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Proceeding Paper

Gluten-Free Breadmaking with Extruded Whole-Grain Andean Maize Flours †

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Abstract: Andean maize can be safely used in gluten-free bread formulation. Extrusion is a technology capable of promoting changes in the techno-functional properties of gluten-free flours, modifying their breadmaking properties. The objective of this study was to evaluate the effect of extrusion on the physical and physicochemical properties of Andean maize whole-grain flours (*bolita* race) and to determine the relationship between the changes to the textural properties of gluten-free dough and bread with the addition of extruded flours. The Andean maize whole-grain flours were extruded in a single-screw extruder. The moisture, temperature and screw speed were varied through an incomplete orthogonal design. The expansion degree of extruded products, the total soluble carbohydrates, and the gelatinization degree of the flours varied mainly with moisture and temperature extrusion. Flours with high, medium, and low degrees of gelatinization treatments were added at 20 % to native flours to make gluten-free dough and bread. The dough made with the addition of extruded flours increased their firmness and adhesiveness in relation to the control made with native flour alone. Bread made with extruded flours generally increased their hardness, gumminess, chewiness, and cohesiveness. Springiness only increased under conditions of high and low degrees of gelatinization. The dough made with extruded flour at the extruded condition of 100 °C-25%H-120 rpm, with the lowest degree of gelatinization, were the least firm and adhesive, which could lead to better dough machinability. Additionally, the bread made with this flour presented high cohesiveness and springiness.

Keywords: Andean maize; bread; extrusion; gluten-free; whole-grain flours

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1. Introduction

In the Puna and Quebrada of Humahuaca, there are several varieties of Andean maize which possess different nutritional and physicochemical properties. Andean maize can be used in the production of gluten-free foods because of the absence of prolamines, a gluten-forming protein fraction that affects celiac patients [1]. Generally, gluten-free bread has defects such as low volume and poor texture because of the gluten absence; gluten acts as a structural support that allows the dough to expand during proofing [2]. Additionally, gluten-free bread is usually formulated with refined flours or starches with low nutritional value, to which technological enhancers such as hydrocolloids are added [3]. Therefore, gluten substitution continues to be a challenge for food technologists.

Whole-grain flours compared to refined ones have more nutrients and dietary fiber. The type of fiber present in flours can affect the stability of the dough and make it difficult to obtain gluten-free bread of good technological quality [4]. Extrusion cooking has been used to modify the techno-functional properties of starchy and high-fiber raw materials. This technology has been applied to gluten-free flours to obtain technologically improved bread with acceptable results [5]. However, few have studied the effects of extrusion on the breadmaking properties of Andean whole-grain flours.

The objective of this study was to evaluate the effect of extrusion on the physical and physicochemical properties of whole-grain flours of Andean maize (*bolita* race) and to determine the relationship of these with the changes in textural properties of gluten-free dough and bread due to the addition of extruded flours.

2. Materials and Methods

2.1. Materials

Andean maize (*bolita* race) grown in the Ocumazo-Humahuaca province of Jujuy was used. The grains were milled in a hammer mill to obtain whole-grain flour with grain size <710 µm. The whole-grain flour was extruded in a Brabender single-screw extruder with a compression ratio of 3:1, 3 mm nozzle, at temperatures of 100, 120, and 140 °C, moistures of 15, 20, and 25%, and screw speeds of 80, 100, and 120 rpm, using an incomplete orthogonal design.

2.2. Extruded Material Characterization

The expansion degree (ED) of the extruded products was determined as the ratio of the diameter of the expanded product and the diameter of the extruder nozzle [6]. Ten replicates of diameters of the expanded products were determined.

The total soluble carbohydrates (TSC) of the extruded flours suspension supernatants were measured using the phenol-sulfuric method according to Taylor (1995) with modifications in the preparation of samples [7]. A calibration curve was established using pure xylose solutions as standards, processed by the same procedures. The measurement was carried out in triplicate.

