Quality Characteristics of Maize Flours and Breads

Paula M. R. Correia
Department of Food Industry, CI&DETS/ESAV, Polytechnic Institute of Viseu, Viseu, Portugal
Email: raquelguine@esav.ipv.pt

Andreia M. Soares
Department of Food Industry, Agrarian School of Viseu, Viseu, Portugal
Email: asoares@gmail.com

Carla Brites
Instituto Nacional de Investigação Agrária e Veterinária, Oeiras, Portugal
Email: carlambrites@mail.telepac.pt

***Abstract*—In this work the effect of different maize flours used for bread production was evaluated, considering their quality characteristics. Traditional maize breads (*broas*) were produced using yellow maize and white maize, both commercial flours and produced by local maize landraces. Flours were chemical and rheological characterized. *Broas* were evaluated considering the moisture, water activity (a_w), hardness, color and sensorial characteristics. Moisture, a_w and amylose content of flours presented similar values, with yellow flours presenting the high value of δ-tocopherol (0.49 µg/g). Commercial maize flours presented high temperature and peak viscosity, with less gel stability after cooling. At the end of pasting process, the regional maize flours produced firm, stable and cuttable gels. The maize breads presented low moisture (8.4-10.2%), being the white commercial *broa* the one with higher a_w (0.56). The b* coordinate for color was higher in the yellow *broas*. The white maize breads were harder, and the hardness increased with storage time for all samples. The sensorial appreciation showed similar cohesiveness for all *broas*, but for the other evaluated parameters there were differences between them, being the most appreciated bread the one made with the yellow regional maize landrace flour.**

***Index Terms*—maize flour, bread, chemical characteristics, color, texture, sensorial properties**

I. Introduction

Bread is among the most common foods prepared through fermentation and is a major food for mankind; thus, breadmaking is one of the oldest processes known [1].

Broa is a typical ethnic Portuguese maize bread, highly consumed and appreciated, especially in the central and north zones of Portugal [2], [3]. Bread making process is mainly empirical, following ancient manufacturing protocols, and several types of *broa* are produced depending on maize types and blending flours and usually local maize landraces are preferred [4]. Stone wheel mills moved by water or wind, and nowadays usually by electricity, are used traditionally to obtain maize flour for breadmaking. The traditional process for bread production is empirical and leads to an ethnic product highly accepted by the consumers because of its distinctive sensorial characteristics, mainly the flavor and unique texture [5]. The same authors mention that, in Portugal, maize flour is used in combination with rye flour to produce broa, a home-baked sourdough bread. Dough for *broa* is obtained by mixing mayze and rye flours with water, salt, and soured via given small amount of previously fermented dough. *Broa* has an average weight of approximately 1,5kg, but it can vary between 1kg and 3.5kg, usually it has a circular to ellipsoidal format, a round top and a flat basis, being the thickness crust with 1-2cm.

Maize (*Zea mays* L.) plays a major role in nutrition in many countries. Maize is together with rice and wheat, the most cultivated cereal in the world, regarding the cultivation areas and total production [6]. Maize is widely used for human nutrition as a source of flour, starch and oil. Maize is used in several food products, such us bread, tortillas, snacks, beverages, pancakes, porridges [7]. In the production of bread, it is also used as wheat flour replacement. Maize is a gluten-free cereal, which is suitable to produce foods addressed to celiac patients. People with this disease are intolerant to certain peptides present in gluten, found in the wheat, barley and rye flours. The only treatment is to follow, throughout life, a gluten-free diet. Thus maize flour, apart from other cereals, pseudo-cereals flours, and starches, could be used to produce gluten-free products, such as breads. These materials presented lower costs and greater availability, when compared to others. Moreover, few studies have deepened the influence of the properties of different gluten-free flours in the production of breads [8].

The aim of this work was to study the influence of different types of maize flours in *broa* breads. Four types

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of maize flours were used and they were analyzed for moisture, water activity, protein, ash, fiber, fat, starch, amylose content. These flours were used to elaborate breads which were evaluated for moisture, water activity, color, hardness, and sensorial characteristics.

