

Effect of nixtamalization on the chemical and functional properties of maize

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Abstract

The high utilization and consumption levels of maize in developing countries calls for investigations into new methods of processing to help introduce variety as well as improve the functionality and nutrient quality of maize-based foods. This study was carried out to determine the effect of nixtamalization on the chemical and functional characteristics of maize. A 2×4 factorial experimental design with cooking time (0, 30 min) and lime concentration (0, 0.33, 0.5 and 1.0%) was performed. Chemical composition (moisture, protein and ash), pH, titratable acidity, water absorption, colour, cooked paste viscosity and texture were determined using standard methods. The cooking time and lime concentration significantly ($p \leq 0.05$) influenced the moisture, pH and colour of the samples. Water absorption capacity was dependent on the lime concentration and all the indices increased with increasing lime concentration used. The effects of lime concentration on cooked paste viscosity, ash and protein were not significant ($p \leq 0.05$); however, a slight increase in protein content was observed. Maize nixtamals, with appropriate moisture and texture for the production of snack products, can be prepared from maize with acceptable quality characteristics.

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1. Introduction

Alkaline cooking of maize with lime, traditionally called nixtamalization, is the primary processing step during manufacture of several maize products, such as maize chips, maize tortillas and taco shells. Even with the growing popularity of these maize products, little improvements have been made in the ancient maize processing method practised by the Aztecs. The basic process begins by cooking whole maize in water with lime and steeping the cooked maize for 12–16 h in large tanks. The steeped maize is nixtamal and the cooked steep liquid, rich in maize solids, is nejayote (Sahai, Surjewan, Mua, Buendia, Rowe, & Jackson, 2000). This pre-Colombian alkaline cooking technique softens the pericarp and allows the endosperm to absorb water, thus facilitating its milling. The nixtamal is washed to

remove loose pieces of pericarp and stone-ground to produce masa. Masa or maize dough is used to produce tortillas, taco shells, tostados, tamales and snacks such as maize chips and tortilla chips. Traditionally, hard white maize is used for tortilla making in Mexico as it results in a superior white tortilla and relatively less maize solids loss than softer maize types (Jackson, Rooney, Kunze, & Waniska, 1988).

The wide range of foods produced from masa are consumed as snacks or as part of breakfast and main meals. In addition to variety introduced in the utilization of maize, other important effects of nixtamalization include, increased bioavailability of niacin, improved protein quality, increased calcium content and the reduction of aflatoxin concentration of masa products (Bressani, Benavides, Acevedo, & Ortiz, 1990; Serna-Saldivar, Knabe, Roodney, & Tanksley, 1987; Wall & Carpenter, 1988). Initial studies by Sefa-Dedeh (1991) on the fermentation of nixtamalized maize dough revealed a drastic reduction in Brabender cooked paste

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viscosity during fermentation. From his work, the pH of nixtamalized maize dough decreased with a corresponding increase in titratable acidity during fermentation, an indication that fermentation of nixtamalized maize dough leads to souring, as observed in traditional maize dough, processing.

The raw material which is popularly processed by nixtamalization is maize, which also happens to be an important staple in tropical Africa, used in many traditional diets. Though the process of nixtamalization is unknown to Ghanaian food processors, the unit operations involved are not totally new. Nixtamalization can therefore be employed to improve the nutritive quality of maize, as well as to introduce and develop variety in maize processing and utilization in West Africa. This research aimed at investigating the effects of nixtamalization on the chemical and functional properties of maize.

2. Materials and methods

2.1. Materials

Corn (*Zea mays*) was obtained from a market in Accra. Cowpea (*Vigna unguiculata*) var *Bengpla* were obtained from the Crop Research Institute in Ghana. They were stored at 4 °C (relative humidity 65–100%). Lime [$\text{Ca}(\text{OH})_2$] laboratory grade was obtained from BDH Chemicals Ltd., Poole, England.