The gelatinization degree (GD) of the extruded flours was determined according to the method of Baks (2007) with modifications in the preparation of samples [8]. The measurement was carried out in triplicate.

2.3. Bread Preparation

The lactal bread was made with whole-grain native maize flour substituted with 20% extruded flour; initially, the flours were mixed for 1 min to achieve homogenization of the samples. For every 100 g of substituted flours, 110 mL of spout water (30 °C), 1 g of previously activated commercial dry yeast, 1 g of salt (NaCl), 2 g of sugar, 3 g of powdered milk, and 6 mL of oil were added and mixed at low speed for 5 min. The dough obtained was put in molds and placed in a fermentation chamber 50 min at 30 °C and 80–90% relative humidity. The fermented dough was baked at 150 °C for 50 min, and textural properties were immediately determined. The bread was evaluated 24 h after baking.

2.4. Textural Properties of Gluten-Free Dough and Bread

The gluten-free fermented dough and bread texture profile analysis (TPA) was performed using a texture analyzer (TAXT plus, Stable Micro System, Godalming, UK) equipped with a 5 kg load cell. A Teflon cylindrical probe with a P/0.5 (12.7 mm) was used for dough, and 25% deformation and a 20.0 s waiting time were used. The test speed was set to 5.0 mm/s. An aluminum cylindrical probe with a P/35 (35.0 mm) was used for bread; samples from the center of the bread (thickness of 10 mm) were compressed to 50% of their original height. The test speed was 1 mm/s and the waiting time was 5.0 s. The measurements were made in quadruplicate.

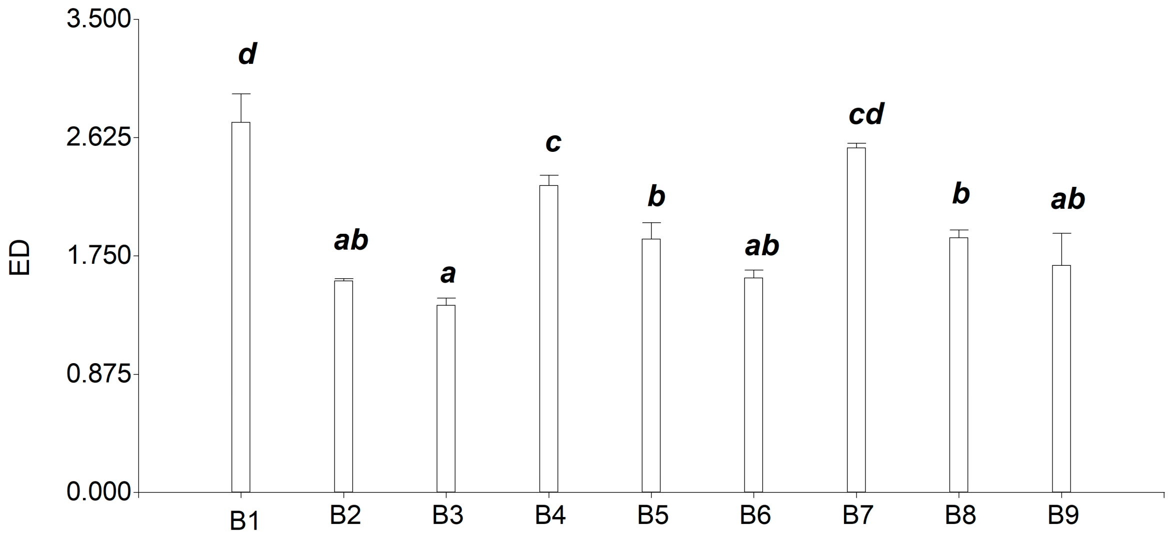
2.5. Statistical Analysis

Data were analyzed using INFOSTAT software. The significant difference between the means was evaluated by Tukey's test ($p < 0.05$) using analysis of variance (ANOVA). Data on the textural properties of the gluten-free dough and bread formulated with the addition of extruded flours (preselected conditions) were summarized in a principal component analysis.