II. Materials and Methods

A. Samples

Yellow and white maize flours were obtained from local farmers, in Arouca region of Portugal, and it was also used commercial flours (yellow “A ceifeira” from Atlanticmeals factory, and white “Farifina” from Carneiro Campos & C Lda factory).

All reagents were analytical grade.

B. Physico-Chemical Analysis of Maize Flours

The moisture content of flours was determined by oven drying [9]. Water activity was determined by a hygrometer (Rotronic) and five determinations were made. Protein, ash, amylose, fat and fiber were determined by NIR (Near Infrared Reflectance), with a wave length between 0.7 and 1.0µm and by using maize calibration kit (Bruker), using a quartz cell. Approximately 10g of flour sample was put inside that cell and the sample was compressed at 2000g.

Tocopherols were determined by using the method described in ISO 9936 (2006) norm.

Viscosity profiles of maize flours suspensions where obtained with a Rapid Viscosity Analyzer (RVA, Newport Scientific, Australia), at 15% solids, using the following conditions: heating range from 0 to 50℃ (2 minutes), continuous heating until 95℃ (4 minutes) holding temperature at 95℃, during 5 minutes, cooling from 95℃ until 50℃ (4 minutes), holding temperature at 50℃, during 10 minutes. The speed rotation programmer applied was: during the first 10 minutes 960 rpm, after that it was applied 160 rpm.

C. Preparation of Maize Breads

Breads were prepared from both commercial and self-milled flours according to the procedures followed in rural areas in Arouca region.

The traditional maize bread formulation for all breads was: 1000g of maize flour, 100g of rye flour, 7 g of salt, 600 ml of water and 100g of sourdough (leavened dough from the late *broa*), previously prepared. Water was heated (95℃) and all the ingredients were manually mixed during 15 minutes. After the dough rest 1h, to ferment. Simultaneously, a traditional wood-fired oven is heated, until the tiles were white, meaning that the oven is ready. After fermentation, the dough was placed in a *escudela* (a special and appropriate bowl), and the definite bread form was given, then the breads were cooked in the wood-fired oven during 3h.

D. Analysis of Broa Color

Color was determined using a handheld tristimulus colorimeter (Chroma Meter - CR-400, Konica Minolta) calibrated with a white standard tile. A CIE standard illuminant D65 was used to determine the CIELab Cartesian coordinates: L*, a* and b*. L* denotes lightness or brightness, ranging from zero (black) to 100 (white), a* and b* are the opposing color coordinates, with a* ranging from -60 (green) to +60 (red) and b* ranging from -60 (blue) to +60 (yellow) [10].

E. Evaluation of Texture

Texture Profile Analysis (TPA) to all the samples was performed using a Texture Analyser (model TA.XT.Plus). The texture profile analysis was carried out by one compression cycle, using a flat 25mm diameter plunger (P/25) and a 10kg force load cell. The test speed was 1.7mm/s. For the analysis it was necessary to cut the broa in 1cm thickness slices. Two slices where placed in the texturometer platform. Twelve replicates were performed.

F. Sensorial Evaluation

Sensory analysis was performed in a laboratory prepared for that purpose, on the day of delivery of the samples by a panel of 23 untrained tasters, aged between 23 and 63 years, who were asked to rate the following attributes: appearance, color, aroma, taste, texture, cohesiveness, and finally the overall appreciation. In this test the taster expressed the intensity of each attribute through a scale where verbal Hedonic expressions are translated into numeric values in order to allow statistical analysis. The scale of values varied from 1 (extremely unpleasant) to 8 (extremely pleasant).

III. Results and Discussion

A. Flours Characteristics

The moisture and water activity (a_w) are important factors for food storage. The results shown that moisture content and water activity values are low, being the white regional flour the one with higher value (0.56) (Table I and Fig. 1), meaning that the water present is not available to react with other components of bread matrix and also the possibility of fungi development is not a concern.

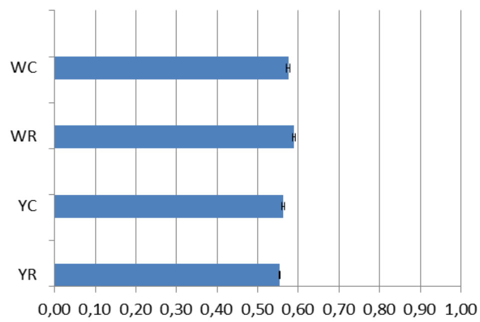


Figure 1. Water activity of maize flours (Y- yellow; W-white; R-regional; C- Commercial).

