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Maize flour parameters that are related to the consumer perceived quality of '*broa*' specialty bread

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Abstract

A wide range of quality parameters have been used to describe maize flours for food use, but there is no general agreement about the most suitable parameters for breadmaking. The objective of this study was to identify the maize flour parameters related to the consumer perceived quality of Portuguese *broa* bread (more than 50% maize flour). The influence of eleven maize landraces was assessed and compared with commercial flour using baking tests. The *broa* were evaluated by instrumental (colour, firmness) and sensory hedonic analysis with a consumer panel of 52 assessors. The *broa* sensory analysis revealed similar assessments among landraces and the lowest scores for commercial flour. The flour particle size distribution is the major influence, with commercial flour showing the highest mean diameter and a large particle distribution range. *Broa* consumer panel linkage associations and specific sensory descriptors have been identified; age as an influence on colour, cohesiveness, and source region as an influence on appearance and texture.

Keywords: *broa*; maize; bread; consumer parameters; sensory analysis.

Practical Application: Maize landrace flours have a narrow particle size distribution and a positive impact on *broa* bread quality.

1 Introduction

Portugal was one the first European nations to adopt maize (*Zea mays* L.) in its agricultural system more than five centuries ago (Vaz Patto et al., 2009). Over time, maize has become highly integrated into the Portuguese agriculture, with the development of numerous landraces (open pollinated varieties, OPV) and its integration into the daily diet as the major grain for bread making in the mid-19th century (Justino, 1988).

Broa is Portuguese ethnic bread comprised of more than 50% maize flour mixed with either wheat or rye flours and is highly consumed in the north and central regions of Portugal (Brites et al., 2010). The bread making process is primarily empirical, and several types of *broa* can be produced depending on the type of maize and blending flours, although local OPVs are usually preferred (Vaz Patto et al., 2007).

There are many recipes used to prepare *broa*, but the traditional process (Brites et al., 2007) involves adding maize flour (sieved whole meal flour), hot water, wheat flour, yeast and leavened dough from a previous *broa* (acting as the sourdough). After mixing, resting and proofing, the dough is baked in a wood-fired oven. This empirical process leads to an ethnic product highly accepted for its distinctive sensory characteristics (Brites et al., 2007) and provides an interesting source of nutritional value due to its lower glycaemic index compared to wheat bread (Brites et al., 2011).

A general consensus has been reached regarding the classification of breads according to the degree of hydration of their dough, the presence or absence of fats and instrumental analysis, including loaf weight and volume, colour and textural parameters (Matos & Rosell, 2012).

The sensory quality of bread is evaluated by the human senses of sight, smell, taste, hearing and touch (Meilgaard et al., 1999) and can be evaluated by effective (e.g., consumer preference) analytical methods (Callejo, 2011). Relationships between bread composition and instrumental evaluations have been detected (Callejo, 2011).

However, bread quality is influenced by many factors in the production chain, from grain cultivation to bread packaging (Kihlberg et al., 2006), and individual consumer perceptions may be influenced by social, demographic and product experiences, primarily in the case of traditional breads.

The aim of this study was to understand the influence of local maize landrace OPVs in *broa* quality and to contribute to the development of specific vocabulary as sensory descriptors for this type of bread. Twelve maize flours were used in baking tests, and the *broa* have been analysed by instrumental methods and evaluated by a consumer sensory panel.

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2 Material and methods

2.1. Samples

Maize OPVs samples

Eleven maize OPVs representatives of the diversity of germplasm participatory breeding program (Vaz Patto et al., 2013) were selected and reproduced in 2011 under controlled trials conducted at Agrarian School of Coimbra. The maize samples from the white type (*Algarro*, *Bastos*, *Broa 57*, *Pigarro, Sinpre* and *Verdial da Aperrela*) and yellow type (*Aljezudo*, *Amiúdo*, *Broa 213*, *Castro verde* and *Fandango*) were kindly provided by Mendes-Moreira and evaluated in baking tests to produce traditional *broa*.

Maize flours

Whole meal maize flour was obtained after milling the grain in an artisan water mill with millstones (Moinhos do Inferno, Viseu). Commercial maize flour (Nacional type 175) was also included to produce *broa*.

Maize flours particle size

Particle size distribution was characterised using the AACC method 55-40.01:1999 (American Association of Cereal Chemists, 1999), with a Malvern multi-channel laser light-scatter instrument, a medium diameter percentile setting ($d_{0.1}$, $d_{0.5}$, $d_{0.9}$) and volume weighted mean D[4.3] expressed in μm.

