearance, texture, flavour and also for overall acceptability, the cluster analysis formed the same four groups, so only the results for the overall acceptability [Figure 1(c)] are presented: one group with cookies with rice flour and with wheat flour, and the three other groups: the cassava starch cookie, the commercial cookie and the whole soy flour cookie.

The scattered points presented in the internal preference mapping [Figure 1(b) and (d)] represent each consumer, and a high number of points near a given sample or near a group of samples indicates higher acceptability scores for these samples. In the internal preference mapping for aroma [Figure 1(b)], there is a higher concentration of consumers around of the group containing the wheat flour, rice flour and cassava starch

Cookies	Appearance*	Aroma*	Texture*	Flavour*	Overall*	Purchase intent**
Rice flour	7.1 (1.5)^{ab}	7.1 (1.3)^{ab}	7.0 (1.6)^{a}	6.9 (1.5)^{a}	7.0 (1.4)^{a}	3.8 (1.0)^{a}
Whole soy flour	6.5 (1.7)^{bc}	5.5 (1.7)^{c}	4.6 (2.0)^{b}	4.4 (2.0)^{b}	4.7 (1.7)^{b}	2.2 (1.2)^{b}
Cassava starch	6.0 (1.8)^{c}	6.8 (1.3)^{b}	6.5 (1.9)^{a}	6.8 (1.6)^{a}	6.6 (1.5)^{a}	3.5 (1.1)^{a}
Wheat flour	7.4 (1.4)^{a}	6.8 (1.6)^{b}	6.5 (1.5)^{a}	6.6 (1.5)^{a}	6.7 (1.4)^{a}	3.6 (1.0)^{a}
Commercial	6.8 (1.7)^{ab}	7.6 (1.5)^{a}	7.0 (1.7)^{a}	7.1 (1.9)^{a}	7.1 (1.7)^{a}	3.9 (1.2)^{a}

Notes: *The nine-point hedonic scale ranged from "1 – dislike extremely" to "9 – like extremely"; **the five-point scale ranged from "1 – I would certainly not buy this" to "5 – I would certainly buy this"; different letters in the same column indicate statistically different means by Tukey's test ($p \leq 0.05$)

Table II. Mean scores (standard deviation) for sensory acceptability ($n = 92$) of chocolate cookies

