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Proceeding Paper

Utilization of Hydrothermally Treated Flours in Gluten-Free Doughs †

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Abstract: Hydrothermal treatments are suitable for modifying the physicochemical properties of flours because they favor the total or partial gelatinization of starch, allowing products with different rheological and water absorption capacities to be obtained. The objective of the study was to apply the processes of extrusion cooking (CE), alkaline extrusion (OHE) and traditional nixtamalization (N) in four races of native maize from the province of Jujuy, Argentina (perlita, cuzco, chulpi and culli) to obtain flours with adequate aptitudes for use in gluten-free doughs. The different processes and the characteristics of each race had a significant effect ($p < 0.05$) on the hydration properties of the flours, both factors showing a greater effect on flour from the chulpi race, indicated by the increase in its hydration properties. Therefore, in the textural properties, the elasticity and the viscosity indices of the dough were dependent on the races and the processes, influencing these properties by the subjective water capacity. CE gives greater elasticity to the dough, presenting the highest values for the dough of the perlita race (5.58 mm). OHE provided a lower viscosity index (0.03 N $\times$ s) in the dough of the perlita race, indicating a poor integration of the flour components. The N did not confer remarkable properties to the dough, showing breakage of the dough touched. It is important to note that the OHE process provided dough with adequate properties due to intermediate values of elasticity (4.47–4.5 mm) and resistance to kneading (0.34–0.078 N $\times$ s). This study will optimize the development of extensible dough from the chulpi and culli races.

Keywords: alkaline extrusion; dough; gluten-free; nixtamalization; maize

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1. Introduction

The native maize from the province of Jujuy, Argentina, represent the base of pre-Columbian food culture, especially in the regions of Puna, Quebrada and Valles [1]. The different races of corn have different technofunctional properties, indicating that the application of different processes of the food industry [2] would allow to obtain flours with properties adequate for use in various food products. Hydrothermal treatments are very attractive to modify the functional properties of cereal flours. Traditional nixtamalization is a process that consists of cooking corn kernels in a water–alkaline agent solution. This process converts the hemicellulose of the cell wall into soluble gums, gelatinizes the starch, saponifies part of the lipids, releases niacin and solubilizes part of the proteins that surround the starch granules, obtaining extensible masses to make taco tops [3]. In extrusion cooking, the flours are subjected to high temperatures and mechanical shearing at relatively low levels of moisture content that allows the pregelatinization of the starch, the denaturation of the protein, which allows changing the rheological properties of the flours [4]. Alkaline extrusion is an environmentally friendly technological alternative that is similar to traditional nixtamalization [5]. These processes directly affect the physicochemical properties of the cereal starch and the viscoelastic properties of the flour.

The objective of the study was to apply the processes of extrusion cooking (EC), alkaline extrusion (EOH) and traditional nixtamalization (N) in four races of native maize from the province of Jujuy, Argentina (perlita, cuzco, chulpi and culli) to obtain flours with suitable aptitudes for use in gluten-free doughs.

2. Materials and Methods

2.1. Raw Materials

Four races of native maize of different endosperm from the province of Jujuy, Argentina: perlita, cuzco, chulpi and culli were acquired from local producers in Ocumazo, Humahuaca, Jujuy, Argentina. Some of the grains of each race were integrally ground in a hammer mill to a particle size of less than 420 μm, and some were left unground.

2.2. Hydrothermal Processes

Cooking extrusion (CE)

Whole flour was conditioned at 28% of moisture 2 h before the extrusion cooking process. A Brabender KE 19 single-screw extruder with 2:1 compression ratio and 3 mm nozzle was used. The process was carried out at a screw speed of 60 rpm and a feed speed of 20 rpm. The extruder equipment managed three heating zones: 40 °C (feeding zone) −60 °C (compression zone) and 80 °C (cooking zone).

Alkaline extrusion (OHE)

At 12 hours before the process, 0.25 g of $Ca(OH)_2$ /100 g of flour was added to each whole meal flour sample, and then they were conditioned at 28% humidity. Each sample was mixed for 3 min and stored in a polyethylene bag in the refrigerator. The OHE was carried out in the same conditions as CE. The extrudates obtained by these two processes were collected in a tray and dried in an oven at 30 °C for 12 h.

Nixtamalization (N)

The corn grains of the different races were nixtamalized following the procedure of Bello-Perez et al. [2], with some modifications. The grains were mixed with water in a 1:3 ratio, and 2% $Ca(OH)_2$ was added. The cooking was carried out for 40 minutes and then left to rest for 24 hours. After nixtamalization, the liquid was drained, and the nixtamalized maize was washed with running tap water for 5 minutes until calcium hydroxide was eliminated and then dried at 40 °C in a forced convection oven. After applying these three processes, the samples obtained were ground in a hammer mill to a particle size of ≤250 μm.