2.2 Bread formulations

The base *broa* formulation described previously (Brites et al., 2011), included 70% maize, 20% rye, 10% wheat flours, 2.8% sugar, 1.76% salt, 1% dry yeast and 10% sourdough (wt/wt. flour basis) and 100% (vol/wt. flour basis) water.

2.3 Baking procedures

The *Broa* bread making process described previously (Brites et al., 2011), consisted of mixing the maize flour with 80% boiling water containing 1.76% salt and kneaded for 5 minutes (Ferneto AEF035). The dough was allowed to rest and cool to 27 °C, and the remaining ingredients (sugar, salt, dry yeast, sourdough) including 20% water were added. The dough was again kneaded for 8 minutes and left to rest for bulk fermentation at 25 °C for 90 minutes. After fermentation, the dough was manually moulded into 400 g balls and baked in an oven (Matador, Werner & Pfleiderer Lebensmitteltechnik GmbH) at 270 °C for 40 min.

The *Broa* bread making process was performed using the same recipe that vary only in the maize flour used (11 OPVs and commercial flour), keeping the remaining ingredients and process identical.

The quality parameters of the twelve *broa* were measured the following day after its production by instrumental and sensory analysis.

2.4 Broa bread evaluations

Physical analysis (colour and texture)

The colour of the crumb and crust were measured at three different sample areas by using a Minolta Chromameter CR-2b. The colour was recorded using CIE with the following variables: L* – lightness, a* – hue on a green (-) to red (+) axis, b* – hue on a blue (-) to yellow (+) axis and ΔE – colour total variation relative to a white surface reference (Pineli et al., 2015). Additionally, the cylindrical coordinates hue or hue angle (h_{ab}) and Chroma (C^*_{ab}) were defined by the following equations:

$$h_{ab} = arc\tan\left(b^* / a^*\right) \quad (1)$$

$$c^*_{ab} = \sqrt{\left(\left(a^*\right)^2 + \left(b^*\right)^2\right)} \quad (2)$$

where the hue angle is the angle for a point calculated from the a* and b* coordinates in the colour space (Equation 1) and the Chroma is the quantitative component of the colour (Equation 2; Kane et al., 2003), which reflects the purity of colour in the CIELAB space.

Bread slices (25-mm thickness) were procured to determine the crumb firmness using a compression test in a texture analyser (TA-Hdi, Stable Micro Systems, Godalming, UK). The firmness (in g force) was automatically recorded (12 measurements per loaf) by the data processing software on days 1, 3 and 7 after baking according to the AIB standard procedure. Three batches of each composition were prepared, and at least five measurements were performed on each batch (Vidigal et al., 2012).

Sensory analysis (appearance, colour, odour, flavour, texture by touch and mouthfeel, cohesiveness and global appreciation)

Sensory evaluation of the *broa* samples was conducted 24 h after their production using a hedonic quantitative response scale (International Organization for Standardization, 2003) in a test room (International Organization for Standardization, 2007) with a consumer panel of 52 assessors. The hedonic test was performed using a numeric category scale from 1 (extremely unpleasant) to 8 (extremely pleasant) for the following eight attributes: appearance (aspect), colour, odour, flavour, texture (by touch and mouthfeel), cohesiveness and global appreciation from 1 (much less than ideal) to 5 (more than ideal). The assessors were volunteers recruited primarily from research and educational institutes at the Oeiras campus, and their characterisation was organised by age, gender and place of birth. The assessors were also asked to declare if they did not have gluten intolerance and were regular consumers of *broa* bread. Each assessor participated in three separate sessions, scoring four *broa* bread samples (20 g sample size) per session with the presentation order randomized between and within assessors. Tap water and apples were served as a palate cleanser between samples.

Attributes that best reflect the assessments of '*broas*' have been identified based on the comments recorded by the assessors, who referred to the bread (Callejo, 2011) and ISO 5492 definitions (International Organization for Standardization, 2008) for appearance, odour, texture and flavour. The present study was approved by the Portuguese Institute for Agrarian and Veterinary Scientific board and also of Technical Standardization Committee for cereals and cereal derivatives.

