

Sensory evaluation and acceptability of gluten-free Andean corn spaghetti

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Abstract

BACKGROUND: Although pasta is one of the most widely demanded products among gluten-intolerant people, few studies have focused on the sensory analysis and acceptability of these products. Spaghetti was made from Andean corn (*Zea mays* var. *amylacea*), *capia* and *cully* varieties from northern Argentina, and the flash profile technique was applied by semi-trained assessors to compare the sensory profile of this type of spaghetti with those made with rice and wheat flours. Acceptability of *capia* corn spaghetti was studied in celiac and non-celiac consumer groups using a 9-point hedonic scale and check-all-that-apply (CATA) questions.

RESULTS: Two Andean corn spaghetti samples were described by assessors as rough, odd-smelling and odd-tasting. These terms were also used by non-celiac consumers to describe the *capia* corn spaghetti sample, which explained its low acceptability scores. However, celiac consumers assigned high acceptability scores to the same sample and described it as tasty, smooth, tender, novel, having a pleasant flavor and good quality, and as a product that can be consumed every day and by the whole family.

CONCLUSIONS: The results of this study suggest that Andean corn flours are a suitable and acceptable product for celiac consumers and can be used in the production of spaghetti for celiac consumers but should be reformulated for non-celiac consumers.

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Keywords: Andean corn; spaghetti; gluten free; sensory analysis

INTRODUCTION

Celiac disease is an autoimmune condition characterized by a disorder in the small intestine caused by intolerance to gluten.¹ The only effective treatment for people who suffer from this disease is excluding any foods that contain wheat, oats, barley or rye from their diet.^{2,3} Some studies suggest that the incidence of this disease is on the rise; it currently affects between 0.3% and 1% of the world's population;^{4,5} hence the interest of the food industry in having a wider range of alternative products available. According to Phimolsiripol and others,⁶ many gluten-free products available in the market have low nutritional quality because they are often made from refined starches, which could increase the risk of nutritional deficiencies.⁷ For this reason, some formulations are enriched with nutritious flour or isolated protein of diverse origins, such as amaranth, quinoa, lupine, chickpea and other leguminous flours.^{8–10}

Corn is a cereal that can be safely included in the production of food products for celiacs.¹¹ The Quebrada of Humahuaca and Puna, in the province of Jujuy, is among the most important *in situ* germplasm banks in Argentina, since various Andean corn varieties with different physical and physicochemical characteristics¹² can be found in said region. Andean crops have become very popular over recent years and their cultivation has increased, especially in the case of the more profitable varieties. The use of Andean wholegrain flours (including bran, germ and endosperm) could

be an alternative option for the formulation of gluten-free products with higher content of dietary fiber, minerals, vitamins B and phytochemicals.^{13–15} These flours in particular are rich in polyphenols – powerful antioxidants associated with lowering the risk of developing cancer and other non-communicable diseases.¹⁶

Although replacing wheat flour with alternative ingredients may lead to improving both nutritional and technological aspects, efforts should be made to ensure that products offer acceptable appearance, aroma, flavor and texture – attributes that are crucial for their sensory acceptability among celiac consumers.¹⁷ Numerous authors have based their studies on the technological characteristics of gluten-free products.^{9,18–23} However, only a small number of articles on the sensory analysis of this type of product have been published. These are mostly

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focused on baked products, and to a lesser extent on pasta products, even though the latter are one of the most widely demanded products among gluten-intolerant people.^{10,24} Kiskini *et al.*²⁵ conducted a descriptive sensory analysis on iron-fortified gluten-free bread, and Hager *et al.*²⁶ compared the sensory profiles of gluten-free breads with their wheat counterparts. Regarding studies involving consumers, Milde *et al.*²⁷ studied the acceptability of gluten-free bread made of cassava starch and corn flour among celiac consumers, Ibanoglu *et al.*²⁸ determined the acceptability of gluten-free snacks with non-celiac consumers. Rodrigues *et al.*²⁹ evaluated acceptability of gluten-free cookies made from irradiated flaxseed in non-celiac consumers. Paglearini *et al.*³⁰ in turn, conducted a sensory analysis of gluten-free bread involving celiac assessors. Laureati *et al.*³¹ compared the sensory profile and acceptability of gluten-free breads for panels of trained assessors and consumers – celiac and non-celiac – and no statistically significant differences between panels were found.