2.2. Experimental design and sample preparation

A 2×4 factorial experimental design with cooking time (0, 30 min) and lime concentration (0%, 0.33%, 0.5%, 1.0%) was used. Maize (500 g) was steeped in the lime solutions for 12 h. Another batch of maize samples was cooked in lime [$\text{Ca}(\text{OH})_2$] solution at 0%, 0.33%, 0.5% and 1% concentrations, respectively, for 30 min. The boiled samples were then steeped in the cooked liquor for 12 h. After steeping, the maize samples were washed thoroughly to remove the excess lime. The nixtamal obtained was drained and milled with a disc attrition mill (Model 10-2A, New Delhi) to produce a dough known as masa. The masa was dried in an air oven at 50 °C for 14 h to a moisture content between 9% and 12%. The dried masa sample was milled into fine flour (250 μm) using a hammer mill (Christy and Norris Ltd., Chelmsford, England) and the flour sample was analysed for the following indices: moisture content, protein, ash, pH, water absorption capacity at 25 and 70 °C, colour and cooked paste viscosity.

2.3. Chemical analysis

The moisture, crude protein ($N \times 6.25$) and ash contents were determined by the Association of Official

Analytical Chemists Approved Methods 925.10, 920.87 and 923.03, respectively (AOAC, 1990). Determinations were done in duplicate.

2.4. pH

Ten gramme of dried flour was mixed with 100 ml distilled water. The mixture was allowed to stand for 15 min, shaken at 5 min intervals and centrifuged at 3000 rpm for 15 min using a Denley centrifuge (Model BS4402/D, Denley, England). The supernatant was decanted and its pH was determined using a pH meter (Model HM-30S, Tokyo, Japan).

2.5. Water absorption capacity

Five gramme of sample was weighed into a centrifuge tube and 30 ml of distilled water, at temperatures of 25 and 70 °C, was added. The mixture was stirred and allowed to stand for 30 min and centrifuged using a Denley centrifuge (Model BS4402/D, Denley, England), at 3000 rpm for 15 min. The supernatant was decanted and the increase in weight noted by weighing. The water absorption capacity was expressed as a percentage of the initial sample weight. The determination was done in duplicate.

2.6. Cooked paste viscosity

The viscosities of the samples were determined using the American Association of Cereal Chemists Approved Method 22-10 (AACC, 1983) with slight modifications. The cooked paste viscosity of 8% slurries in 500 ml water were measured using the Brabender Viscoamylograph (Brabender, Duisburg, Germany), equipped with a 500 cmg sensitivity cartridge. The viscosities of the samples were continuously monitored as they were heated from 25 °C at a rate of 1.5 °C/min to 95 °C, held for 30 min, cooled to 50 °C and held for 15 min. Brabender Viscoamylograph indices were measured.

2.7. Colour

Colorimetric measurements of the dry flour samples were recorded using a Minolta CR-310 tristimulus colorimeter (Minolta Camera Co. Ltd., Osaka, Japan). The instrument was calibrated with a standard white tile ($L = 97.95$, $a = -0.12$, $b = +1.64$). Surface colour differences were minimized by reporting an average of three readings for each flour sample. Psychrometric colour terms, L (Lightness), a (red-greenness) and b (yellow-blueness) were recorded.

2.8. Statistical analyses

The data obtained from the analyses were statistically analysed using Statgraphics (Graphics Software System,

STCC, Inc. USA). Comparisons between sample treatments and the indices were done using analysis of variance (ANOVA) and multiple range analysis with a probability $p \leq 0.05$. The effects of cooking time and concentration of lime on the physical, chemical and functional characteristics of nixtamalized maize were studied.