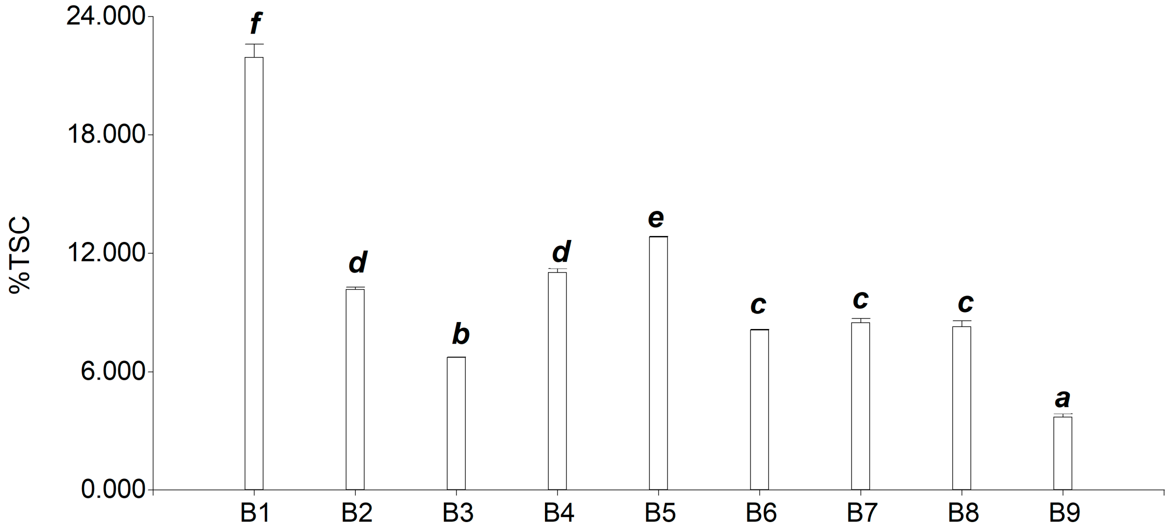
3. Results and Discussion

3.1. Properties Physical and Physicochemical of the Extruded Material

Figure 1A shows the ED of the maize (*bolita* race) extrudates; it varied between 1.68 ± 0.24 and 2.74 ± 0.21, with the highest value at 100 °C-15% H-80 rpm. ED showed a tendency to decrease with the increase in extrusion moisture at different temperatures. This variation was only significantly different between extruded samples at the same moisture between 15 and 20% and 100 and 120 °C; the most important effect was the moisture. A similar trend was found by Byars (2015) in mixtures of degermied corn flour with chia [6].