Sensory science has recently developed new sensory profile alternatives. There are methodologies based on the construction of their own vocabulary by the assessors such as flash profile. The flash profile is an original combination of free-choice terms selection with a ranking method based on simultaneous presentation of all products in a set. This method forces assessors to focus on the perceived differences and to use solely discriminative attributes. This recent methodology is attractive because it does not demand a training stage and individual sessions are possible.³²

Various authors have compared the flash profile technique with classic descriptive methods such as Quantitative Descriptive Analysis (QDA[®]), and found that results obtained through both methods correlate well and report that the flash profile technique is a faster alternative that provides more detailed and discriminative information on the sample characteristics than conventional profiles.^{32–37}

Even though the information obtained with these methodologies with regard to the sensory characteristics of a product are accurate and reliable, the time and resources necessary tend to be significant; hence the increasing interest in applying methodologies for the sensory description of products with consumers. Among these, check-all-that-apply (CATA) questions have gained popularity. A CATA question consists of a multiple-choice list of attributes from which respondents select those they consider applicable to the product being tested. This enables the assessment of sensory reactions toward a consumed product and provides a description of qualitative and quantitative aspects of consumer perceptions that can be correlated with other parameters. CATA questions include not only sensory attributes but also hedonic appraisals, in addition to willingness to purchase and affective responses.³⁸ This method has been used to obtain sensory descriptions of various food products.^{39–44} All the authors agree that CATA questions are a quick and easy method of gathering information about consumer perceptions. Reliable sensory evaluations by consumers can be obtained more quickly and inexpensively than using a trained tasting panel.^{40,41}

The purposes of this study were to compare the sensory profile of corn spaghetti with that of spaghetti made of rice and wheat flour using the flash profile technique, and to analyze the acceptability of capia corn spaghetti and evaluate its acceptability among celiac and non-celiac consumer groups by analyzing sensory characteristics obtained throughout CATA questions.

Table 1. Ingredients and cooking times of samples for Study 1

Sample	Ingredients	Cooking time (min)
PC	Whole cully corn flour, water	7
CC	Whole capia corn flour, water	12
IWS	Durum wheat semolina, water, eggs	8
DWS	Durum wheat semolina, water, eggs	12
BWS	Bread wheat flour, water, β -carotene, eggs	9
RS	Rice flour, water, eggs, β -carotene	6

EXPERIMENTAL

Manufacture of gluten-free Andean corn spaghetti

Andean corn grains capia and cully (*Zea mays* var. *amylacea*) were provided by a cooperative of producers (CAUQUEVA, Tilcara, Jujuy, Argentina). Corn grains were milled using a Buhler-Miag roller mill. The pericarp and germ were not removed. For spaghetti preparation a wholemeal flour fraction with a particle size of <420 μ m was used.

The spaghetti-type product was obtained by extrusion cooking. The process was carried out in a Brabender 10 DN single-screw extruder, using a 3:1 compression ratio screw, a 1.5 mm \times 3 (diameter \times no. of holes) die and a screw speed of 100 rpm. It was implemented at 100 °C and 28% of moisture for capia corn spaghetti (CC), and 80 °C and 28% for cully corn spaghetti (PC). The products were dried at a low temperature of 40 °C and 50% relative humidity for 16 h.

Study 1: Sensory description using flash profile technique

Samples and cooking process

The first study looked at two samples of Andean corn spaghetti – varieties capia (CC) and cully (PC) – and four spaghetti samples purchased at a local market, made from rice (RS) which contained eggs, durum wheat semolina (DWS), bread wheat – *Triticum aestivum* – (BWS) and Italian durum wheat flour (IWS). Table 1 shows the ingredients of samples and their cooking times.