3. Results and discussion

3.1. Moisture Content

The moisture contents of the lime-treated maize grains followed similar patterns. Moisture contents of both the uncooked and cooked samples increased with increasing lime concentration, an indication that lime facilitates the absorption of water by the maize grains (Fig. 1). The moisture content of the uncooked grains ranged from 28.27% to 36.75% while that for the cooked ranged from 39.77% to 45.77%. The maize grains absorbed more water at lime concentrations from 0% and 0.33%, and increased slightly to maximum moisture absorption at a lime concentration of 0.5%. The highest grain moisture absorption was observed with the 0.5% lime concentration for both treatments. Samples treated with 1% lime had a slightly lower moisture content than those treated with 0.5% lime.

Maize grains cooked in lime before steeping had a higher moisture content, with all the lime concentrations, than the uncooked maize. This could be due to gelatinization of the maize starch during cooking, making hydration of the endosperm easier and faster. For both cooked and uncooked maize, the lime-treated samples had a higher moisture content than those

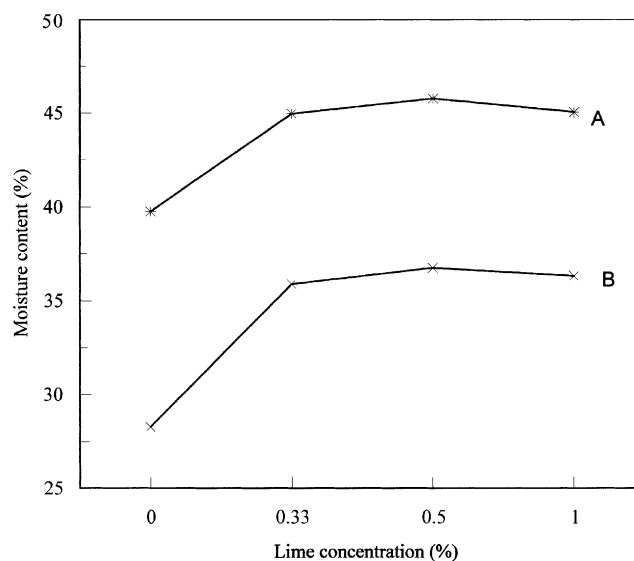


Fig. 1. Effect of lime concentration on moisture content of cooked (A) and uncooked (B) nixtamalized maize.

Table 1
Significant *F*-ratios of process variables for the chemical and functional properties of nixtamalized maize

Process variables	Moisture	pH	Pasting temperature	Colour (<i>L</i> -value)
Cooking	221.598*	8.736*	19.791	17.828
% Lime	27.956*	21.693*	6.038	1.450

* Significant at $p \leq 0.05$.

without lime. In the presence of lime, there is the possibility of an osmotic potential developing in the grain and this will cause the maize to absorb more water until equilibrium is attained. The higher moisture content of the grains treated with the lime can therefore be attributed to osmotic effects. The effect of lime on moisture absorption has also been studied by Chang and Hsu (1985), who reported that maize cooked in lime solution absorbs more water than maize cooked in ordinary water.

Analysis of variance (ANOVA) showed that cooking and lime concentration significantly affected ($p \leq 0.05$) the moisture content of the nixtamal (Table 1). Multiple range analysis of the results revealed that cooking had a significant effect on the moisture content of the sample. Multiple range analysis, to determine the effect of the lime concentration on the moisture content of the sample, also indicated that the effect of lime concentration on the moisture content of the samples treated with lime was significantly different from that of the maize which did not contain lime (0% lime). The effects of the various concentrations of lime on the moisture content were, however, comparable.

In the production of alkaline-cooked products from maize, the moisture content of the lime-cooked grains (nixtamal), among other factors, is a significant determinant of the quality and acceptability of the final product. Different nixtamal moisture contents are required for different end products. The suggested control limits for soft tortillas and corn chips are 45–51% and 48–54% (Serna-Saldivar, Gomez, & Roodney, 1990; Snack Food Association, 1987). This suggests that cooking is critical in order to produce nixtamal with an acceptable moisture content.