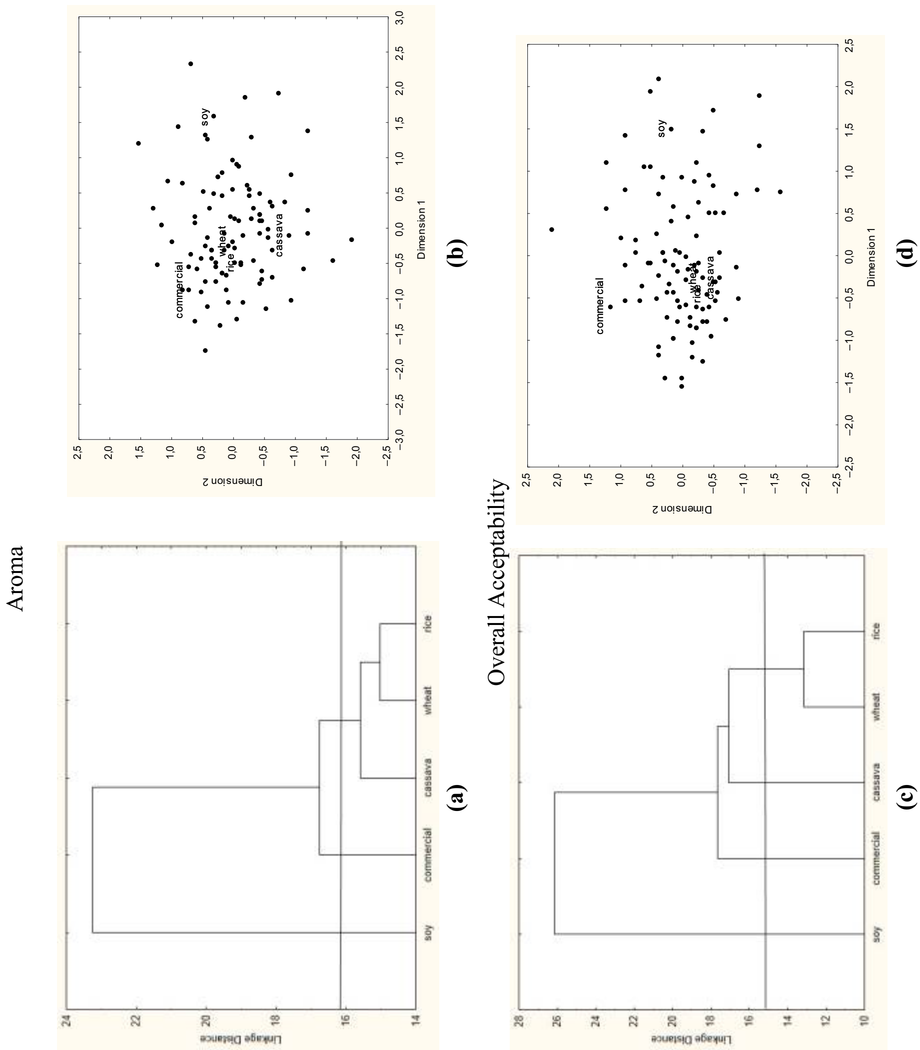

Figure 1.
Dendograms (a), (c) and internal preference mapping (b), (D) for chocolate cookies. In the dendograms, cookies joined by lines under the horizontal line are similar regarding to sensory acceptability, while cookies that are not linked have dissimilarities in the acceptability. The points in the internal preference mappings indicate each consumer who participated in the sensory analysis and more agglomerated points near cookies or group of cookies indicates higher acceptability by these samples

cookies, a result which indicates that the consumers liked the aroma of the samples. The aroma of the cookies with whole soy flour and of the commercial cookies was liked only slightly, as evident by the few consumers near these samples. Although the average acceptability of the aroma was statistically equal between the rice flour cookie and the commercial cookie, and between the cookies with rice flour, cassava starch and wheat flour (Table II); the analysis of individual consumer data showed less acceptability for the commercial cookie [Figure 1(b)].

The internal preference mapping for overall acceptability [Figure 2(d)] and hence for appearance, texture and flavour shows that there is a higher concentration of consumers around the group of cookies with wheat flour and rice flour, plus the cookie with cassava starch, although this sample stayed in a separate group after cluster analysis [Figure 2(c)]. Similar to the results based on the acceptability for aroma, the commercial cookie and especially the whole soy flour cookie did not receive good acceptability scores from the consumers, although average scores for texture, flavour and overall acceptance for the commercial cookie were statistically equal to those for cookies with rice flour, cassava starch and wheat flour (Table II).

Rice flour starch granules are smaller compared to wheat flour starch granules (Torbica *et al.*, 2012), and rice flour has a mild and neutral taste (Kadan *et al.*, 2008), which may have contributed to the similar sensory acceptability scores between the rice flour cookies and the wheat flour cookies (Table II and Figure 1). Moreover, even few differences on chemical composition of rice flour and cassava starch are found (Table I), both flours are more similar in relation to whole soy flour, especially considering the quantity of available carbohydrate, which may have contributed to similar acceptability by their respective cookies. On the other hand, consumer rejection by the cookie with whole soy flour may have been because of characteristic flavour of this raw material, as the lipoxygenase present in soy catalyses the peroxidation of polyunsaturated fatty acids, producing volatile compounds that promote its beany, raw soy and green flavours (Lv *et al.*, 2011; Ivanovski *et al.*, 2012; Peng and Guo, 2015).

Laureati *et al.* (2012) compared sensory and hedonic perception of celiac and non-celiac subjects, while assessors (descriptive analysis) and consumers (acceptability analysis), to establish whether the two groups might be considered as not significantly different in sensory testing of breads. The results showed no difference between the two groups in the description and perception of gluten-free bread, and the choice of bread was based upon the same sensory attributes, but the authors concluded that more researches must be done varying the products and the consumers. Therefore, even with results of this paper, this work has a limitation about not applying the acceptability test with celiac consumers.