Spaghetti was cooked in unsalted boiling water at a 1:10 spaghetti:water ratio. The market samples were cooked according to time indicated on the package. The cooking times for the PC and CC spaghetti samples were determined according to Giménez *et al.*⁹

Flash profile

Flash profile was carried out by 10 semi-trained assessors, with experience in sensory description of other foods; they were recruited among staff of the School of Chemistry (Universidad de la República, Uruguay).

The flash profile consisted of two sessions. During the first session the assessors were given an explanation of the procedure and each assessor generated their own list of attributes individually. Coded samples were presented simultaneously and the consumers were asked to observe, smell and taste them in order to generate descriptors. In the second session they ranked the six samples from 'less' to 'higher' according to each attribute. Assessors were free to taste the products as much as they liked, and they could take as much time as they wished to complete the evaluation. Samples were presented for evaluation in white thermal containers containing 20 g of each product, coded with random

three-digit numbers. Drinking water was used for cleansing the palate.

Data analysis

For the flash profile data GPA (generalized Procrustes analysis)⁴⁵ XL-Stat 2011 software (Addinsoft, New York, NY, USA) was used. It is important to point out that GPA reduces the scale usage effects, delivers a consensus configuration and also allows one to compare the proximity between the terms that are used by different assessors to describe products;³⁵ therefore it is very suitable for this methodology. Hierarchical cluster analysis (HCA), using Euclidean distances and Ward's aggregation criterion, was carried out in order to identify samples with similar characteristics.

Study 2: Consumer acceptability

Samples and cooking process

For the second study, samples of Andean corn spaghetti, capia variety (CC), were used. Spaghetti was cooked for 12 min in boiling water at a 1:10 spaghetti:water ratio.

Consumer test

A total of 85 individuals (30 celiac and 55 non-celiac) were randomly recruited at university centers, public places and at the Celiac Association of Uruguay. Taking into account the areas where the participants were recruited, the sample was assumed to represent the general Uruguayan middle-income groups.

The capia corn spaghetti sample was presented to consumers in white thermal containers holding 20 g spaghetti and a 5 g dollop of butter on top.

Consumers were instructed to taste the sample and indicate acceptability using a structured 9-point hedonic scale ranging from 'dislike extremely' to 'like extremely' and to qualify their purchase intention using another structured 9-point scale ranging from 'definitely would not buy' to 'definitely would buy'.

The test ended with a CATA question,³⁸ in which consumers were presented with a 32-word list and instructed to tick the ones that most accurately described the product they were tasting. Terms selected for the test may be grouped into different categories: those denoting liking (tasty, delicious) or disliking (disgusting), those referring to color (too white), smell (cereal-like, odd), texture (granular, smooth, sticky, tender, rough, hard, soft, rubbery), flavor (odd, unpleasant, pleasant, bland, cereal-like, peculiar flavor), health (nutritious, healthy, for special diets), quality (different, low quality, high quality, novel, gourmet, exclusive) or usage (to be consumed by the whole family, on special occasions, every day). Terms used for the CATA question included those selected by the semi-trained panel in Study 1 and other additional terms that researchers considered relevant.

Since the presentation order of CATA terms could affect responses,⁴³ three different manners of presentation and organization of the terms were used for sample evaluation, and they were alternatively given to different consumers. The participants' socio-demographic data (age, gender, number of children in the family and educational level) were recorded after the session. They were also requested to inform about frequency of dried pasta consumption by selecting one among the following options: once a month or less; one to four times a month; more than once a week.

Data analysis

In order to establish whether celiac and non-celiac consumers differed in their overall liking and intention to purchase CC samples,

data were first submitted to analysis of variance considering the presence of celiac disease as the variation factor. Significant differences between means were determined according to the Tukey's test ($P \leq 0.05$).

For the CATA question, frequency of mention for each term was determined by counting the number of consumers that used that term to describe each sample. The chi-squared test was carried out to establish differences in the number of terms selected to describe the sample by the celiac and non-celiac population. XL-Stat 2011 software (Addinsoft) was used to conduct the above analyses.