3.2. Protein content

The protein content increased slightly from 8.14% in the raw maize sample to 8.88% in the sample cooked for 30 min in lime solution. For the uncooked maize samples (steeped without cooking), the protein content generally decreased with increasing lime concentration. The opposite was observed in the cooked samples, whose protein content increased with increasing lime concentration (Fig. 2). Most researchers have reported a small increase in nitrogen content of nixtamals, which has been attributed to a concentration effect. Bressani,

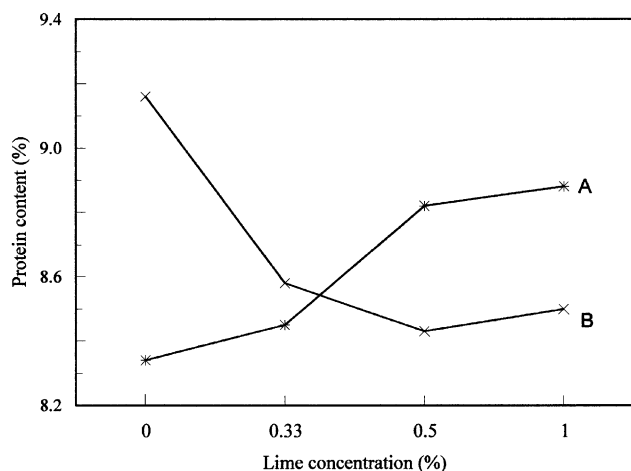


Fig. 2. Effect of lime concentration on protein content of cooked (A) and uncooked (B) nixtamalized maize.

Paz y Paz, and Scrimshaw (1958) reported increased protein content from 9.6%, 10.3% and 10.7% for raw maize, nixtamal and tortilla, respectively. Work done by other researchers shows comparable amounts of protein when alkaline-cooked corn products were compared to original grain (Gomez, Rooney, Waniska, & Pflugfelder, 1987; Serna-Saldivar et al., 1987).

When the data from protein measurements were subjected to analysis of variance, the results indicated that neither cooking or lime concentration had any significant effect ($p \leq 0.05$) on the protein content of the flours produced. This could be due to the fact that the changes in protein quantity of the lime-treated samples were slight.

3.3. Ash

Trends observed in the ash content of the cooked and uncooked maize were different (Fig. 3). The uncooked

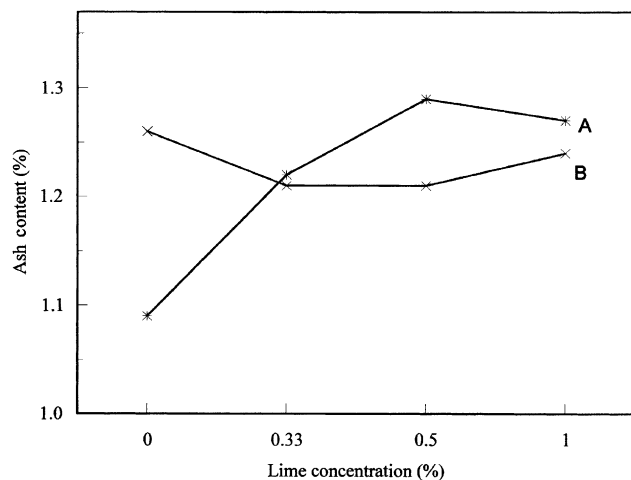


Fig. 3. Effect of lime concentration on ash content of cooked (A) and uncooked (B) nixtamalized maize.

samples had ash contents ranging between 1.24% and 1.26%, while those of the cooked maize ranged from 1.09% to 1.29%. The ash content of the samples cooked in lime increased as the lime concentration was increased to 0.5%, and then decreased slightly when the lime concentration was increased to 1.0%. This trend was similar to the pattern observed in the moisture content determinations. Most findings on changes in ash contents of nixtamalized products have shown an increase in total ash content from maize to tortillas (FAO, 1992) which is due to the lime used for cooking. Statistical analysis, conducted on the results, indicated that the effect of cooking and lime concentration on the ash content of the treated samples was, however, not significant ($p \leq 0.05$).