2.5 Statistical analysis

The influence of maize flours OPVs origin in the *broa* physical and sensory differences were analysed using one-way analysis of variance (ANOVA). The means were classified by Duncan's multiple-range test ($p \leq 0.05$). Any significant linkage associations between the consumer panel respondents' variables (gender, age and region of born) and level of sensory analysis response by attribute were tested using the chi-square test. Individual assessor age, region and response data by attribute were grouped on three levels (unpleasant, pleasant, very pleasant), and contingency tables, Pearson chi-square and probabilities values were calculated by crosstabs. All of the procedures were computed using the statistical package SPSS (SPSS, V. 20.0).

3 Results and discussion

The slices from the twelve *broa* samples that were produced from the 11 maize OPVs and commercial maize flour (Figure 1) show perceived differences in their colouring.

3.1 Physical analysis

Analysis of the collected data by ANOVA showed that all of the instrumental analyses were able to distinguish between the *broa* breads tested ($p \leq 0.05$).

Colour and firmness broa evaluation

Table 1 presents the means of the colour obtained in the analysis of each *broa*.

The colour of the crumb is an important parameter for characterizing bread. A lower L* value indicates a darker crumb, a positive a* value is associated with crumb redness, and a positive b* value indicates yellow colour. A strong correlation (r^2=0.993, $p<0.01$) between the maize flour and bread crumb b* colour was observed. The *broa* breads presented with a negative a* value (hue on green axis), positive b* value (hue on yellow axis), low variability in lightness and negative hue values, which reflect a yellow-greenish hue. Large variations with respect to b* and chroma values were observed between the *broa* samples (Table 1).

Castro verde, *Fandango* and *Aljezudo broa*s showed b* and chroma values higher than the other samples, which suggests their higher colour purity related to the major intensity of the yellow component.