RESULTS

Study 1: Sensory description using flash profile technique

Each participant selected between five and nine terms to describe differences across samples. The following 38 terms were selected (many of them repeated by two or more assessors): adherence, granularity, roughness, astringency, color, yellow color, homogeneous color, violet color, consistency, noodle diameter, friable, hardness, elasticity, firmness, color intensity, flavor intensity, length, rice-like smell, cereal-like smell, egg-like smell, regular smell, odd smell, typical smell, pasty, specks, stickiness, dark spots, flavor, rice-like flavor, cereal-like flavor, egg-like flavor, odd flavor, corn-like flavor, smoothness, homogeneous surface, floury texture, uniform texture and viscosity.

Figure 1 displays the biplot obtained by GPA from the FP data; the first two principal axes accounted for the 82.40% of the variability (57.34% and 25.06%, respectively).

Flavor-related terms (flavor intensity, odd flavor, cereal-like flavor, rice-like flavor and corn-like flavor) were mostly found in the lower-left quadrant, and were negatively correlated with the F1 and F2 dimensions. Most of the smell-related terms were located in the same quadrant (odd smell, rice-like smell and egg-like smell).

The upper-left quadrant displayed terms related to appearance (dark spots and specks), while the upper-right quadrant showed mainly yellow-related terms. Most of the texture terms were negatively correlated with the F1 dimension (stickiness, roughness, viscosity, floury texture, friable, adherence and granularity), whereas hardness, elasticity and uniform texture were positively correlated with the F1 dimension. As shown in Fig. 2, the two corn spaghetti samples, elaborated with Andean corn grains capia (CC) and cully (PC), were close in the graph and were found to the left of the F1 dimension, being described as rough, sandy, displaying odd flavor, corn-like flavor, cereal-like smell and specks and dark spots. The rice spaghetti (RS) samples were negatively correlated to the F2 dimension and were described as sticky, having a floury texture, odd smells and flavors of cereal and rice.

The three wheat spaghetti (DWS, BWS and IWS) samples were also close to each other, located to the right of the F1 dimension, being mainly described by their texture (hardness, elasticity and consistency), length and typical and regular smell.

Study 2: Consumer acceptability

Table 2 shows the socio-demographic population that participated in the study and their frequency of dried pasta consumption. The non-celiac population participating in the study were aged between 21 and 69 (mean = 35.9, SD = 13.4) and the celiac population were aged between 19 and 77 (mean = 40.1, SD = 13.3).

Whereas the use of a non-probabilistic sampling method and the recruiting procedure utilized did not provide a statistically representative sample, thus preventing the generalization of these