Texture plays a decisive role in the cookies' acceptability (Laguna *et al.*, 2014), and, acceptability of texture did, in fact, correlate strongly and positively with overall acceptability in the cases of rice flour cookies ($r = 0.72$; $p \leq 0.05$), whole soy flour cookies ($r = 0.72$; $p \leq 0.05$), cassava starch cookies ($r = 0.77$; $p \leq 0.05$) and the commercial cookies ($r = 0.71$; $p \leq 0.05$). In addition, flavour acceptability correlated strongly and positively with overall acceptability of rice flour cookies ($r = 0.85$; $p \leq 0.05$), whole soy flour cookies ($r = 0.85$; $p \leq 0.05$), cassava starch cookies ($r = 0.79$; $p \leq 0.05$), the commercial cookies ($r = 0.87$; $p \leq 0.05$) and wheat flour cookies ($r = 0.80$; $p \leq 0.05$).

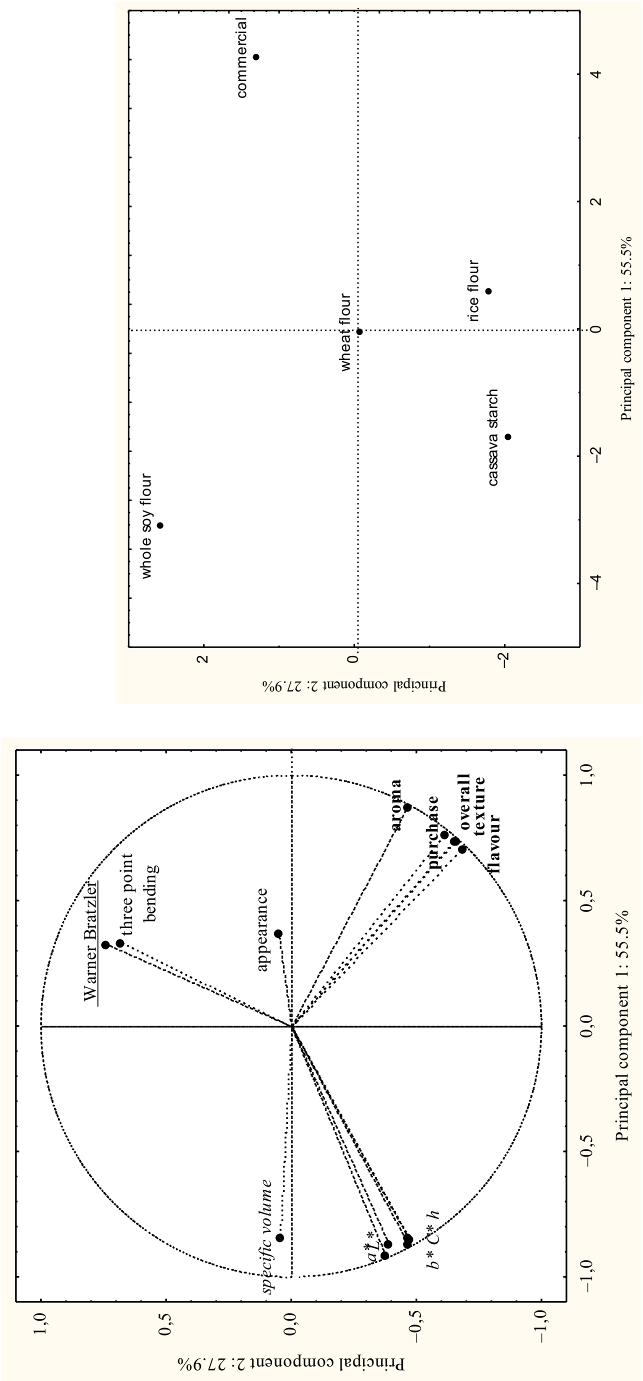

Figure 2.
External preference mapping obtained through principal component analysis to identify correlations between physical properties and sensory acceptability of the chocolate cookies