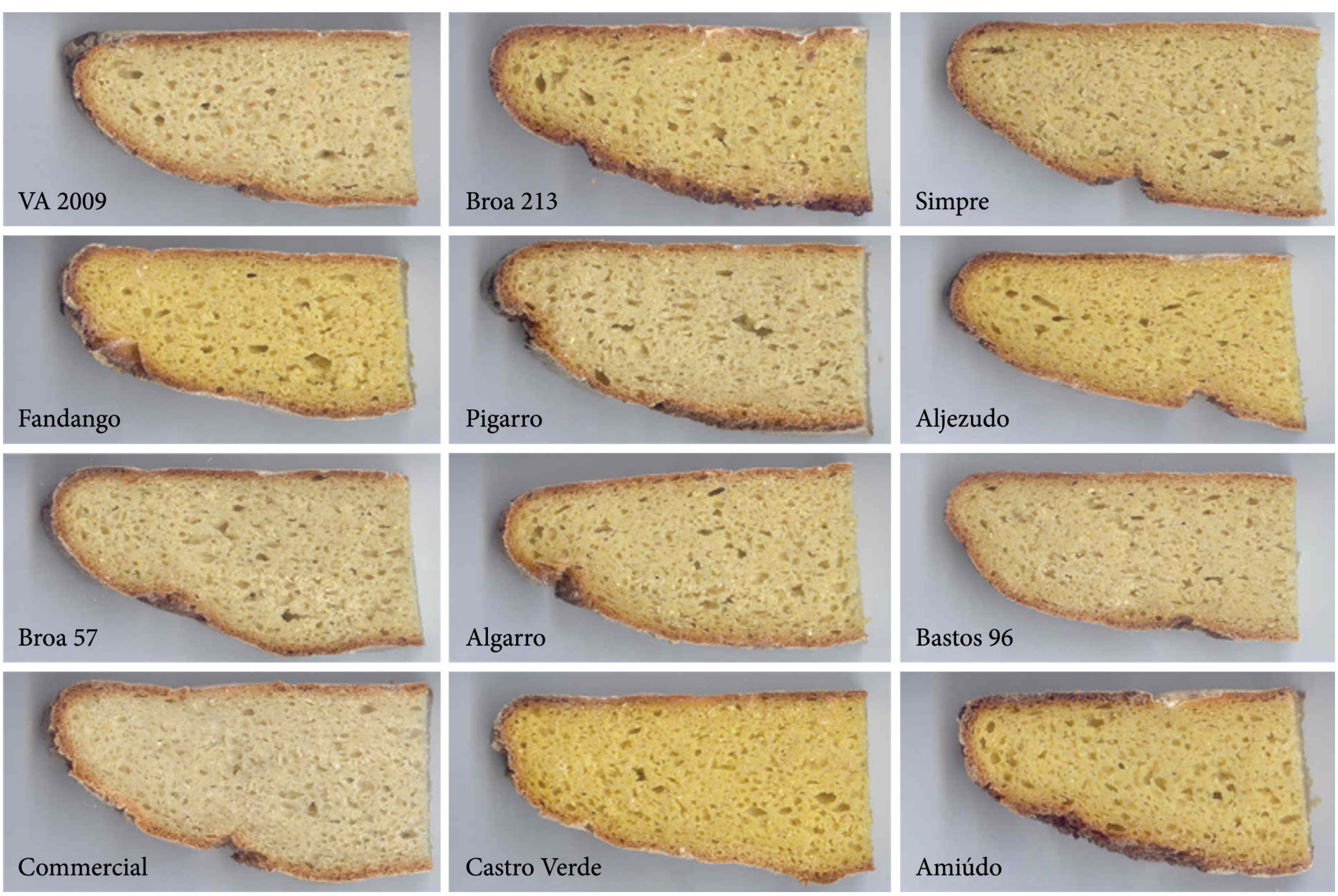

Figure 1. Images of sliced *broa* samples produced from the 11 maize OPVs and commercial flour *broas*.

Table 1. Means and Duncan test classification of the colour of the analysed *broa* samples.

	Colour bread crumb			**Chroma**	**Hue angle**
	L*	**a***	**b***	C^*_{ab}	h_{ab}
Simpre	64.6^{bcd}	-1.1^{cdef}	24.9^{e}	24.9^{e}	-1.5^{abc}
Aljezudo	63.6^{d}	-1.2^{def}	31.9^{b}	32.0^{b}	-1.5^{abc}
Bastos 96	65.9^{abc}	-0.7^{ab}	22.2^{f}	22.2^{f}	-1.5^{bc}
Amiúdo	64.4^{d}	-0.7^{bc}	29.6^{c}	29.6^{c}	-1.6^{cd}
Broa 213	65.4^{abc}	-1.3^{g}	27.5^{d}	27.5^{d}	-1.5^{ab}
Pigarro	66.6^{a}	-0.8^{bcd}	21.4^{fg}	21.4^{fg}	-1.5^{abc}
Algarro	66.0^{ab}	-1.3^{ef}	24.3^{e}	24.3^{e}	-1.5^{a}
C. Verde	65.3^{abc}	-0.3^{a}	35.5^{a}	35.6^{a}	-1.6^{d}
VA 2009	66.6^{a}	-0.9^{bcde}	20.6^{gh}	20.7^{gh}	-1.5^{abc}
Fandango	65.4^{abc}	-0.8^{bcd}	32.4^{b}	32.5^{b}	-1.5^{cd}
Broa 57	65.6^{abc}	-0.6^{ab}	20.1^{h}	20.2^{h}	-1.5^{bc}
Commercial	66.1^{ab}	-0.5^{ab}	15.1^{i}	15.2^{i}	-1.5^{abc}

Parameter values followed by the same letter are not significantly different (Duncan, $p<0.05$).

The crust colour is highly related with Maillard reactions that take place in the oven during baking, and no significant differences between *broa*s were observed.

In addition to the flour specifications and bread attractiveness aspects, the colour also has nutritional implications. Significant correlations between the b* parameter and lutein contents, an important carotenoid with antioxidant properties and beneficial nutritional effects, have been identified (Brites et al., 2013). The commercial variety *broa* is white and has the lowest b* value and lutein content (1.2 µg/g). In contrast, *broa* made from *Castro verde* presents a higher b* value due to its intense yellow colour and also shows higher lutein content (19.5 µg/g).

Crumb firmness was determined on days 1, 3 and 7, and the results obtained on days 1 and 3 show a significant increase in hardness for all of the sample breads, which is consistent with observations of other bread types (Ishida & Steel, 2014) due to the loss of freshness derived from starch retrogradation (Figure 2).

Most of the sample breads show similar crumb firmness profile from day 3 to day 7; however, the *Bastos* 96 and VA 2009 *broas* showed increased shelf lives, whereas the *Amiudo broa* shelf life was decreased. The commercial *broa* presented higher crumb firmness and longer shelf life, whereas a softer *broa* was obtained with *Aljezudo* maize variety.