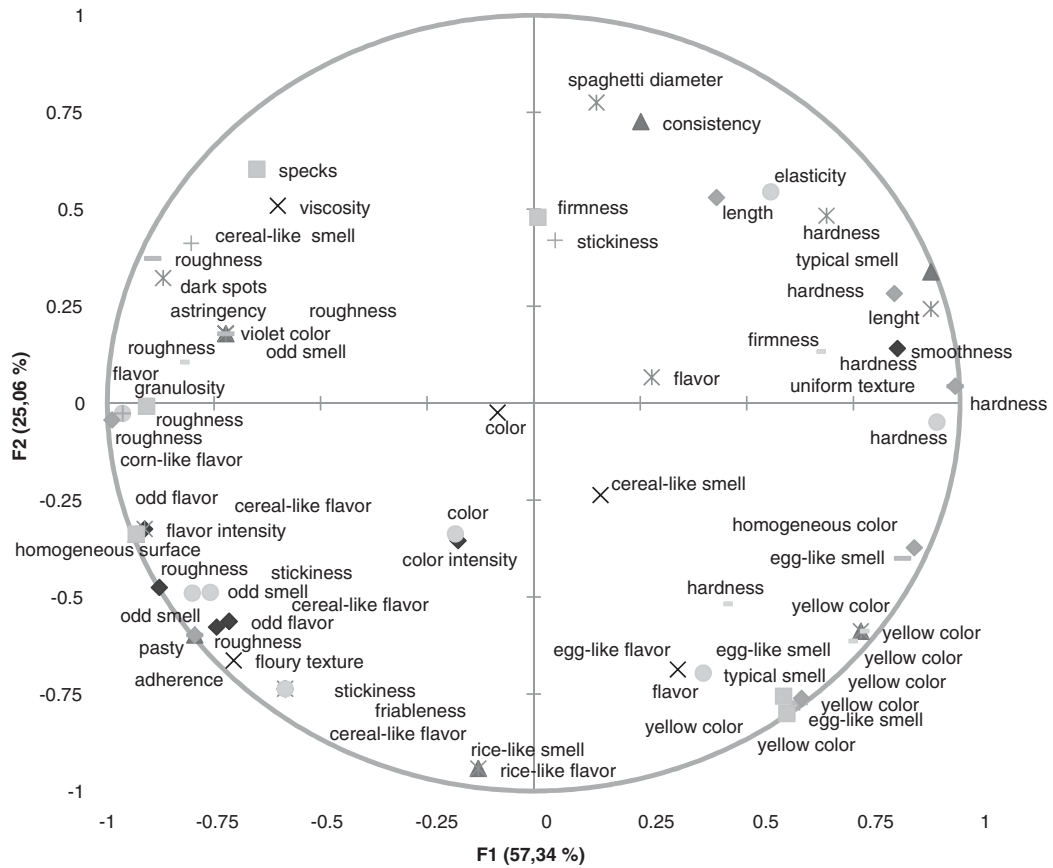


Figure 1. Representation of descriptive variables retained for the flash profile in the two first dimensions. Attributes generated by 10 assessors for all spaghetti samples.

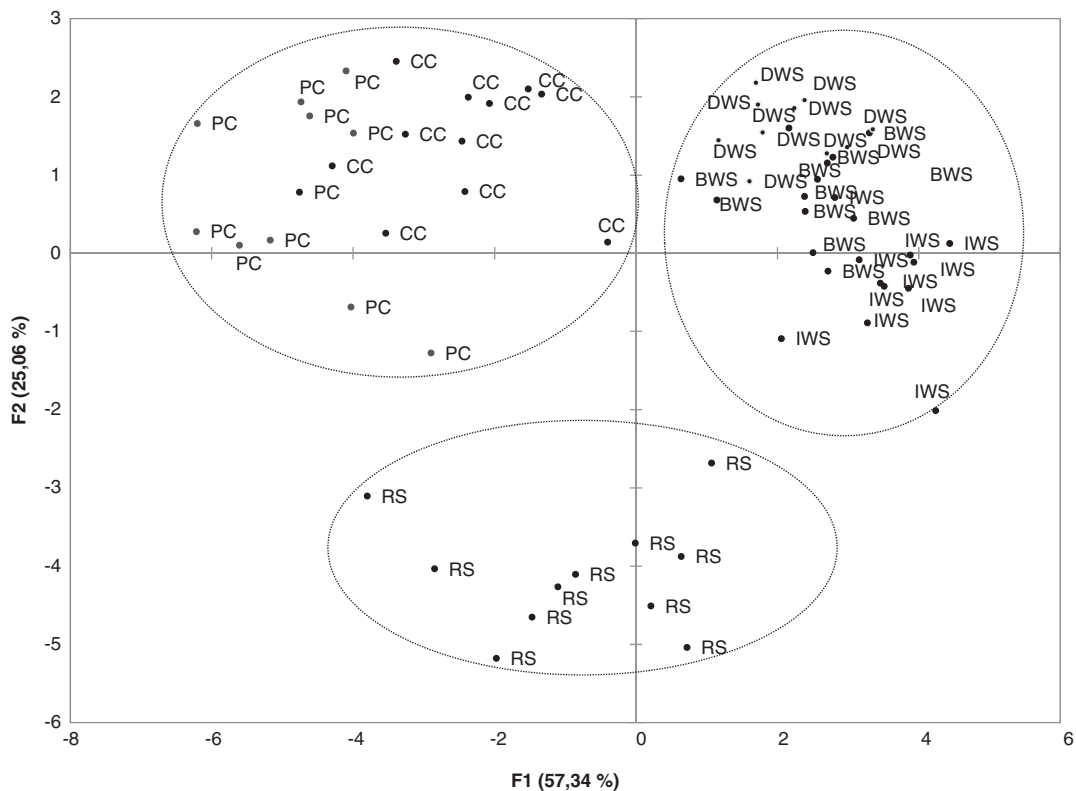


Figure 2. Plot of samples according to the descriptors retained for the flash profile in the two first dimensions. Individual configuration of each of the 10 assessors.