3.4. pH

The pH of nixtamalized maize and tortillas is an important quality parameter which affects the flavour and shelf life of the products made from alkaline maize (Serna-Saldivar et al., 1990). The pH of the flour samples ranged from 6.10% to 7.88%. The maize sample soaked in water without lime had the lowest pH while maize boiled in 1% lime for 30 min and steeped in the cooking liquor had the highest.

Similar pH trends were observed in the uncooked and cooked samples. The pH of the lime-treated maize increased with increasing lime concentration (Fig. 4), which may be due to absorption and retention of lime. Work done by Serna-Saldivar et al. (1990) showed that the pH of alkaline-cooked maize and its products, is closely related to the amount of lime used and retained during cooking and steeping. Bedolla and Rooney

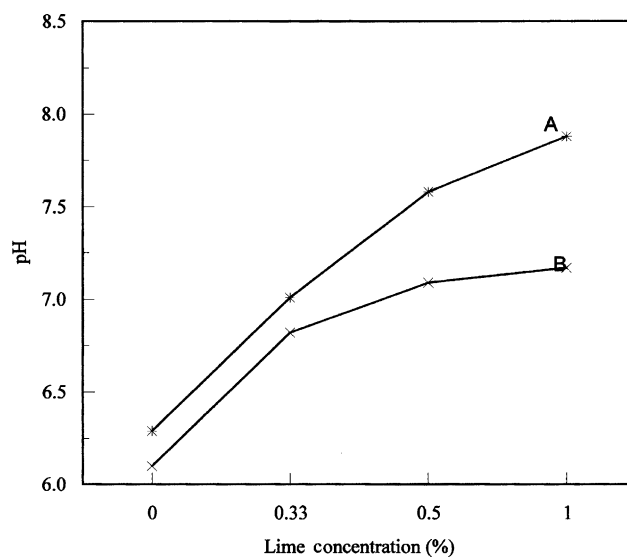


Fig. 4. Effect of lime concentration on pH of cooked (A) and uncooked (B) nixtamalized maize.

(1984) reported that pH of nixtamalized maize flours from commercial markets ranged from 7.1 to 7.4 and, in this experiment, a similar pH range of 7.01–7.88 was obtained for the maize samples boiled in alkali.

Analysis of variance showed that cooking and lime concentration had a significant effect ($p \leq 0.05$) on the lime-treated maize (Table 1). Multiple range analysis on the effect of lime concentration revealed that pH values of the samples treated with lime were comparable and significantly different from those treated without the lime (0% lime).

3.5. Water absorption capacity

The water absorption capacity patterns at 25 and 70 °C of the cooked and uncooked samples were different. The water absorption capacity at 25 °C of the uncooked samples increased with increasing lime concentration, while that of the cooked samples decreased (Fig. 5(a)) to

