EFFECT OF OHMIC HEATING NIXTAMALIZATION ON THE STRUCTURAL AND PHYSICOCHEMICAL CHARACTERISTICS OF INSTANT MAIZE FLOURS AND THEIR RELATION TO STARCH MODIFICATIONS

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INTRODUCTION

Ohmic heating (OH) nixtamalization seems to have great potential to replace traditional nixtamalization at an industrial scale since cooking time is reduced, no waste-water is produced and electricity is utilized efficiently. Consists in the flow of an electrical current through a semi-solid mixture of raw ground grains and alkaline solution, causing internal heating, and cooking of the mixture. Generally, OH nixtamalized products have similar textural properties than traditional ones, but some outcomes, such as tortilla making ability were affected by factors other than temperature, moisture and cooking time. Indeed, little is known about how the electrical nature of OH can affect maize starch and how this relates to the properties of resulting nixtamalized products. Therefore, the aim of this study was to monitor the starch-related changes in rheological, thermal, and morphological characteristics of instant masa flour during OH nixtamalization under different temperature, heating time and voltage conditions.

EXPERIMENTAL

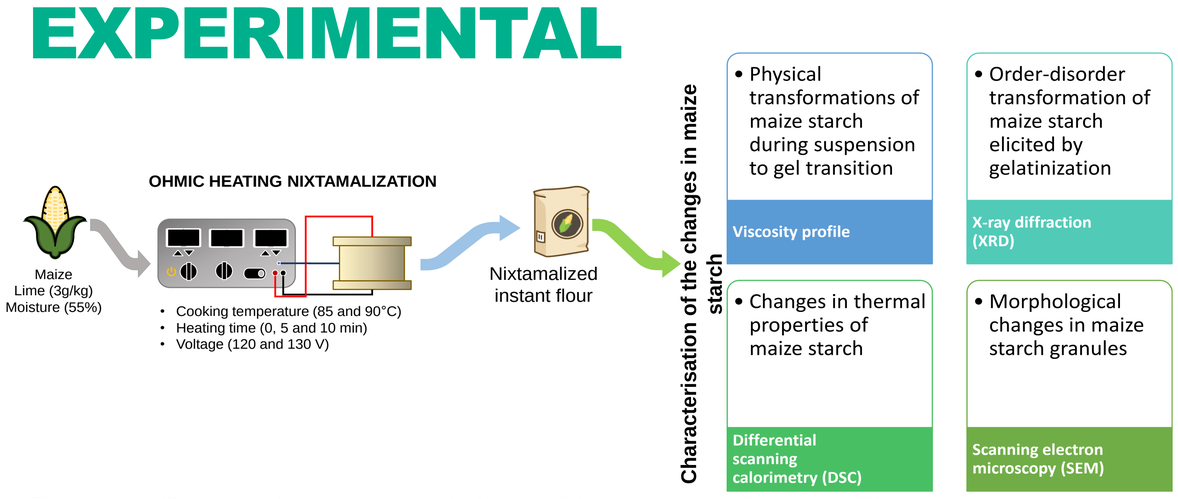

Figure 1. Schematic representation of the processing conditions and experimental strategy.

RESULTS AND DISCUSSION

The SEM micrographs showed continuous and irreversible starch granule disruption and aggregation induced by the electric fields during OH nixtamalization treatments (Figure 2). They also seemed to indicate that, at short holding times, surface disruption and partial gelatinization was more affected by voltage, while at longer times (10 min), temperature played a larger part in the disruption/ agglomeration of the inner granule structures.

In Table 1, the thermal parameters of OH flours show typical values for maize starch undergoing gelatinization. Samples processed at 120 V had less gelatinized starch than the samples cooked at 130 V, so they required more energy to elicit phase transition during DSC. Increasing holding time also increased To and Tp. At the most severe treatment (130 V, 90 °C and 10 min), it was observed that %SG was lower, but transition temperatures were high, suggesting starch reorganization or increased order.

In terms of the rheological properties of the samples, a continuous reduction in maximum and retrogradation viscosity was observed as treatment intensity increased in terms of voltage, temperature and time. These results would imply that as conditions become more thermally intense, at higher voltages, there were fewer intact starch granules available to develop viscosity in the OH samples prior to analysis. This combined effect of the studied factors can also be appreciated in the lowering maximum viscosity for the more intense OH treatments.