Table 2. Socio-demographic characteristics of consumers and frequency of dried pasta consumption

		Non-celiac population (n = 55)	Celiac population (n = 30)
Gender	Male	25.5%	24.1%
	Female	74.5%	75.9%
Education level	Complete secondary education	27.3%	20.7%
	Incomplete tertiary level	45.4%	27.6%
	University graduates	27.3%	51.7%
Children in the family	0	69.1%	69.0%
	1 or more	30.9%	31.0%
Frequency of dried pasta consumption	Once a month or less	7.3%	20.0%
	1 to 4 times a month	69.1%	53.3%
	More than once a week	23.7%	26.7%

Values are expressed as percentages of surveyed people, celiac and non-celiac separately.

results to the entire population living in Montevideo, a wide range of consumers was covered in terms of socio-demographic variables, as shown in Table 2. The sample was biased towards females, more highly educated individuals and individuals with no children, probably as a result of an overall higher readiness of such individuals to participate in the study.

Highly significant differences were found between the acceptability ($P \leq 0.01$) and purchase intention scores ($P \leq 0.01$) assigned by non-celiac and celiac consumers to the samples in this study. Celiac consumers assigned 8.3 and 8.4 scores to acceptability and purchase intention respectively for the CC spaghetti, whereas the scores assigned by non-celiacs were significantly lower (6.5 and 6.4 respectively). Considering a score of 6 on a 9-point hedonic scale as the lowest acceptable score for a product to be considered commercially viable,⁴⁶ the sample was just above that score for non-celiac consumers but proved to enjoy strong acceptability and purchase intention among the celiacs in the study.

Of the 32 words listed in the CATA question, eight terms were used by less than 10% of the consumers in each group. Most of those terms had negative hedonic and sensory connotations (disgusting, unpleasant flavor, odd smell, sticky and low quality) or quality-related connotations (gourmet, exclusive and for special occasions), which indicated that while consumers did not perceive characteristics that could lead them to reject the product, they did not consider it to be sophisticated either.

Table 3 shows the cited frequency for each CATA term by consumers. All terms were cited by at least 10% of consumers from one of the two populations: celiac and non-celiac. The CC sample was described by more than 40% of the non-celiac population as tasty, a pleasant flavor, cereal-like taste, tender, novel and as a product to be consumed by the whole family. The same sample was described by more than 40% of the celiac population as tasty, having a pleasant flavor, smooth, tender, high quality, novel, and as a good-quality product to be consumed every day and by the whole family.

Significant differences were found ($P \leq 0.05$) between the celiac and non-celiac consumer groups in 8 of the 24 terms of the CATA questions used by more than 10% of participants. The most frequently used term to describe this sample was 'tasty', with a total of 55 marks. The celiac population used terms denoting positive attributes with a significantly higher frequency ($P \leq 0.05$) – tasty, smooth, tender, delicious and for special diets – which explains the high scores for acceptability and purchase intention assigned to the sample.

On the other hand, the non-celiac population used terms denoting negative attributes for flavor and texture with a significantly higher frequency ($P \leq 0.05$) – cereal-like taste, granular and rubbery – which explains the lower acceptability and purchase intention scores assigned to the sample.

DISCUSSION

According to HCA (Fig. 2) three clusters of samples were found. Wheat samples (DWS, BWS, IWS) were characterized as harder, with yellow color, elasticity, consistency and with egg odor and flavor. Andean corn samples (CC and PC) were described as rough, with dark spots and strange odor and flavor. These samples were characterized also as sandy, less yellow, odd flavor, corn-like flavor, cereal-like smell, presence of specks, and with less egg odor and flavor. Finally, the sample prepared with rice flour (RS) was described as stickier, with rice odor and flavor and with floury texture.