Notes: (a) Projection of the variables; (b) projection of the cookies); bold variables are positively correlated each other, and the same occurs for italic variables, but bold and italic variables have negative correlation with each other; the underline variable has no correlation with the others variables; the proximity of a cookie from variables indicates that the sample is described by these variables

3.3 Physical characteristics of chocolate cookies

The cassava starch cookie was lighter in colour (L* high), with a more intense redness (a*) and yellowness (b*) and a higher colour saturation (C*). These factors gave the cookie a different hue than the other cookies (h) (Table III). This result may to be related to the greater available carbohydrate content in cassava starch than in other gluten-free flours (Table I), which likely led to the Maillard reaction during the baking process (Oliver *et al.*, 2006; Laguna *et al.*, 2012). However, the same cookie was found to be lighter in colour (high L*), which can be understood as higher brightness. In contrast, the commercial cookie was darker in colour (low L*), with less intense redness and yellowness and less colour saturation, and it therefore also possessed a different hue than the other cookies. Cookies with rice flour, whole soy flour and wheat flour presented colour characteristics that were between the cassava starch and commercial cookies.

The cutting forces, which were measured through three-point-bending and Warner-Bratlzer probes, were smaller in the case of the rice flour cookie than that in all of the other cookies, even in relation to the cookie with cassava starch, the chemical composition of which is similar to that of rice flour (Table I). On the other hand, the whole soy flour cookies presented higher cutting forces than the cookies with rice flour or cassava starch (Table III), which may be because of the high dietary fibre content in whole soy flour and especially in the insoluble fibre (Table I). Likewise, the use of whole soy flour in the dough also increased firmness because of the increased viscosity of the dough as a function of water absorption by the soy fibre (Shin *et al.*, 2013). Ingredients rich in dietary fibre significantly affect the baked product properties, and changes include increased crumb hardness, loss of crispness, changes to appearance and differences in flavour (Ktenioudaki and Gallagher, 2012).

In contrast, it is interesting to note that the cookie with whole soy flour presented a higher specific volume than the cookies with rice flour or cassava starch (Table III). This result may be because of the protein content of the whole soy flour compared to that of the other flours (Table I). Flours with high protein content, specifically gluten, are more suitable for baking, as they result in a final product with a high volume (Cauvain and Young, 2008).

The cookie with whole soy flour was found to have a smaller expansion factor overall than the other cookies (Table III). This expansion phenomenon is primarily physical and is controlled by the ability of the components to absorb water. Thus, the addition of components with higher water holding capacities than wheat flour (which may be the case of whole soy flour) results in a competition for free water present in the cookie dough and thus limits the expansion rate (Kissel *et al.*, 1975; Mareti *et al.*, 2010).

3.4 External preference mapping

The first principal component explained 55.5 per cent of variation in the data, and the second principal component explained 27.9 per cent. Thus, the total variation in the data reached 83.4 per cent (Figure 2).

The first principal component is explained by the acceptability for aroma, texture, flavour, overall acceptability and purchase intent (factorial charges ≥ 0.7 of these variables in Principal Component 1), as well as by the colour parameters (L*, a*, b*, C*, h) and the specific volume (factorial charges ≤ -0.7 of these variables in the Principal Component 1). The sensory variables were found to be positively correlated with each other, but they were found to be negatively correlated with the physical parameters

Table III. Mean scores (standard deviation) for physical characteristics (n = 10) of chocolate cookies