2.3. Hydration Properties of Hydrothermally Treated Flours

Water absorption (WAI) and water solubility (WSI) indices

To determine the water absorption (WAI) and the water solubility (WSI) indices of the flours treated, the methodology described by Sing et al. [6] was followed. The experiment was carried out in triplicate. WAI and WSI were calculated by using the following expressions.

Subjective Water Absorption Capacity (SWAC)

SWAC was determinate according to Gaitan-Martinez et al [7].

2.4. Textural Properties of Dough

A total of 200 g of the flours obtained by extrusion cooking (CE), alkaline extrusion (EOH) and nixtamalization (N) were rehydrated according to the subjective water absorption capacity (SWAC) to obtain the respective masses. The fresh dough was divided into discs of 25 grams, 8 cm in diameter and 1 cm thick. All masses were analyzed after 12 h of refrigeration. The discs obtained from fresh masses were subjected to a puncture test of 40% of the original height with a flat-tip SMSP/3 probe (3 mm diameter) and a 25 kg cell. The test speed was 1 mm/s, and six disks were tested for each process and race. The following parameters were analyzed: penetration force in Newton (N) and elasticity (mm) and viscosity indices, also called cohesion work expressed in units of N × s.

2.5. Statistical Analysis

Multiple analyses of variance were used to determine the individual effects of thermal treatment and the corn race. Fisher's least significant differences test was used to calculate the means with 95% confidence intervals. The statistical analysis was performed with the XLStat trial (Copyright © 2015 Addinsoft, Paris, France).

3. Results and Discussion

3.1. Gel Hydration Properties (WAI and WSI) and Subjective Water Absorption Capacity (SWAC)

Gel hydration properties are important in bulking and depend on proteins and polysaccharides.

The race factor had a statistically significant effect on WSI ($p < 0.05$), mainly in the meal of the chulpi race, indicated by the increase in WSI in all cases (Table 1). This can be attributed to the higher protein content (8–13%) of chulpi and the higher protein compaction in its vitreous endosperm [8] compared to the protein content of the other races (7–11%) reported by Gimenez et al. [2] generating less interaction between proteins and water, increasing dissolved solids. The simple ANOVA analysis showed that the different processes generated significant differences in the WSI and WAI of the flours. Showing in most cases that CE and N caused the lowest WSI value and the highest WAI value, but not for the culli race, which did not show significant differences in the gel hydration properties with respect to the processes. In CE and N, the content of soluble fibers and complexes that involve starch could have increased, which favored the formation of a compact structure that decreased accessibility to water, obtaining low WSI values [4]. On the other hand, it is possible that the presence of a high percentage of damaged starch has an impact on a higher IAA. The Subjective Water Absorption Capacity (SWAC) is an important property from an economic point of view because it impacts the yield of the flour to dough conversion. The multifactorial analysis indicated that only the race factor had a statistically significant effect on the SWAC (Table 1). These values ranged from 0.74 to 0.96 ml water/g flour. It was observed that with the cuzco race a greater amount of water was needed to form dough and less was needed with the chulpi race, for all the processes. With OHE, the process was generally observed with the highest values. This property influences the texture parameters of the dough since it is related to the interaction of the components of the flour and its ability to bind water [7].

Table 1. Gel hydration properties of maize flour from the extrusion cooking (CE), alkaline extrusion (EOH) and nixtamalization (N) processes.z.

Race	Process	WAI (%)	WSI (*) (g/g)	SWAC (mL/g)
Cuzco	CE	3.80^{b} **	0.05^{b} **	0.93^{b} **
	OHE	4.46^{c} **	0.06^{c} **	0.96^{b} **
	N	2.65^{a} **	0.03^{a} **	0.84^{a} **
Chulpi	CE	3.16^{b} **	0.115^{a} **	0.74^{a} **
	OHE	2.62^{a} **	0.18^{b} **	0.84^{b} **
	N	3.61^{c} **	0.205^{c} **	0.93^{c} **
Perlita	CE	3.68^{b} **	0.065^{a} **	0.89^{c} **
	OHC	3.24^{a} **	0.08^{c} **	0.86^{b} **
	N	3.09^{a} **	0.05^{b} **	0.81^{a} **
Culli	CE	4.15^{b} **	0.055^{a} **	0.85^{b} **
	OHC	3.57^{ab} **	0.055^{a} **	0.90^{c} **
	N	3.21^{a} **	0.045^{a} **	0.81^{a} **

WAI: water absorption index. WSI: water solubility index. SWAC: subjective water absorption capacity. * Indicates that the race factor had a statistically significant effect on WSI (>0.05). ** Indicates the significant differences by process by race. Values followed by different letters within each parameter.