The major chemical component of maize flour is starch, being the high value presented by the commercial yellow flour (Table I). After starch the next largest chemical component is protein. However, its quality is poor due to the low contents of the two essential amino acids, tryptophan and lysine, and the high concentration of leucine, which causes imbalance of amino acids [6]. Fat content are quite high for traditional maize flour, but lower than other maize flours [11] [12]. Fiber content is similar for all the maize flours, except for the yellow commercial flour probably due to the technological process used for flour production. Generally, the yellow commercial maize flour showed the low values for protein, fat, ash and fiber. Some authors mention that some nutrients could be removed or altered through home, small-scale industry or big factories processing [7].

TABLE I. ROXIMATE COMPOSITION OF MAIZE FLOURS

Sample	Moisture (%)	Protein (% DWB)	Fat (% DWB)	Ash (% DWB)	Fiber (% DWB)	Starch (% DWB)	Others (% DWB)
YR	12.1a	10.5b	6.1c	0.9c	3.8b	68.5a	10.3b
YC	12.2a	8.5a	2.8a	0.2a	1.2a	79.0c	8.3a
WR	12.5a	11.2b	6.4c	0.8c	3.7b	68.1a	9.9b
WC	11.5a	9.4ab	4.8b	0.5b	3.1b	70.8b	11.5c

Y-yellow; W-white; R-regional; C-commercial. Values are means. Values in the same column with different letters are significantly different at P≤0.05. DWB- dry weight basis.

From the results it is possible to verify that over half the mass of flour maize is carbohydrates, predominantly starch (Table I). The commercial flours presented the higher values. Starch, which is stores in the form of water insoluble granules, is composed by two types of α-glucan: amylose and amylopectin [13]. The white regional maize flour presented the highest value of amylose, and the white commercial flour the lowest (Fig. 2). The differences encountered in starch and amylose contents could be due to the different varieties of maize used for flour production.

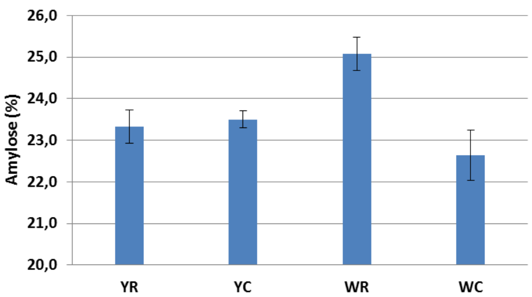


Figure 2. Amylose content of maize flours (Y-yellow; W-white; R-regional; C-commercial).

Maize contains bioactive phytochemicals such us carotenoids, tocopherols and phenolic compounds, which the most important chemical property is their ability to act as antioxidants [14]. Corn kernels contain α- and γ-tocopherols, as well as low amounts of δ-tocopherol, being the most prominent tocopherol the γ-tocopherol, followed by α-tocopherol [15]. These tendencies are in accordance with our results (Fig. 3). The yellow regional maize flours presented the high value of γ-tocopherol, and the less value is presented by the yellow commercial flour. The commercial flours presented high values of α-tocopherol. In spite of these, it is known that these phytochemicals are located mainly in the embryo, aleurone and pericarp of maize kernel, and a small percentage of these compounds are present in the free form, which is one of the major problems associated with maize-based foods [14].

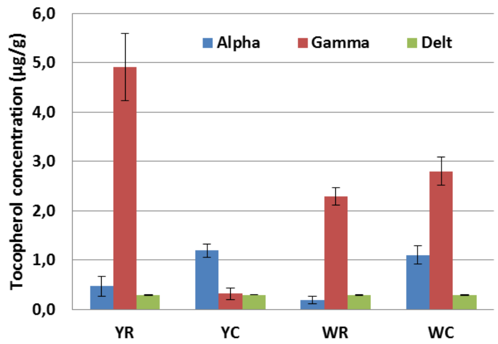


Figure 3. Tocopherols content of maize flours (Y-yellow; W-white; R-regional; C-commercial).