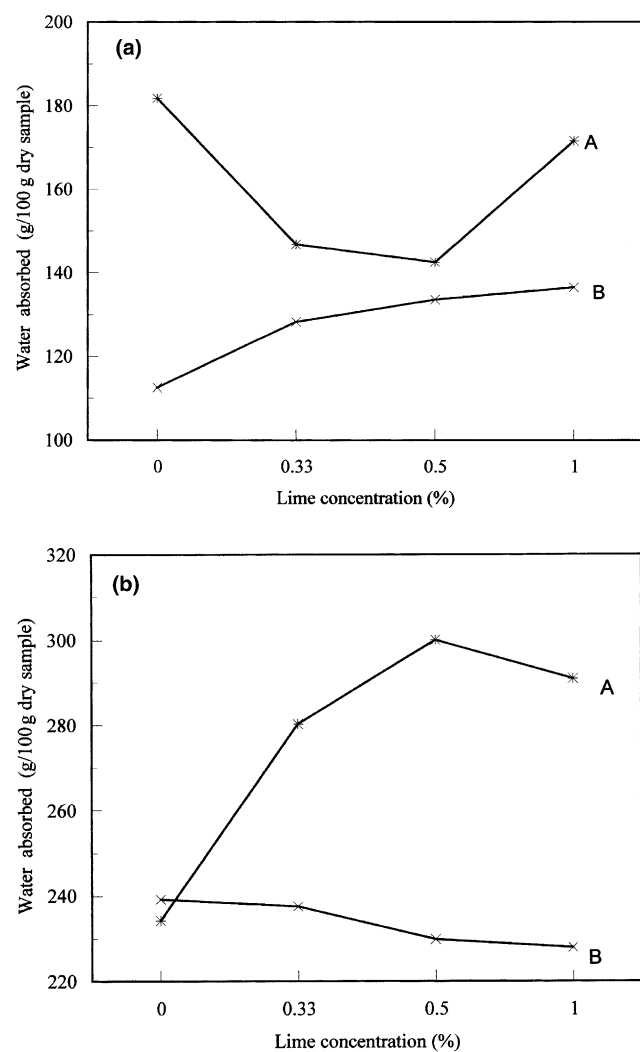


Fig. 5. Effect of lime concentration on water absorption at 25 °C (a) and 70 °C (b) of cooked (A) and uncooked (B) nixtamalized maize.

a minimum and increased when it was cooked in 1.0% lime. The reverse of these trends was observed when water absorption capacity was measured at 70 °C. At that temperature, water absorption of the uncooked samples decreased with increasing lime concentration while that of the cooked samples increased to a maximum and decreased when the maize was cooked in 1.0% lime (Fig. 5(b)). The different trends observed in water absorption of the alkaline-treated flours could be attributed to the effect on gelatinization, as well as Ca^{2+} and $\text{Ca}(\text{OH})^+$ –starch interactions.

The increase in water absorption, with concentration of lime in the cooked sample, could be due to the facilitating effect of lime on gelatinization. At 1.0% lime concentration, the starch hydroxyl sites in the maize might have been saturated, resulting in the decreased water absorption observed. Bryant and Hamaker (1997), in their work on the effect of lime on gelatinization of corn flour and starch, indicated that the effect of lime on the gelatinization properties of starch is a complex, concentration-dependent phenomenon. The water absorption capacities (25 and 70 °C) for the uncooked sample, at all concentrations of lime, were lower than those of the cooked samples. This could be due to the raw nature of the starch in the uncooked sample, since gelatinized starch is more readily hydrated than ungelatinized starch.

Analysis of variance on the data indicated that lime concentration and cooking significantly affected ($p \leq 0.05$) the water absorption capacities of the sample flours. Multiple range tests on the effect of lime showed that, irrespective of the concentration of lime used, the lime treatment had the same effect on the water absorption capacities (25 and 70 °C) of the flours. Further analysis, to determine the effect of cooking, revealed that cooking influenced the water absorption of the cooked samples in a manner which was significantly different from that of the uncooked samples.

3.6. Viscosity

The cooked paste viscosity characteristics of the lime-treated samples were determined to the effect of lime on the viscosity of the nixtamalized products. The Brabender viscosity indices, measured on the products, are shown in Table 1. The pasting temperature of the products ranged from 69.0 and 78.0 °C. The uncooked sample steeped in 0.5% lime had the lowest pasting temperature while the sample cooked for 30 min in 0% lime had the highest pasting temperature (Table 2). With all the indices measured on the amylograph, the cooked paste viscosity values recorded for the cooked maize samples were higher than the uncooked samples (Table 1) which may be attributed to gelatinization of the maize starch during cooking. These viscosities, however, were still much lower than that of the raw maize.