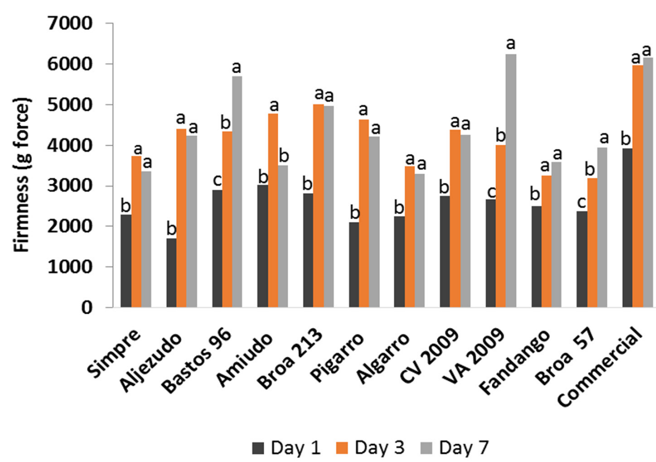

Figure 2. Means of the firmness (g force) of the *broa* sample analysed on days 1, 3, and 7 after baking; days with the same letter are not significantly different (Duncan, p<0.05).

Assessors aged between 31-50 years responded that the colour and cohesiveness were more pleasant than the younger assessors. Respondents from Lisbon and Vale do Tejo region gave higher scores for appearance and texture compared to panellists form other regions.

3.2 Sensory analysis

Profile of consumer panel assessors

The consumer panel assessors (n=52) with 23.15% males and 76.9% of females, was comprised of primarily women aged 20 to 50 years from Lisbon and the Vale do Tejo region (Figure 3).

The linkage associations between the sensory response by attribute and the consumer panel variables (gender, age, region of born) revealed significant influences of consumer age on the colour ($\varkappa^2$=10.913; p=0.028) and cohesiveness ($\varkappa^2$=15.131; p=0.004), whereas the birth region had influences on the appearance ($\varkappa^2$=10.395; p=0.034) and texture ($\varkappa^2$=16.006; p=0.003).

Scoring of sensorial attributes

According to the ANOVA results, the *broa* samples differed significantly (p<0.05) in appearance, odour, texture, flavour, colour and global appreciation. Despite this fact, the *broa* sensory analysis scores revealed poor discrimination of the different maize OPV and provided evidence that the commercial *broa* had the lowest mean scores for the evaluated attributes (Table 2).

In general, *Castro verde broa* scored higher for the majority of the sensorial attributes, but the *Fandango broa* matched the *Castro verde*'s global appreciation score while achieving the highest appearance score. Additionally, *Broa 57* recorded the highest flavour score.

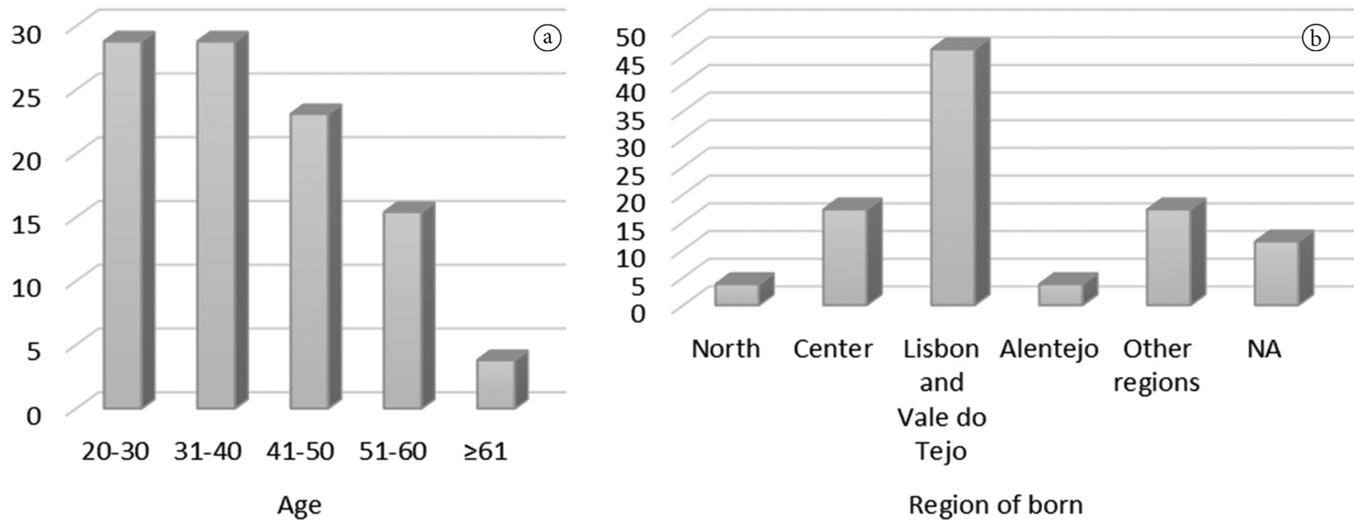

Figure 3. (a) Differentiation of the consumers based on age; (b) Region of born.