This, along with the thermal and SEM results presented in Figure 2, seemed to indicate that gelatinization of starch under OH were affected by non-thermal effects due to the application of an electrical field for a prolonged time. This would explain the erosion of the granule surface or “pores” observed in the micrographs, in a phenomenon called electroporation, which is known to enhance trans-membrane water and solute diffusion.

The diffractograms of the studied treatments can be seen in Figure 3. They show peaks at 2θ values of 15, 17,18 and 23°, which are characteristic of orthorhombic crystalline A-type maize starches. Increasing voltage and heating duration, generally increased the diffraction pattern intensity. As cooking time increased, peak intensity of samples heated at 90°C was not as pronounced as in samples cooked at 85°C (Figure 3 a and b).

Table 1 Thermal and rheological parameters of instant masa flours made using OH.

Nixtamalization process	Treatment			Viscosity		Thermal parameters					
	Voltage (V)	Temperature (°C)	Time (min)	Maximum (cP)	Retrogradation (cP)	T_o (°C)	T_p (°C)	T_e (°C)	ΔT (°C)	ΔH_{gel} (J·g^{-1})	% SG
Ohmic Heating	120	85	0	2241a	2789a	65.82	72.45a	79.84	14.01	3.97	48.44
			5	2381a	2772a	66.14a	72.63a	80.83	14.69	4.66	39.49
			10	2114a	2555a	66.91a	73.21a	81.35a	14.44	4.21	45.39
		90	0	2179a	2622a	66.73a	73.3a	81.19a	14.46	3.74	51.49
			5	1903a	2418a	66.8a	73.72a	81.08a	14.27	3.02	60.76
			10	1699a	2190a	67.11a	73.87a	81.26a	14.15	2.78a	63.94a
	130	85	0	1882a	2330a	66.66a	73.04a	80.4	13.73	3.69	52.14
			5	1961a	2416a	66.17a	73.22a	81.15a	14.98	3.28	57.39
			10	1774a	2254a	66.65a	73.22a	79.01	12.36	3.17	58.88
		90	0	1861a	2381a	67.35a	73.81a	80.88	13.53	3.48	54.86
			5	1748a	2274a	66.71a	73.46a	80.91	14.19	3.02	60.76
			10	1730a	2217a	67.56a	74.21a	82.3a	14.74	4.38	43.19

Means not labeled with “a” are significantly different from the control level mean (Dunnett test, $p<0.05$). Gelatinization onset (T_o), end (T_e) and peak (T_p) temperatures. ΔH_{gel}, gelatinization enthalpy with respect to raw maize. Temperature range of gelatinization, $\Delta T = T_e - T_o$. %SG, starch gelatinization percentage.