Cookies	Colour† L*	a*	b*	C*	h	Cutting force†† Three-point bending	Warner-Bratzler	Specific volume†††	Expansion factor††††
Rice flour	27.1 (1.1)^{c}	10.2 (0.2)^{b}	13.1 (0.7)^{c}	16.6 (0.7)^{c}	52.2 (1.1)^{d}	2.7 (0.3)^{b}	3.5 (1.0)^{d}	2.9 (0.3)^{a}	0.72 (0.0)^{a}
Whole soy flour	31.4 (0.8)^{b}	10.6 (0.2)^{b}	14.5 (0.6)^{b}	17.9 (0.5)^{b}	53.8 (0.9)^{c}	4.3 (0.5)^{a}	9.0 (4.1)^{abc}	3.2 (0.4)^{a}	0.53 (0.0)^{b}
Cassava starch	37.0 (1.5)^{a}	11.0 (0.1)^{a}	19.3 (0.6)^{a}	22.2 (0.6)^{a}	60.4 (0.7)^{a}	3.2 (0.5)^{b}	5.9 (1.1)^{c}	2.7 (0.4)^{ab}	0.71 (0.1)^{a}
Wheat flour	31.8 (0.8)^{b}	10.1 (0.7)^{b}	14.5 (1.0)^{b}	17.6 (1.3)^{b}	55.5 (0.8)^{b}	5.3 (1.0)^{a}	8.9 (0.7)^{b}	3.1 (0.3)^{a}	0.62 (0.1)^{ab}
Commercial	18.6 (0.8)^{d}	7.0 (0.7)^{c}	6.1 (0.9)^{d}	9.3 (1.1)^{d}	41.1 (1.7)^{e}	5.1 (0.4)^{a}	10.9 (0.7)^{a}	2.3 (0.2)^{b}	^{b}

Notes: †L* ranges from 0 (absolute black, i.e. dark colour) to 100 (absolute white, i.e. bright colour); crescent values of a*, b* and C* indicate increasing of redness, yellowness and colour saturation, respectively; h indicates the colour hue; ††lower values, in Newtons, indicate decrease of the maximum force to break completely the cookie; †††higher values, in $cm^3.g^{-1}$, indicate more expanded cookies; ††††higher values indicate a higher gain in diameter and thickness of the cookie after baking (the expansion factor of the commercial cookie was not determined because of the lack of pre-baked diameter and thickness values); different letters in the same column indicate statistically different means by Dunn's test ($p \leq 0.05$)

[Figure 2(a)]. The cookie made with rice flour had higher sensory acceptability and purchase intent, because it is positioned in the same quadrant of acceptability, even a little far from these vectors. This acceptability is negatively correlated with colour intensity and specific volume of the rice flour cookies [Figure 2(b)]. That is to say, the rice flour cookies are characterized by higher sensory acceptability, less colour intensities and lower specific volumes. On the other hand, the cookie with whole soy flour had lower sensory acceptability and purchase intent, as it is positioned in the quadrant opposite to these variables. The cookie with cassava starch stands out for its higher colour intensity.

The second principal component is explained only by the cutting force obtained through the Warner-Bratzler probe [Figure 2(a)], and the commercial cookie stands out for this variable, i.e. it is described by high cutting force [Figure 2(b)].

Though they were built using different multivariate statistical techniques, the internal and external preference mappings revealed similar results in terms of sensory acceptability of chocolate cookies. The rice flour cookie is a part of the group with the wheat flour cookie and the cassava starch cookie in terms of its aroma acceptability scores [Figure 1(b)]. It is also in a group with the wheat flour cookie because of its acceptability scores for appearance, texture, flavour and overall acceptability [Figure 1(d)]. Therefore, it is located in the region of greatest consumer acceptability. Likewise, the principal component analysis (Figure 2) indicates that the rice flour cookie stands out for the sensory acceptability for its aroma, texture and flavour, in addition to overall acceptability and purchase intention. Therefore, the rice flour cookie stands out for its sensory acceptability in relation to the other cookies evaluated. Finally, the fact that the rice flour cookie is as accepted as the wheat flour cookie, and the commercial cookie indicates that rice flour is the best substitute for wheat flour out of the flours tested in this study.

4. Conclusions

The chocolate cookie in which wheat flour was replaced with rice flour was as widely accepted as the cookie with wheat flour, and the largest acceptability for the rice flour cookies correlated with less colour intensity and a lower specific volume. The cookie with cassava starch stood out for its colour intensities (as this flour resulted in the most intense colour parameters), and it also received good acceptability scores from consumers. The cookie with whole soy flour had lower sensory acceptability scores, and the commercial cookie stood out for its high cutting force (instrumental texture). It can be concluded, therefore, that the replacement of wheat flour is feasible in chocolate cookies and that rice flour is the best substitute for this product.