The fact that the non-celiac individuals who participated in the second study are habitual wheat pasta consumers (see Table 2) affected the evaluation of CC spaghetti. When they tasted CC spaghetti, they probably compared their perceptions against their mental references for the attributes of wheat pasta. That is why they found CC spaghetti to be more rubbery and granular and to have a cereal-like taste.

This description obtained from consumers through CATA questions in Study 2 fairly coincides with that obtained by the assessors using the flash profile technique in Study 1.

Celiac consumers, in turn, regularly consume rice flour pasta, which led them to perceive the CC sample as tastier, smoother, more tender and more delicious. This comparison may explain the acceptability differences found between both populations. Moreover, while pasta products are among the most widely demanded by gluten-intolerant people, very few brands are available in the Uruguayan market (and they are only made of rice flour), which most likely influenced the perception of gluten free corn spaghetti, increasing its acceptability and purchase intention.

The study conducted by Laureati *et al.*³¹ on commercially available gluten-free breads is one of the few comparing the acceptability of gluten-free product samples in celiac and non-celiac populations. The authors did not find any significant influence of the celiac disease on the acceptability of samples and that finding is not consistent with the results of this study.

The attributes that negatively influenced the acceptability of the non-celiac population may be considered important parameters

Table 3. Check-all-that-apply question results for CC sample: frequencies (%) for each attribute

Categories	Attribute	Non-celiac population (n = 55)	Celiac population (n = 30)	χ^2	Signification level
Linking/dislinking	Tasty**	54.5%	83.3%	7.044	0.008
	Delicious**	0.0%	20.0%	11.835	0.001
Color	Too white ^{ns}	36.4%	23.3%	1.521	0.218
Smell	Cereal-like ^{ns}	16.4%	10.0%	0.648	0.421
Texture	Granular*	23.6%	6.7%	3.846	0.050
	Smooth**	29.1%	63.3%	9.397	0.002
Flavor	Tender**	43.6%	76.7%	8.567	0.003
	Rough ^{ns}	14.5%	3.3%	2.578	0.108
	Hard ^{ns}	10.9%	10.0%	0.017	0.896
	Soft ^{ns}	9.1%	13.3%	0.369	0.544
	Rubbery*	23.6%	6.7%	3.846	0.050
	Pleasant ^{ns}	54.5%	53.3%	0.011	0.915
	Bland ^{ns}	27.3%	33.3%	0.343	0.558
Health	Cereal-like**	40.0%	10.0%	8.415	0.004
	Peculiar ^{ns}	23.6%	26.7%	0.096	0.757
	Nutritious ^{ns}	34.5%	20.0%	1.978	0.160
	Healthy ^{ns}	34.5%	23.3%	1.149	0.284
Quality	For special diets*	7.3%	23.3%	4.444	0.035
	Different ^{ns}	29.1%	33.3%	0.165	0.685
	High quality ^{ns}	27.3%	46.7%	3.248	0.071
Use	Original ^{ns}	43.6%	46.7%	0.072	0.788
	For whole family ^{ns}	49.1%	66.7%	2.426	0.119
	For every day ^{ns}	32.7%	53.3%	3.434	0.064

* $P \leq 0.05$; ** $P \leq 0.01$; ns, no significant differences ($P > 0.05$) according to χ^2 test.

for reformulating the product in such way that it can target the entire population.

CONCLUSION

The use of the flash profile technique for the evaluation of spaghetti-type pasta made from different cereals allowed for a rapid sensory characterization of the product. The use of Andean corn varieties in the spaghetti's manufacture gave it a particular flavor that allowed differentiation from those of wheat and rice. CC and PC spaghetti samples showed a marked decrease in firmness and hardness with respect to wheat samples; on the other hand, its lower stickiness and friableness differentiated them from RS.

The CATA question allowed an explanation, from the point of view of the consumer, of the differences in acceptability between the celiac and non-celiac population of the corn spaghetti samples in Study 2.

Results of this study suggest that Andean corn flour, in its wholegrain form, is an adequate and acceptable product to use in the formulation of spaghetti for celiac consumers, although these should be reformulated to target a non-celiac population.

This is a rather interesting result since very few works have addressed the gluten-free corn spaghetti hedonic dimension.

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