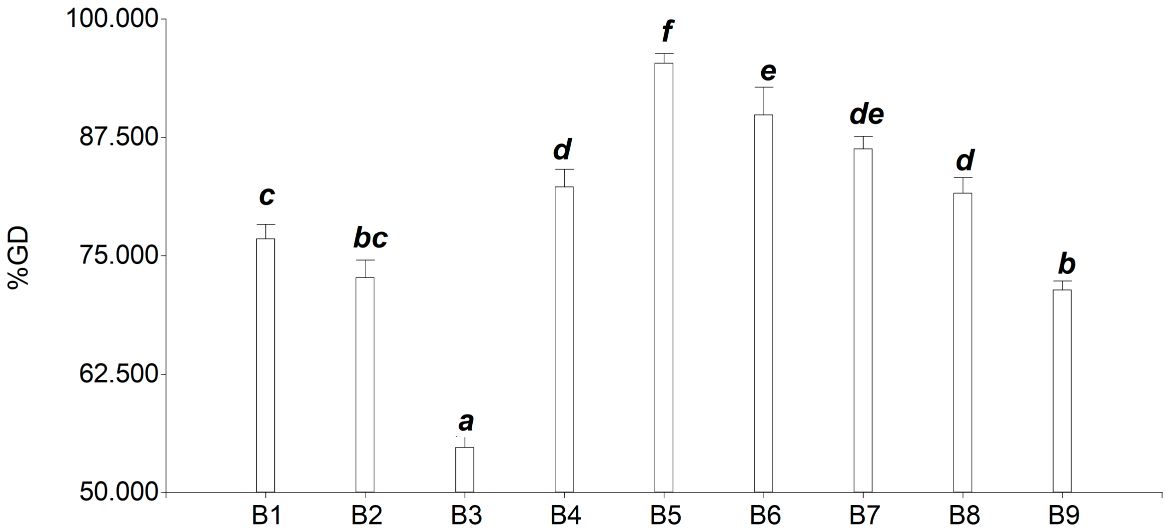


(**A**)



(**B**)

Figure 1. *Cont.*



(**C**)

Figure 1. (**A**) Expansion degree of extruded products. (**B**) Total soluble carbohydrates of the supernatants and (**C**) gelatinization degree of the extruded flours of Andean maize (*Bolita* race). B1:100 °C-15%H-80 rpm; B2:100 °C-20%H-100 rpm; B3:100 °C-25%H-120 rpm; B4: 120 °C-15%H-100 rpm; B5:120 °C-20%H-120 rpm; B6:120 °C-25%H-80 rpm; B7:140 °C-15%H-120 rpm; B8:140 °C-20%H-80 rpm; B9:140 °C-25%H-100 rpm.

Figure 1B shows the variation of the content of the TSC present in the supernatant of suspensions of extruded flours in water (3.68 ± 0.18 to 21.95 ± 0.68%). The extruded flour at 100 °C-15% H-80 rpm presented the highest content of TSC. A tendency to decrease the content of TSC was observed with increasing extrusion moisture, which was more pronounced at 100 °C. The difference was significant between extruded samples at the same moisture level at the different temperatures, which suggests a greater influence of the extrusion temperature on this parameter. The TSC content was not affected by screw speed.

The content of TSC in the supernatant of suspensions of flours extruded in water was determined due to the increase in the water solubility index of these samples with respect to the native flour (data not shown). The flour extruded at low extrusion temperatures (100 °C and 120 °C) had a high DE and a higher content of TSC in the supernatants of the suspensions. This indicates the degradation of complex carbohydrates during extrusion. These results agree with those of Sarifudin (2014), who indicated that there is greater degradation at low extrusion moisture due to shear [9].

The GD of the extruded flours is shown in Figure 1C. This parameter increased at equal moisture levels at temperatures of 100 and 120 °C. The highest GD was observed at 120 and 140 °C; the greatest was at 120 °C-20% H-120 rpm. No trend was observed regarding the variation of this parameter with screw speed.

To carry out the breadmaking tests, the extruded samples that were significantly different in terms of the parameters studied were selected: B1 (100 °C-15%H-80 rpm) with an intermediate GD, high TSC content, and high ED; B3 (100 °C-25%H-120 rpm) with a low GD, low TSC content, and low ED; B5 (120 °C-20%H-120 rpm) with a high GD, intermediate TSC content, and intermediate ED.

3.2. Textural Characteristics of the Doughs and Bread Gluten Free

Figure 2 shows the principal component analysis of the physical–physicochemical properties of the extruded flours B1, B3, and B5, and the textural properties determined in the dough and breads added with these flours. A positive correlation was observed between the adhesiveness of the dough, the ED, and the content of TSC. The hardness, springiness, gumminess, and chewiness showed a negative correlation with the ED and the content of TSC. The cohesiveness showed a negative correlation with the GD. In general, the GD did not show a correlation with the textural properties.

