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Characterization of alkaline-cooked quality protein maize as raw material for noodle processing

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Quality protein maize (QPM) possesses high tryptophan and lysine contents and may be processed into food products with improved protein content. Alkaline cooking enhances the functional and nutritional properties of corn and can be employed as an intermediate step in processing corn products. In this study, we aimed to evaluate the textural, sensorial, and cooking characteristics of noodles prepared from two white QPM varieties (SWQ 11 and SWQ 15) with different kernel characteristics. The QPM varieties had different starch, protein, fiber, and fat contents. The QPM varieties were nixtamalized and the resulting *masa* was used for noodle production. The QPM noodles had lower cooking yields (2.5%) than yellow alkaline noodles (YAN) from wheat (3.8%) and corn starch noodles (CSN) (5%). Cooking loss of the SWQ 11 noodles (3.9 %) was lower than SWQ 15 noodles (6.8 %) and YAN (6.9 %). CSN had the greatest cooking loss (15%). Among texture parameters, hardness and cutting stress values of the QPM noodles (7 kg_f and 0.6-1.4 kg_f, respectively) were greater than YAN (4 kg_f, and <0.1 kg_f, respectively), but gumminess and cohesiveness values were equivalent. Sensory characteristics showed that the QPM noodles had similar flavor absorbance as the control, but YAN and CSN were still preferred. Amylose content significantly influenced the properties of the noodles. The cooking properties of the corn noodles were satisfactory, but the sensory attributes could still be improved. The results of this study can be used to diversify the food use of QPM.

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INTRODUCTION

Alkaline cooking or nixtamalization is a common method in processing tortillas, tamales, tortillas, and pozole from corn (Méndez-Montealvo et al. 2008). The interactions among the maize components during the alkaline cooking and steeping processes may influence the final characteristics of the processed products from the *masa*. Alkaline cooking promotes total gelatinization of the external layers of the starch granule and the partial gelatinization of the inner layers of the endosperm (Cornejo-Villegas et al. 2013). Proteins surrounding the starch granules are solubilized during alkaline cooking and allow the release of starch (Rodríguez-Miranda et al. 2011). However, the steeping process may inhibit amylose release and promote cross-linking. The calcium content increases and lipids are saponified (Guzmán et al. 2011, Mondragón et al. 2004a). Calcium directly affects the gelatinization temperature as it binds with the hydroxy groups in the starch molecule that ionize at high pH values (Bryant and Hamaker 1997). Lime solution used in nixtamalization may also promote calcium-protein and protein-calcium-protein interactions and increase the thermal resistance of proteins (Guzmán et al. 2011). Further, it was found that the swelling power, solubility, and degree of gelatinization increased at low lime concentrations (Mondragón et al. 2004a). Other alkali sources may be used, as long as the resulting *masa* is sufficiently cohesive to allow sheeting and shaping (Guzmán et al. 2009, Ruiz-Gutiérrez et al. 2012). Amylose, amylopectin, and proteins form a cohesive system that links the non-gelatinized starch and the endosperm in the resulting *masa* (Guzmán et al. 2009). It was theorized that amylose-lipid complexes form during cooking and are reorganized during steeping (Mondragón et al. 2004b). Overall, alkaline cooking improves the protein quality of corn, in-

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creases calcium content and niacin bioavailability, and may even be used to develop other food products, such as extruded snacks (Rodríguez-Miranda et al. 2011).

The Philippines utilizes a large amount of corn for processing. Data from 2002-2012 showed the country imported 127 thousand metric tons (MT)/y. Approximately 838 thousand MT/y were processed, resulting in an average per capita utilization of 16.1 kg/y (DA-BAS 2014). In some areas, more maize is consumed than rice, and corn varieties with higher nutritive and better eating qualities are desired. Clark et al. (1977) reported that lysine and tryptophan are the two limiting amino acids in the maize endosperm. Hence, diets rich in corn need to be supplemented with other protein sources. Compared to other types of corn, quality protein maize (QPM) varieties contain twice as much tryptophan and lysine, and thus possess improved protein content (Prasanna et al. 2001). Further, the leucine:isoleucine ratio is improved, which increases niacin bioavailability (Clark et al. 1977).