References

AACC (2000a), *Approved Methods of the AACC, Method 10-05*, 10th ed., AACC International, St. Paul, MN.

AACC (2000b), *Approved Methods of the AACC, Method 10-50D*, 10th ed., AACC International, St. Paul, MN.

AOAC (1990), *Official Methods of Analysis of AOAC International*, 15th ed., AOAC International, WA, MD.

Capriles, V.D. and Arêas, J.A.G. (2013), "Effects of prebiotic inulin-type fructans on structure, quality, sensory acceptance and glycemic response of gluten-free breads", *Food & Function*, Vol. 4 No. 1, pp. 104-110.

Capriles, V.D., Martini, L.A. and Arêas, J.A.G. (2009), "Metabolic osteopathy in celiac disease: importance of a gluten-free diet", *Nutrition Reviews*, Vol. 67 No. 10, pp. 599-606.

Cauvain, S.P. and Young, L.S. (2008), "Ingredients and their influences", in Cauvain, S.P. and Young, L.S. (Eds), *Baked Products: Science, Technology and Practice*, Wiley-Blackwell, Oxford, pp. 72-98.

Hair, J.F., Black, B., Babin, B., Anderson, R.E. and Tatham, R.L. (2006), *Multivariate Data Analysis*, Prentice Hall, NJ.

Härdle, W.K. and Simar, L. (2012), *Applied Multivariate Statistical Analysis*, 3rd ed., Springer, Heidelberg.

Ishwarya, P.S. and Prabhasankar, P. (2013), "Fructooligosaccharide – retention during baking and its influence on biscuit quality", *Food Bioscience*, Vol. 4, pp. 68-80.

Ivanovski, B., Seetharaman, K. and Duizer, L.M. (2012), "Development of soy based bread with acceptable sensory properties", *Journal of Food Science*, Vol. 77 No. 1, pp. S71-S76.

Johnson, R.A. and Wichern, D.W. (1992), *Applied Multivariate Statistical Analysis*, 3rd ed., Prentice Hall, Englewood Cliffs, NJ.

Kadan, R.S., Bryant, R.J. and Miller, J.A. (2008), "Effects of milling on functional properties of rice flour", *Journal of Food Science*, Vol. 73 No. 4, pp. 151-154.

Kagnoff, M.F. (2007), "Celiac disease: pathogenesis of a model immunogenetic disease", *Journal of Clinical Investigation*, Vol. 117 No. 1, pp. 41-49.

Kissel, L.T., Prentice, N. and Yamazaki, W.T. (1975), "Protein enrichment of cookie flours with wheat gluten and soy flour derivatives", *Cereal Chemistry*, Vol. 52, pp. 638-649.

Kruskal, J.B. and Wish, M. (1978), *Multidimensional Scaling*, Sage, Newbury Park, CA.

Ktenioudaki, A. and Gallagher, E. (2012), "Recent advances in the development of high-fibre baked products", *Trends in Food Science & Technology*, Vol. 28 No. 1, pp. 4-14.

Laguna, L., Salvador, A., Sanz, T. and Fiszman, S.M. (2011), "Performance of a resistant starch rich ingredient in the baking and eating quality of short-dough biscuits", *LWT – Food Science and Technology*, Vol. 44 No. 3, pp. 737-746.

Laguna, L., Varela, P., Salvador, A., Sanz, T. and Fiszman, S.M. (2012), "Balancing texture and other sensory features in reduced fat short-dough biscuits", *Journal of Texture Studies*, Vol. 43 No. 3, pp. 235-245.

Laguna, L., Primo-Martín, C., Varela, P., Salvador, A. and Sanz, T. (2014), "HPMC and inulin as fat replacers in biscuits: sensory and instrumental evaluation", *LWT – Food Science and Technology*, Vol. 56 No. 2, pp. 494-501.