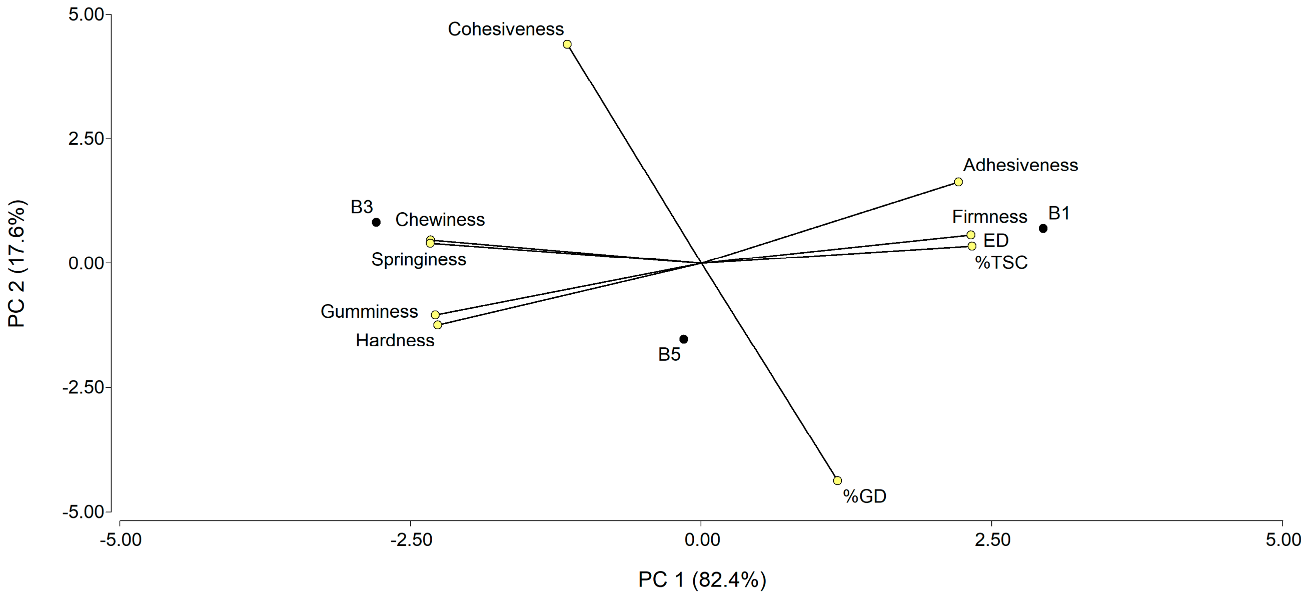


Figure 2. Principal component analysis of textural properties of the gluten-free doughs and breads made from native flours added at 20 % of the B1:100 °C-15%H-80 rpm, B3:100 °C-25%H-120 rpm, and B5:120 °C-20%H-120 rpm.

The dough increased its firmness between 67.7 and 91.9% compared to the native flour control (9.93 g). The firmness was higher in the dough made with extruded flours with contents high in TSC and intermediate ED (B1 and B5); the dough made with flour with a TSC and a low ED (B3) presented the lowest firmness of the three preselected flours. The adhesiveness increased between 129.5 and 268.9% in relation to the control (3.73 gs); the dough made with B3 showed the lowest value. The dough made with B3 presented textural characteristics that could facilitate its handling during the breadmaking process.

Breads made with the addition of extruded flours increased their hardness (107.4–194.7%), cohesiveness (36.6–43.3%), gumminess (78.3–163.6%), and chewiness (54–186.9%) with respect to the native flour control. Condition B3 presented the highest increases in the parameters mentioned above. Springiness increased by 10.3% in this condition alone compared to the control. Greater cohesion and elasticity could positively contribute to the acceptability of bread by consumers.

4. Conclusions

Extrusion modified the physical and physicochemical properties of whole-grain Andean maize (*bolita* race) flours, with a greater effect of moisture and temperature of processing. In general, the textural properties of the formulated dough and bread showed a correlation with the expansion degree and the content of total soluble carbohydrates. The selection of low temperature and high moisture extrusion conditions, such as 100 °C and 25%H, would positively contribute to the industrial handling of the dough and to the acceptability of the baked product.

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Conflicts of Interest: The authors declare no conflict of interest.

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