Table 2
Cooked paste viscosity of nixtamalized maize

Sample	Pasting temperature (°C)	Peak viscosity (BU)	Viscosity at 95 °C (BU)	Viscosity at 95 °C – hold (BU)	Viscosity at 50 °C (BU)	Viscosity at 50 °C – hold (BU)
Raw maize	70.0	90	90	280	960	990
Uncooked (0% lime)	72.0	90	90	120	330	410
Uncooked (0.33% lime)	70.3	40	30	30	90	130
Uncooked (0.5% lime)	69.0	40	40	60	160	230
Uncooked (1.0% lime)	69.7	50	50	50	140	220
Cooked (0% lime)	78.0	30	30	70	240	340
Cooked (0.33% lime)	72.6	80	80	160	320	480
Cooked (0.5% lime)	72.0	90	90	200	410	680
Cooked (1.0% lime)	72.9	100	100	210	380	790

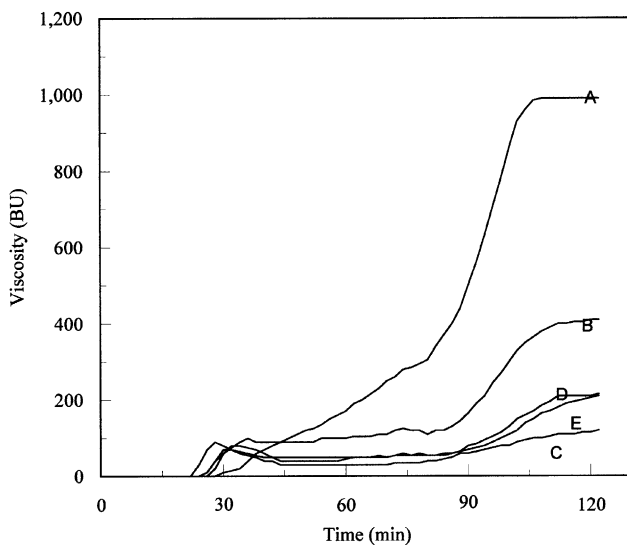


Fig. 6. Amylograph viscosity characteristics of uncooked maize steeped in lime: (A) raw maize; (B) 0% lime; (C) 0.33% lime; (D) 0.5% lime; (E) 1% lime.

The lime-treated samples (cooked and uncooked) had a more distinct peak than the raw (untreated) maize sample. Lime treatment also resulted in a drastic reduction in cooked paste viscosity (Figs. 6 and 7). Sefa-Dedeh (1991) reported a drastic reduction in amylograph viscosity when maize was treated with lime. The observed reduction was more pronounced in the cooled paste viscosity, which is an indicator of the consistency at which the gruel will most likely be eaten. The reduction in viscosity, especially during the cooling period, could be due to a saturation of the starch-hydroxyl sites with Ca^{2+} and $\text{Ca}(\text{OH})^+$ ions preventing any further association of the starch molecules, resulting in the reduction of the cooked paste viscosity.

The highest viscosity values of the samples were obtained after holding after holding at 50 °C for 15 min and these increased with increasing lime concentration (Fig. 7), an indication that lime concentration influences set-back viscosity. The highest viscosity value obtained after the cooling period was from the sample which was

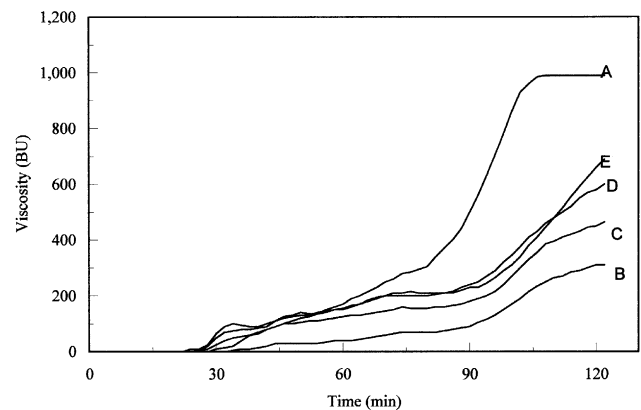


Fig. 7. Amylograph viscosity characteristics of nixtamalized maize: (A) raw maize; (B) 0% lime; (C) 0.33% lime; (D) 0.5% lime; (E) 1% lime.