Lamacchia, C., Camarca, A., Picascia, S., Di Luccia, A. and Gianfrani, C. (2014), "Cereal-based gluten-free food: how to reconcile nutritional and technological properties of wheat proteins with safety for celiac disease patients", *Nutrients*, Vol. 6 No. 2, pp. 575-590.

Laureati, M., Giussani, B. and Pagliarini, E. (2012), "Sensory and hedonic perception of gluten-free bread: comparison between celiac and non-celiac subjects", *Food Research International*, Vol. 46 No. 1, pp. 326-333.

Leighton, C.S., Schönfeldt, H.C. and Kruger, R. (2010), "Quantitative descriptive sensory analysis of five different cultivars of sweet potato to determine sensory and texture profiles", *Journal of Sensory Studies*, Vol. 25 No. 1, pp. 2-18.

Lv, Y.C., Song, H.L., Li, X. and Guo, S.T. (2011), "Influence of blanching and grinding process with hot water on beany and non-beany flavor in soymilk", *Journal of Food Science*, Vol. 76 No. 1, pp. S20-S25.

MacFie, H.J. and Bratchell, N. (1989), "Designs to balance the effect of order of presentation and first order carry-over effects in hall tests", *Journal of Sensory Studies*, Vol. 4 No. 2, pp. 129-148.

Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979), *Multivariate Analysis*, Academic Press, London.

Mareti, M.C., Grossmann, M.V.E. and Benassi, M.T. (2010), "Physical and sensorial characteristics of cookies containing deffated soy flour and oat bran", *Food Science and Technology*, Vol. 30 No. 4, pp. 878-883.

Meilgaard, M., Civille, G.V. and Carr, B.T. (2007), *Sensory Evaluation Techniques*, 4th ed., CRC Press, Boca Raton, FL.

Nascimento, A.B., Fiates, G.M.R., Anjos, A. and Teixeira, E. (2014), "Gluten-free is not enough – perception and suggestions of celiac consumers", *International Journal of Food Sciences and Nutrition*, Vol. 65 No. 4, pp. 394-398.

Oliver, C.M., Melton, L.D. and Stanley, R.A. (2006), "Creating proteins with novel functionality via the Maillard reaction: a review", *Critical Reviews in Food Science and Nutrition*, Vol. 46 No. 4, pp. 337-350.

Peng, X. and Guo, S. (2015), "Texture characteristics of soymilk gels formed by lactic fermentation: a comparison of soymilk prepared by blanching soybeans under different temperatures", *Food Hydrocolloids*, Vol. 43, pp. 58-65.

Prosky, L., Asp, N.G., Schweizer, T.F., Devries, J.W. and Furda, I. (1988), "Determination of insoluble, soluble and total dietary fiber in foods and foods products: intralaboratory study", *Journal of the Association of Official Analytical Chemists*, Vol. 71 No. 5, pp. 1017-1023.

Sapone, A., Bai, J.C., Ciacci, C., Dolinsek, J., Green, P.H.R., Hadjivassiliou, M., Kaukinen, K., Rostami, K., Sanders, D.S., Schumann, M., Ullrich, R., Villalta, D., Volta, U., Catassi, C. and Fasano, A. (2012), "Spectrum of gluten-related disorders: consensus on new nomenclature and classification", *BMC Medicine*, Vol. 10, p. 13.

Shin, D.J., Kim, W. and Kim, Y. (2013), "Physicochemical and sensory properties of soy bread made with germinated, steamed, and roasted soy flour", *Food Chemistry*, Vol. 141 No. 1, pp. 517-523.

Torbica, A., Hadnađev, M. and Dapčević Hadnađev, T. (2012), "Rice and buckwheat flour characterisation and its relation to cookie quality", *Food Research International*, Vol. 48 No. 1, pp. 277-283.

Trefts, P.E. and Kagnoff, M.F. (1981), "Gluten-sensitive enteropathy I. The T-dependent anti-A-gliadin antibody response maps to the murine major histocompatibility locus", *The Journal of Immunology*, Vol. 126 No. 6, pp. 2249-2252.

Corresponding author
Ana Carolina Conti-Silva can be contacted at: contisil@ibilce.unesp.br