Table 2. Means and Duncan test classification for the sensory scores for appearance, odour, texture, flavour, colour, global appreciation and cohesiveness attributes of each *broa* sample analysed.

	Appearance	Odour	Texture	Flavour	Colour	Global Appreciation	Cohesiveness
Simpre	5.89^{d}	5.89^{a}	5.87^{b}	5.70^{d}	5.98^{cd}	5.64^{b}	3.08^{ab}
Aljezudo	6.47^{bc}	5.87^{a}	6.17^{ab}	6.04^{bcd}	6.70^{ab}	6.06^{ab}	3.17^{a}
Bastos	6.13^{bcd}	5.91^{a}	6.08^{ab}	6.28^{bc}	5.87^{d}	6.14^{a}	3.12^{ab}
Amiúdo	6.42^{bc}	5.98^{a}	6.30^{ab}	6.15^{bcd}	6.29^{c}	6.12^{a}	3.02^{ab}
Broa 213	6.39^{abc}	5.85^{a}	6.13^{ab}	5.96^{bcd}	6.34^{bc}	6.02^{ab}	3.04^{ab}
Pigarro	6.13^{bcd}	5.95^{a}	6.11^{ab}	6.13^{bcd}	5.87^{d}	6.00^{ab}	3.09^{ab}
Algarro	6.17^{bcd}	5.93^{a}	6.02^{ab}	5.85^{cd}	5.96^{cd}	5.87^{ab}	3.09^{ab}
Castro verde	6.72^{a}	6.20^{a}	6.35^{a}	6.17^{bcd}	6.89^{a}	6.28^{a}	3.09^{ab}
VA 2009	5.98^{cd}	5.93^{a}	5.89a^{b}	5.84^{cd}	5.75^{d}	5.89^{ab}	2.95^{ab}
Fandango	6.75^{a}	6.20^{a}	6.27^{ab}	6.20^{bc}	6.84^{a}	6.27^{a}	3.09^{ab}
Broa 57	6.97^{cd}	5.86^{a}	6.25^{ab}	6.36^{a}	5.70^{d}	6.20^{a}	3.07^{ab}
Commercial	5.34^{e}	5.39^{b}	4.89^{c}	4.67^{e}	4.98^{e}	4.54^{c}	2.82^{c}

Means followed by the same letter are not significantly different (Duncan, $p<0.05$).

Sensory quality responses

Most of the positive comments were attributed to the *broa* made from *Castro verde* variety, with comments such as *'appealing colour'*, '*nice texture*', '*ideal humidity*' and *'most tasty'*. In contrast, the majority of the negative comments were attributed to the *broa* made from commercial flour, including *'dry texture'*, 'weak *typical flavour*', '*with a weak maize flavour*', '*no history*'.

Sensory descriptors for appearance, odour, texture and flavour attributes

Table 3 summarises the proposed attributes considering the comments obtained from the 52 assessors, the visio-tactile perception and texture seems to be the most decisive criterion of consumer acceptability of *broa*. In fact, the texture of the bread crumb is related to the perception of quality (Gámbaro et al., 2002; Jensen et al., 2010).

3.3 Relationship between instrumental and sensory evaluations

Despite the hedonic sensory evaluation, strong linear relationships were observed with the instrumental colour parameters because the assessors assigned high scores to the intense yellow colours.

In Portugal, white bread consumption was preferred in the 1800s due to its association with higher social class. Anyway, any value of the enjoyment of bread colour associated with life experience and memory remains objectively unexplained (Kihlberg & Risvik, 2007).

Furthermore, concerning texture, the commercial *broa* had the highest firmness and worst sensorial evaluation, which denotes a good relationship between sensory appreciation and instrumental measurements. Similar results were reported on

Table 3. Appearance, odour, proposed attributes and related comments obtained from the consumer panel sensory analysis of the *broa* samples.