boiled in 1.0% lime. Similar trends were observed by Bryant and Hamaker (1997) who reported that the highest value recorded for the viscosity at the end of the 95 °C holding period resulted from heating flour in 1.0% lime solution. Analysis of variance on the data indicated that cooking had a significant effect ($p \leq 0.05$) on the pasting temperature (Table 1). The effects of cooking and lime concentration on all the other indices, apart from pasting temperature, were not significant ($p \leq 0.05$).

3.7. Colour

The colour of alkaline-cooked maize products is an important quality parameter which has a direct influence on the acceptability of the product. Colour development in lime-treated products results from the lime used; hence the intensity of colour is closely related to the lime concentration. Even when tortillas are produced from white kernels, a high concentration of lime leads to a yellowish product (Serna-Saldivar et al., 1990).

The *L*-values (lightness) of the lime-treated samples ranged from 75.24 to 83.88 for the maize cooked and steeped in 1% lime and raw maize, respectively. The samples which were cooked in lime before steeping had lower *L*-values and higher *b*-values (deeper yellow) than

Table 3
Colour measurements of dry flours produced from nixtamalized maize

Sample	Hunter values		
	<i>L</i>	<i>a</i>	<i>b</i>
Raw maize	83.88	−0.05	19.36
Uncooked (0% lime)	83.02	−0.18	11.19
Uncooked (0.33% lime)	83.33	−0.55	10.32
Uncooked (0.5% lime)	82.64	−0.61	10.60
Uncooked (1.0% lime)	82.52	−0.63	11.26
Cooked (0% lime)	78.55	−0.50	11.99
Cooked (0.33% lime)	80.00	−0.86	11.79
Cooked (0.5% lime)	80.13	−1.07	13.99
Cooked (1.0% lime)	75.24	−0.78	13.47

those which were steeped without cooking (Table 3). This observation is due to the fact that the process of cooking resulted in gelatinization of the maize starch, allowing the cooked grains to imbibe the lime solution more readily than the uncooked grains, thereby changing the colour of the cooked samples. The *L*-values of the alkaline-treated maize generally decreased with increasing lime concentration (Table 3). Similar work done by other researchers (Bazua, Rosaura, & Hank, 1979; Gomez et al., 1987; Johnson, Rooney, & Khan, 1980) showed that the colour of dry nixtamalized maize flours ranged from white to dark yellow, depending on the alkali concentration, processing conditions and corn type. The samples with the darkest colour (lowest *L*-value) also had the highest pH (Table 3), confirming that the yellow colour resulted from the high amounts of lime absorbed and retained.

Analysis of variance on the data (*L*-values) showed that the cooking and lime concentration significantly ($p \leq 0.05$) influenced the colour of the lime-treated maize (Table 1). Multiple range analysis, to determine the effect of cooking, showed that the colour of maize cooked in lime was significantly different from that of the maize steeped in lime without cooking. Further multiple range analysis on the effect of lime concentration revealed that the effect of treating maize with 1.0% lime, on the colour of the maize, was significantly different from those of all the other samples treated with or without lime. This means that the effect of lime on the colour of alkaline-treated maize, as observed, is dependent on cooking.

4. Conclusions

Masa with appropriate moisture can be prepared from maize for the production of snack products, by cooking in lime solution for 30 min and steeping in the cooking liquor for 14 h. Nixtamalization of the maize resulted in increased pH, moisture content, water absorption capacity and yellowing of products derived from the process. Alkaline cooking improved the protein content of the nixtamalized maize products. Nix-

tamalization and fermentation can therefore be employed in the improvement of the nutritional quality of maize-based traditional foods as well as to widen the product base of maize processing.

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