Some authors mention that the results of proximate analysis of maize flours are quite similar for the respective maize breads [6]. Thus it is expected that the *broas* had similar proximate composition as the respective maize flours.

Gelatinization is an order-disorder phase transition which involves the diffusion of water into the starch granules, hydratation and swelling, during heating, with loss of starch granules crystallinity and birefringence, and amylose leaching. The resulting changes in starch after gelatinization are called pasting [16]. The viscosity profile of the four maize flours during the heating and cooling cycles is showed in Fig. 4. The commercial flours presenting high peach viscosities, lower pasting temperatures, and lower final viscosities, beginning the gelatinization process earlier. Similar results were obtained for white and yellow hybrid maize [17]. The peak viscosity and temperature indicate the water binding capacity of the starch, and only intact swollen granules can give high paste viscosity [18]. Furthermore, the paste viscosity is highest when the majority of intact and swollen starch granules are present in the cooking medium [19]. Thus, these statements induce to the conclusion that the commercial flours presented a low degree of starch damage, which can be caused by the milling process used for flour production [17]. During cooling, reassociation between starch molecules, mainly amylose, resulted in the formation of a gel structure and an increase in viscosity before reaching the final viscosity. At the end of pasting process, the viscosity of regional maize flours was higher for regional maize flours. This could be due to the high amylose contents and/ or the capacity of amylose molecules to aggregate, resulting in the formation of a strong gel when cooling [18], which produce a paste that will set into a firm and cuttable gel [19].

The breakdown is another property present in pasting flours. It is a measure of the ability of a swollen granule in the starch past to resist thinning when it is subject to a prolonged heating and mechanical shear, reflecting the successive degree of granular swelling and friction between swollen granules [20]. Moreover, the breakdown gives an indication of paste stability [18]. Our results revealed that commercial maize flours showed the high values for breakdown, meaning that they were less stable when subject to heating at high temperatures and shear stress rates. Furthermore, the ability of starches to withstand heating at high temperatures and mechanical shear is an important factor in many processes [21].

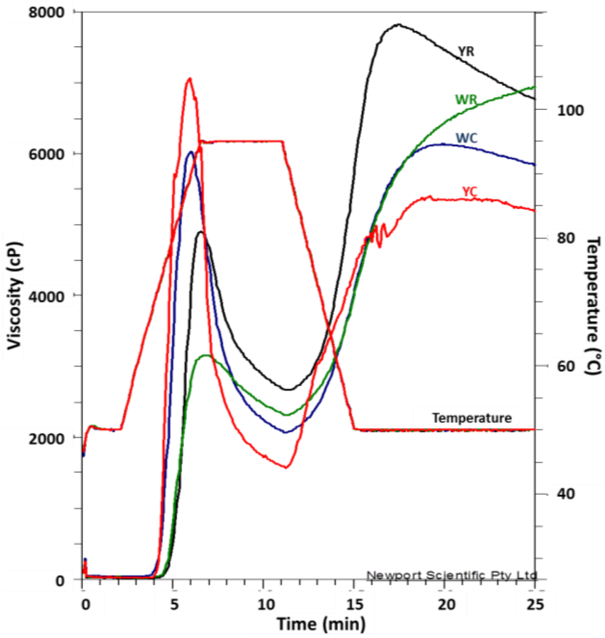


Figure 4. Viscosity profiles of maize flours (Y-yellow; W-white; R-regional; C-commercial).

B. *Quality Characteristics of Maize Breads*

The moisture content of *broas* are lower than 10.2% (white commercial *broa*) and higher than 8.4% (yellow regional *broa*), with low a_w, less than 0.56, which is a guaranty for breads long preservation period (Fig. 5). Comparing with the moisture and a_w values of flours, it is possible to verify that maize breads presented low values of moisture and similar values for a_w.

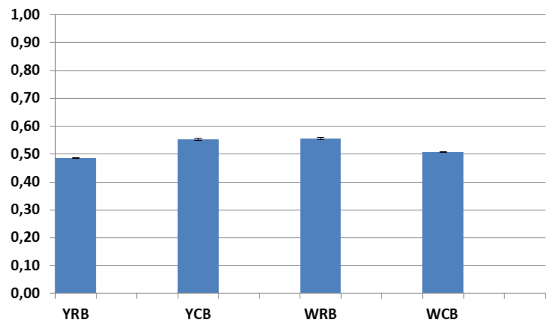


Figure 5. Water activity of maize breads (B-Broa, Y-yellow; W-white; R-regional; C-commercial).