Corn is employed in manufacturing local noodles called “bihon”, which are produced mostly from corn starch. Corn samples that contain 27−28% amylose yield the best noodles (Tam et al. 2004). Structurally, corn-based noodles differ texturally from wheat noodles because corn proteins are hydrophobic, whereas wheat proteins are hydrophilic. However, zein-starch dough was found to exhibit significant viscoelasticity at 60 °C, above the glass transition temperature of zein (Lawton 1992), and may yield noodles of comparable quality to wheat. Waniska et al. (1999) were able to produce corn-based noodles by extruding corn flour heated to 90 ºC and corn meal to 95 ºC. The process variables during alkaline cooking (such as cook time, temperature, steeping time, and alkali concentration) may be modified to manufacture products of different textural attributes (Guzmán et al. 2011, Méndez-Montealvo et al. 2008, Rodríguez-Miranda et al. 2011, Sahai et al. 2001). This study explored the suitability of alkaline cooking as a preparatory step in noodle processing, and aimed to evaluate the cooking and eating quality attributes of the QPM noodles.

MATERIALS AND METHODS

The QPM used in this study were open-pollinated varieties cultivated by the Institute of Plant Breeding, University of the Philippines Baños. Two white QPM cultivars (SWQ 11 and SWQ 15) with different endosperm hardness values (60% and 88%, respectively) measured by floatation technique and grit:germ ratios (5.5 and 4.7, respectively) were used. All chemicals used were reagent-grade.

Kernel characteristics

Proximate analysis

Standard methods of analysis from the Association of Official Analytical Chemists (AOAC 2000) were used to determine moisture content (Method Number: 925.10), ash (Method Number: 923.03), fat (Method Number: 920.39C), crude fiber (Method Number: 962.09), and protein (Method Number: 920.87).

Starch content

Undamaged and intact corn kernels were soaked in distilled water for 2−3 h or until the hull could be easily peeled off manually. Degermed and dehulled corn samples were blended for 0.5−1 min using a commercial food grinder (Shimono Technology Electronic Co., Ltd, Anhui, China). The ground sample (0.1 g) was placed in a centrifuge tube and 5 mL of distilled water were added and vortexed to disperse the residue. Perchloric acid (6.5 mL, 52% v/v, Univar, Ajax Finechem Pty., Ltd, NSW, Australia) was then added. The solution was placed in an ice bath for 30 min and stirred continuously for 5 min and occasionally thereafter for 15 min. Distilled water (20 mL) was added and the solution was centrifuged at 2000 rpm for 10 min. After centrifugation, the supernatant was decanted. The solid residue was re-extracted as described previously. The collected supernatant fluids were pooled in a 100-mL volumetric flask and diluted to mark with distilled water. The sample was then filtered through sintered glass.

An aliquot (0.5 mL) of the extract was combined with 2 mL distilled water in a borosilicate test tube. The solution was cooled in an ice bath and combined with 5 mL of cold anthrone reagent (HiMedia Lab., Pvt., Ltd., Mumbai, India). The sample was mixed well, covered with marbles, and placed in a boiling water bath for 7.5 min. The solution was cooled to 25 ºC before the absorbance was measured at a λ of 630 nm using a spectrophotometer (Spectronic 20, Milton Roy Company, Rochester, NY). A standard curve was prepared with glucose (Mallinckrodt Chemical Works, St. Louis, MO) and perchloric acid (6.76% v/v) as blank. Glucose and starch content (in percent) were calculated as follows:

$$\%glucose = \frac{conc'n\ from\ std\ curve\left(\frac{\mu g}{mL}\right) \times DF \times vol\ sol'n(mL)}{weight\ of\ sample(g) \times 10000} \quad (1)$$

$$\%starch = 0.90 \times \%glucose \quad (2)$$

Apparent amylose content

The extraction procedure was adapted from Tam et al. (2004) with some modifications. The kernels (200 g) were soaked in 0.45% (m/v) sodium metabisulfite (JT Baker Chem. Co., Phillipsburg, NJ) solution acidified with 0.5% (m/v) lactic acid (Univar, Ajax Finechem Pty., Ltd, NSW, Australia) and incubated at 52 ºC for 36 h. The soaked kernels were drained, blended at medium speed for 1 min with an equal volume of distilled water in a Waring blender, and strained through a coarse 20-mesh sieve (850 μm) to collect the starch milk. The residue was re-extracted and the combined starch milk was filtered using a 100-mesh sieve (75 μm). The starch suspension was washed repeatedly with distilled water until both residue and supernatant were clean. The starch particles were air-dried at room temperature, ground using a mortar and pestle, passed through a 60-mesh sieve (250 μm), and kept in polyethylene bags at −20 ºC prior to use.