	Proposed attributes	Comments
Appearance		
Crust colour	Crust darkness	"slightly burnt crust"
Crumb colour	Whiteness/darkness of the crumb	"more white crumb"
	Crumb colour tone (yellow/red)	"yellow colour appealing/excellent"
Crumb structure	Surface texture	"hole/eyes in crumb"
	Fracturability	"tendency to crack", "pulverulent"
	Granularity	"graininess", " little rough"
Others	Smoothness of the surface	"plain crust"
	Crust smoothness	"slightly rough"
	Thickness	"thin slice"
Odour		
	Toasted	"smell of smoke"
	Overall intensity of bread aroma	"agreeable odour", "slightly aromatic"
Texture		
By touch	Softness	"soft in overused"
	Granularity of mass	"no homogeneous, poorly milled grains"
	Denseness	"very dense"
	Compactness	"very compact"
Mouthfeel	Dryness	"dry texture"
	Moisture of bread crumb	"humidity, doughy texture, wrapped"
	Adhesiveness	"sticky"
	Springiness	"malleable"
	Toughness (crust)	"hard crust"
	Cohesiveness	"little chewiness", "very chewiness"
	Granularity	"corn feel, rough texture", "grainy"
	Fibrousness	"little fibrous"
	Hardness	"soft texture"
	Crispness (crust)	"crispy crust", "little crusty"
Flavour		
	Raw grain	"feel the corn in mouth", "maize cob"
	Grain	"weak maize", "small bits of maize"
	Cereals flavour	"flour sensation in the mouth"
	Toasted (crust)	"slightly burnt crust, with burnt taste"
	Sourness	"sour taste"
	Saltiness	"low salt content"
	Bitterness	"caffeine taste in the end"
	Sweetness	"sweet taste", "little sweet"
	Aftertaste intensity	"taste remains in the mouth"
	Bland	"weak flavour"
	Flavour intensity	"great taste"
	Overall flavour	"good taste", "greedy"

wheat bread analysis by Gámbaro et al. (2002) using a texture profile analysis.

The *broa* textural properties are significantly influenced by the particle size index of maize flours. The flour particle size distribution obtained on the Malvern multi-channel laser light-scatter instrument and expressed as medium diameter percentiles (d0.1, d0.5, d0.9) and volume weighted mean D[4.3] in μm were registered (Table 4).

The particle size D[4.3] parameter of the maize flour and the firmness of the *broas* showed a positive correlation ($p<0.01$). The commercial maize flour *broa* exhibited the highest D[4.3] of 364 μm, which is on the higher end of the mean diameter distribution range, with d0.1, d0.5, and d0.9 values of 16 μm, 250 μm and 887 μm, respectively, as well as higher *broa* firmness (3920 g force, Figure 2). However, the *Fandango* flour *broa* showed the lowest D[4.3] of 211 μm and a smaller range of

Table 4. Particle size distribution of the eleven maize OPVs and commercial flour.

OPV maize flour	D[4.3]	d0.1	d0.5	d0.9
Simpre	241	20	166	532
Aljezudo	311	40	261	645
Bastos	231	30	160	508
Amiúdo	329	43	273	694
Broa 213	295	40	222	642
Pigarro	258	29	200	572
Algarro	235	20	196	509
Castro verde	243	34	202	509
VA 2009	310	24	207	746
Fandango	211	25	160	425
Broa 57	244	28	173	549
Commercial	364	16	250	887

mean diameter distribution, with d0.1, d0.5, and d0.9 values of 25 µm, 160 µm and 425 µm, respectively. Similar results were obtained with the remaining OPV maize flours.

The odour and flavour of bread is detected by the release of aromatic substances from the bread into the orthonasal route (Callejo, 2011). Sourdough fermentation that occurs during the process of baking *broa* produces more aromatic compounds and flavour components than traditional yeast leavened breads, primarily in the crumb, whereas the flavour products originating from the thermal reaction dominate in the crust (Gänzle et al., 2008).

The most potent odorants of wheat bread crumb have been identified as 2-phenylethanol (E)-2-nonenal and (E,E)-2,4-decadienal (Grosch & Schieberle, 1997), which are two aldehydes known as antioxidant products of linoleic acid and are responsible for the fatty smell. The *broa* formulation described above includes rye flour. The most intense and bread-like flavour notes of sourdough rye bread crumbs have been associated with the volatile compounds 2-propanone, 3-methyl-1-butanal, benzyl alcohol and 2-phenylethanol (Hansen et al., 1989). 2-phenylacetaldehyde has been suggested to be a key odorant for rye bread crumb and methional for rye bread crust (Schieberle, 1996).