3.2. Textural Properties of Dough

Figure 1a–c show the firmness, elasticity and viscosity indices of the dough of the flours of different races treated with EC, OHE and N. In the puncture test, the firmness of the dough was measured as the maximum force recorded during penetration (Figure 1a). The analysis of variance showed that the applied processes did not have a significant impact ($p < 0.05$) on this property. Regarding this property, the chulpi dough showed a different behavior from that of the other races. The chulpi dough with nixtamalized corn flour presented the greatest firmness; this may be due to the particular characteristics of the endosperm of this race characterized by the presence of crystallized sugars [8]. Alkaline hydrothermal treatments also solubilize the fibers of the pericarp, allowing greater interaction with the water, contributing to the formation of firmer dough. In the dough of the other races, the shear forces in the EC process could have produced structural changes in the macrocomponents of the flours that favored the interaction with the water, increasing their firmness. The viscosity index (Figure 1b) showed a significant dependence ($p < 0.05$) with the applied treatments. This parameter is related to the cohesion of the dough and indicates the resistance to tearing during kneading. The OHE process presented a higher value in the viscosity index (0.44 N $\times$ s) for the cuzco breed, indicating a greater integration of the components that are part of the dough matrix, while the perlite flour mass presented the lowest value. The Figure 1c shows the elasticity presented by the masses of the treated flours. In this parameter, both the process applied and the race of the maize had a significant effect. The EC process provides greater elasticity in the masses, observing the highest value in the mass of perlite (5.58 mm). The addition of the alkaline agent to the process had a significant decreasing effect ($p < 0.05$), finding the lowest value in the dough of the nixtamalized culli race (3.02 mm). High elasticity values are undesirable in laminated dough; however, dough with low elasticity values breaks when it is laminated [9].