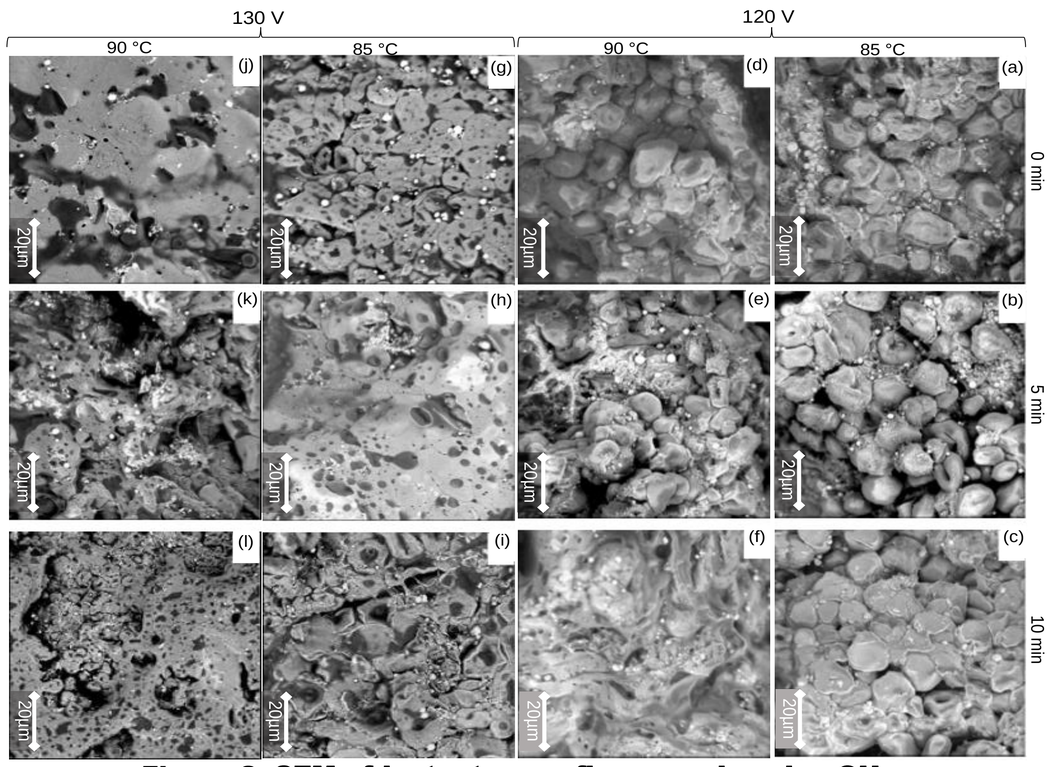

Figure 2. SEM of instant masa flours made using OH.

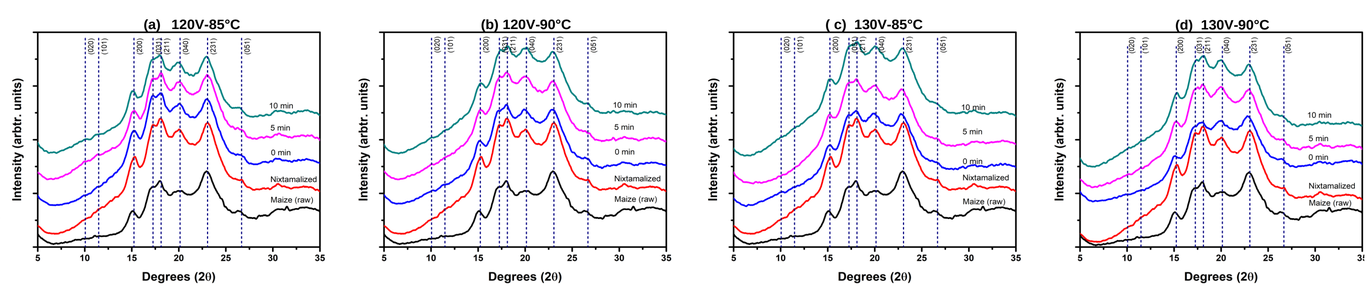

Figure 3. X-ray diffraction patterns of instant masa flours using OH. Traditional nixtamalization and raw maize are shown for reference.

These differences could have been caused by the different degrees of crystallinity loss in the starch, achieved by the OH processing conditions. Simultaneously, it was observed that the peak corresponding to the formation of amylose-lipid complexes (2θ, 20°), increased its intensity with respect to raw maize. At a molecular level, it is possible that the combination of electrical effects and thermal effects at higher voltage and temperature caused damage in the outer layer of the starch granules inducing leaching of amylopectin, but also amylose. This would contribute to the reduction of crystalline structures and enthalpy at the high voltage and high temperature treatments, as well as lower peak viscosity.

CONCLUSIONS

Morphology of the OH flours, thermal properties as well as X-ray diffraction patterns indicated that during processing, gelatinization and electroporation phenomena occur in a low mechanical stress setting, which enhances gelatinization but allows sufficient starch granule remnants, crystalline structures and chain associations to remain and form a stable matrix with low viscosity and lower retrogradation tendencies. The proposed scenario seems to indicate that the desirable properties of the studied instant flours are a consequence of simultaneous thermal and non-thermal effects occurring in maize starch treated with OH. Viscosity values showed that a range of gelatinization degrees in OH flours can be obtained, depending on the intensity of the process.

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