The appearance of the maize breads is showed in Fig. 6.

The maize breads produced with the commercial flowers showed high values of hardness, and this parameter increase during storage time for all samples, presenting similar profiles (Fig. 7). Generally, the differences in hardness during storage time were quite different, probably due to the retrogradation of starch.

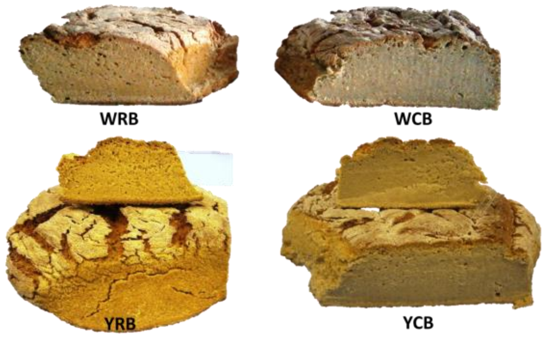


Figure 6. Appearance of maize breads (B-Broa, Y-yellow; W-white; R-regional; C-commercial).

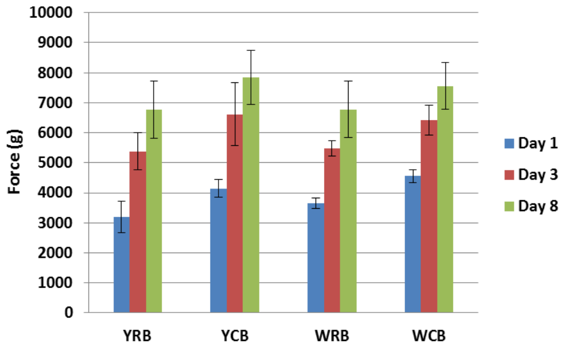
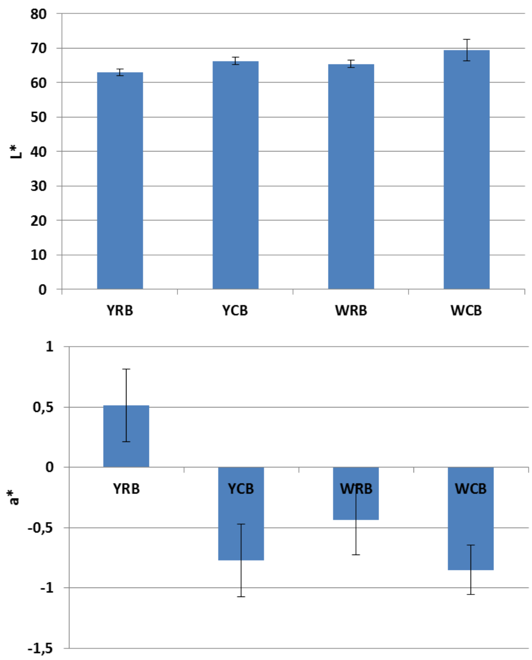


Figure 7. Hardness of maize breads (B- Broa, Y-yellow; W-white; R-regional; C-commercial).

The results of color coordinates of the crumb are presented in Fig. 8. The maize breads presented the luminosity between 63 and 69.4, being the yellow regional *broa* the darker one and the lightness the white commercial *broa*. The a* values are similar, ranging from +0.52 to -0.85, with no predominant color of green or red. As expected the yellow maize breads presented b* values higher than the white ones, and the predominant yellow color was showed by the yellow regional maize bread.



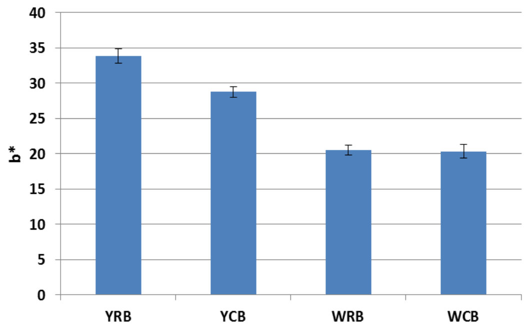


Figure 8. Color coordinates (L*, a*, b*) of the different broas analyzed (B-Broa, Y-yellow; W-white; R-regional; C-commercial).