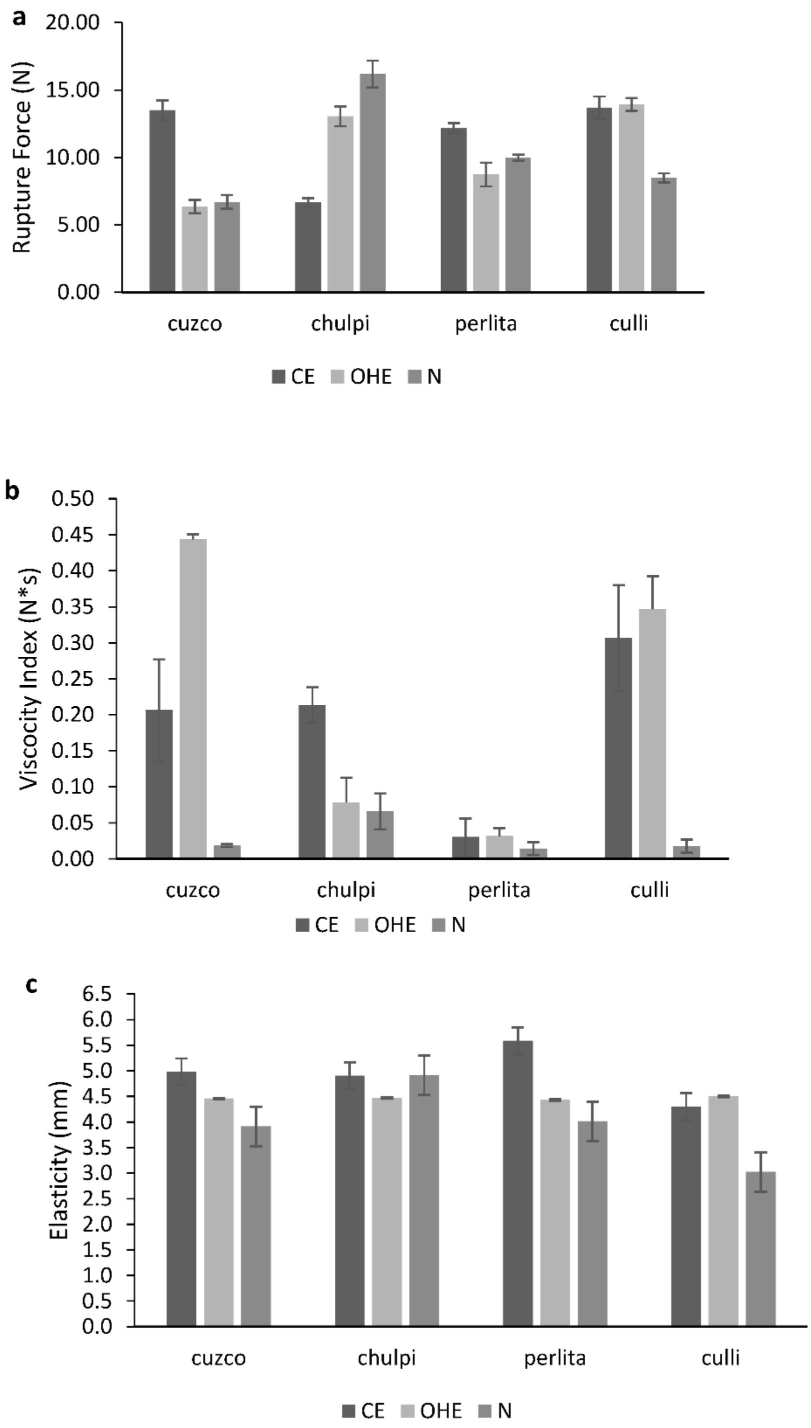

Figure 1. (**a**) Rupture Force (N); (**b**) Viscosity Index (N × s); (**c**) Elasticity (mm) of dough of the races cusco, chulpi, perlita and culli from the CE, OHE, N processes.

4. Conclusions

The processes applied and the characteristics of each race had an important effect on the textural properties of their masses. In particular, the characteristics of the endosperm of the chulpi race give it properties and behavior that were different from the rest of the races studied. The alkaline extrusion process provided dough with intermediate values of elasticity, firmness and good resistance to kneading. The chulpi breed presented the best aptitude to be used in gluten-free dough.

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References

1. Ramos, R.S.; Hilgert, N.I.; Lambaré, D.A. *Agricultura Tradicional y Riqueza de Maíces (Zea mays)*; Estudio de Caso en Caspalá: Provincia de Jujuy, Argentina, 2013. (In Spanish)
2. Giménez, M.A.; Segundo, C.N.; Lobo, M.O.; Sammán, N.C. Physicochemical and Techno-Functional Characterization of Native Corn Reintroduced in the Andean Zone of Jujuy, Argentina. *Proceedings* **2020**, *53*, 7. [CrossRef]
3. Bello Pérez, A.B.; Díaz, P.O.; Acevedo, E.A.; Santiago, C.N.; López, O.P. Propiedades químicas, fisicoquímicas y reológicas de masas y harinas de maíz nixtamalizado. *Agrociencia* **2002**, *36*, 319–328. (In Spanish)
4. Martínez, M.M.; Pico, J.; Gómez, M. Physicochemical modification of native and extruded wheat flours by enzymatic amylolysis. *Food Chem.* **2015**, *167*, 447–453. [CrossRef] [PubMed]
5. Enríquez-Castro, C.M.; Torres-Chávez, P.I.; Ramírez-Wong, B.; Quintero-Ramos, A.; Ledesma-Osuna, A.I.; López-Cervantes, J.; Gerardo-Rodríguez, J.E. Physicochemical, rheological, and morphological characteristics of products from traditional and extrusion nixtamalization processes and their relation to starch. *Int. J. Food Sci.* **2020**, *2020*, 5927670. [CrossRef] [PubMed]
6. Singh, N.; Singh, J.; Kaur, L.; Sodhi, N.S.; Gill, B.S. Morphological, thermal and rheological properties of starches from different botanical sources. *Food Chem.* **2003**, *81*, 219–231. [CrossRef]
7. Gaytán-Martínez, M.; Figueroa, J.D.C.; Vázquez-Landaverde, P.; Morales-Sánchez, E.; Martínez-Flores, H.E.; Reyes-Vega, M.L. Caracterización fisicoquímica, funcional y química de harinas nixtamalizadas de maíz obtenidas por calentamiento óhmico y proceso tradicional. *CyTA-J. Food* **2012**, *10*, 182–195. [CrossRef]
8. Salvador-Reyes, R.; Rebellato, A.P.; Pallone, J.A.L.; Ferrari, R.A.; Clerici, M.T.P.S. Kernel characterization and starch morphology in five varieties of Peruvian Andean maize. *Food Res. Int.* **2021**, *140*, 110044. [CrossRef] [PubMed]
9. Topete-Betancourt, A.; Santiago-Ramos, D.; Figueroa-Cárdenas, J.D.D. Relaxation tests and textural properties of nixtamalized corn masa and their relationships with tortilla texture. *Food Biosci.* **2020**, *33*, 100500. [CrossRef]