The 2-acetyl-1-pyrroline (ACPY) is a popcorn-like key odorant evoking the roasted note of the aroma profile of wheat bread crust (Grosch & Schieberle, 1997). Different concentrations of ACPY have been identified in wheat bread crust and crumb, which might be explained by a burst of yeast cells induced by the high temperature in the crust. This might lead to a release of ornithine (the baker's yeast amino acid precursor of the ACPY) and the formation of ACPY (Grosch & Schieberle, 1997). Rye bread crust is very low in ACPY and much higher in 3-methylbutanal, methional, 4-hydroxy-2,5-dimethyl-3(2H)-furanone compared to wheat bread. These differences in the concentrations of potent odorants are most likely responsible for the differences in the overall odours of wheat and rye bread crust (Grosch & Schieberle, 1997).

A perceived sourness of *broa* is closely related with the concentrations of lactic and acetic acids primarily from sourdough lactic fermentation. The wholemeal maize flour also contributes to the acidification of sourdough and the strengthening of the rye-like flavour, which is also influenced by free phenolics acids present in the outer layers of the rye grain (Heiniö et al., 2008).

The phenolic content of maize flours and breads has been quantified using the Folin assay. Among the different maize flours, *Bastos* presented the highest free phenolic content (101.74 ± 15.67 mg GAE (gallic acid equivalents)/100 g dw) and *Amiúdo* the lowest phenolic content (66.33 ± 1.85 mg GAE/100 g dw). These results are in agreement with the values reported by Lopez-Martinez et al. (2011) for white maize samples and higher than the values described by Mora-Rochin et al., 2010, who reported a total phenolic content (free and bound phenolics) between 137.7 and 167.4 mg GAE/100 g dw. As far as *broa* is concerned, the *Aljezudo* 2006 maize variety showed the lowest phenolic content (152.16 ± 3.04 mg GAE/100 g dw) and *Broa 57* the highest content (225.08 ± 28.10 mg GAE/100 g dw). However, the sensory analysis of these *broa*s shows assessments of spicy, slightly sour and bitter in the *Aljezudo* 2006 *broa* and no relevant flavours for *Broa 57*. In fact, the phenolic content quantified by Folin are the free compounds, which are soluble in the extract, but other phenolic compounds present in maize flours are bound, and the insoluble compounds (Mora-Rochin et al., 2010) are released to some extent during baking and are likely responsible for the differences in the flavour detected.

3.4 Sensory panel profile vs comments recorded

As a result of analysis of the panel profile and comments recorded by the 52 assessors, we observed that most *broa* consumers are traditional by nature whose values are connected to food choice motives, such as 'familiarity', 'natural content', 'ethical concern', where to some extent a preference is the result of personal experience (Pohjanheimo et al., 2010). Consumer perceptions of *broa* involve to a large extent personal experiences, interactions between sensory signals and feelings. What is remembered and not just what is consciously perceived during the moment of eating is the reason for the difficulty to identify, describe and access specific words for odours and flavours.

Broa has a dense texture with higher degree of mastication resistance, which is likely to negatively influence its consumption by hedonistic consumers who prefer bread with higher smoothness, elasticity and juiciness. However, for traditional consumers, *broa* is 'familiar', and strategic market communication should combine this affinity value with the fact that *broa* consumption should be highly recommended because of its beneficial effect on satiety and health (Brites et al., 2011).

4 Conclusions

The results obtained depict that *broa* made from commercial maize flour have lowest mean score for all the attributes, the reason being related flour particle size distribution as commercial flour had highest mean diameter and large particle distribution range.

This study is a first known approach of consumer perceived product characteristics of *broa*, with correlations observed for age and the birth region, and the definition of specific attributes for *broa* appearance, odour, texture and colour.

The *Castro verde* landrace variety was best among all the varieties tested for *Broa* making and should be indicated for eventual protected geographical indication.

The traditional consumers highlighted the poor quality of commercial flour and memory values associated with *broa* quality. This is useful knowledge for marketing communication design where values may be used as a tool to stimulate sustainable *broa* production and consumption.

This study showed that texture is the most relevant attribute for consumer acceptability of specialty maize bread broa and is associated with the flour particle size distribution, which depends on the maize type. These results are relevant to the use of maize flours in breadmaking as in gluten free formulations.

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