The sensorial analysis results of the *broas* are presented in Fig. 9. Generally, the maize breads produced with white maize flours presented similar scores, and quite different from the yellow ones, being the last ones more appreciated. The cohesiveness of the samples was low and similar, and the other parameters were different. The yellow regional *broa* showed the high shores, with a global appreciation of 6.2, meaning that this *broa* was pleasant to very pleasant for the consumer.

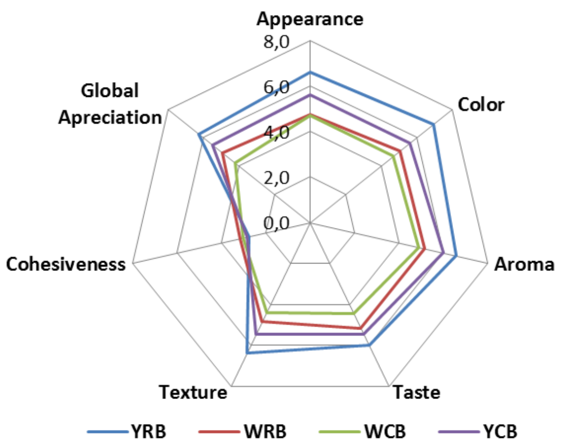


Figure 9. Sensorial evaluation of maize breads (B-Broa, Y-yellow; W-white; R-regional; C-commercial).

IV. Conclusions

The type of maize flour influenced significantly the quality characteristics of *broas*, and this is quite noticed by the consumers. The moistures and the water activity in maize flours and breads were low, meaning that they can be preserved for a long period of time. The proximate composition of the maize flours was different and the yellow commercial flour showed the low values for protein, ash, fat and fiber, and presented the high values of starch. The yellow regional maize flours presented the high value of γ-tocopherol, and the less value is presented by the yellow commercial flour. The commercial flours presented high values of α-tocopherol. It was observed that the pasting properties of maize flours were also quite different. The commercial maize flours presented a high peak and temperature viscosity, and start the gelatinization process earlier. This means, that they presented less damage in starch granules probably due to milling process used to produce commercial flours. On the other hand, the regional maize flours produced strong, stable and cuttable gels after cooling. These differences will influence the maize breads produced with these flours. The maize breads presented the luminosity between 63 (yellow regional *broa*) and 69.4 (white commercial *broa*), with the predominant yellow color showed by the yellow regional maize bread. The hardness of breads increased with storage time, and the *broas* produced with commercial flours showed high values. The cohesiveness was considered by the panelists very similar for all breads. The yellow maize breads were more appreciated by the consumers, and the regional one presented the high global score, 6.2.

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Paula Correia was born in Morfortinho, Portugal, on 17th of April 1967. She is graduated in Agro-Food Engineering (1992), Master in Food Science and Technology (1996), and doctor in Food Engineering (2011), all by University of Lisbon, Portugal. Experience in food science and technology field, mainly in food conservation and processing; cereal and starch technology; food drying; food quality and safety; food composition and analysis

She is a professor in Agrarian High School of Polytechnic Institute of Viseu, Portugal, and also a researcher in the Agrarian, Food and Veterinary Sciences group in the research center CI&DETS (Viseu, Portugal). She was the institutional leader of one international project, COMPASS (Leonardo da Vinci transfer of innovation project), and one national project, AGRO 448. She also participated in other 2 EU and 3 national projects. She is author/co-author of 2 books, 5 book chapters, 26 papers in peer-reviewed journals (H-index 9, 283 citations) and more than 50 papers in conferences. She is a co-editor of 1 book. She has experience in supervision of Master students (8 finished, 2 in progress). She has been member of the Editorial boarder of Millenium Journal. She is a regular Referee of several scientific journals. (http://orcid.org/0000-0002-2023-4475).

Prof. Correia is a member of ISHS (International Society of Horticulture Science), and Portuguese Engineer Order and Portuguese Chemical Society.