The method previously presented by Juliano (1971) and modified by Han et al. (2002) was used to determine the apparent amylose content. Absorbance was measured at a λ of 600 nm. Amylose content was calculated using a standard curve

Figure 1. Noodles made with QPM (left–SWQ 11, middle–SWQ 15) and wheat (right–wheat).

made with potato amylose (Sigma Chemical Co., St. Louis, MO) and the following formula:

$$\%amylose = \frac{conc'n\ from\ std\ curve\ \left(\frac{mg}{mL}\right) \times DF \times 100}{amt\ of\ sample\ (mg)} \quad (3)$$

Alkaline cooking

Corn kernels (500 g) were combined with 20 mL of commercially available lye solution (white "*lihia"* composed of water, sodium carbonate, and sodium silicate) and added to water (1:7 mass:volume ratio of maize:water). The mixture was cooked at 95 ± 5 °C for 90 min and the kernels were soaked in the solution and allowed to cool at room temperature for 16 h. The liquor was decanted and the cooked maize was washed at least thrice with distilled water to remove the alkali residue and hull. The dehulled corn was ground with water (1:2 w/v) at room temperature using a mechanical stone grinder to produce the nixtamal and pressed using muslin cloth to remove excess moisture. The *masa* contained approximately 70% (wet basis) moisture and was stored at −20 ºC prior to use.

Noodle preparation

The process for making noodles involved: (a) preparation of the starch binder, (b) addition of the starch binder to the *masa*, (c) cooking, and (d) drying. A starch binder was prepared by gelatinizing commercially available cornstarch. Distilled water (60 mL) was added to 10 g of cornstarch and the mixture was heated at 100 ºC in a double boiler and stirred until a translucent, pasty substance with a thick consistency was achieved (approximately 20 min). The binder was immediately incorporated in the corn nixtamal at a mass ratio of 3:7 (binder:nixtamal). Cornstarch was added at a mass ratio of 1.5:8.5 cornstarch:nixtamal-binder mixture to produce the dough (containing approximately 50% moisture content) and to facilitate kneading. The dough was kneaded until the binder and cornstarch were well-distributed in the dough, resulting in smooth and firm texture. The dough was then covered with polyethylene film and allowed to rest for 15 min to distribute the moisture in the dough. Afterwards, the dough was divided into small portions, sheeted, and cut into strips using a commercially available fabricated noodle maker. Sheeting was done as quickly as possible until long sheets were produced (approximately 5−7 sheeting passes). The roller gap of the noodle maker was gradually increased to 1.5 mm prior to cutting. The uncooked noodle strands were placed in wire meshes and cooked in boiling water. From preliminary experiments, an optimum cooking time of 5 min was recommended. The cooked noodles were rinsed in running water, dried in a convection oven at 55 ºC for 16 h, packed and sealed in polyethylene bags, and stored at −20 ºC until use. To rehydrate the noodles, 60 g of noodles were cooked with 650 mL of boiling water for 3 min. Figure 1 shows the appearance of the processed noodles.

Control samples included (a) corn starch noodles (CSN) purchased from a local grocery and (b) wheat-based yellow alkaline noodles (YAN) processed in our laboratory. CSN was used in preliminary cooking and sensory tests. The formulation for YAN consisted of 100 g of all purpose wheat flour, 36.2 mL of distilled water, 1 g of commercial sodium chloride, and 0.25 g of sodium carbonate (Merck, Darmstadt, Germany). The ingredients were mixed well in a bowl, allowed to rest for 15 min, sheeted, cooked, dried, and stored as previously described.

Noodle characteristics

Cooking properties

Cooking properties of noodles were determined according to AACC method 66-50 (AACC 2000).

Cooking Yield

Dry noodles (5 g) were cooked in 75 mL of boiling distilled water for 11 min, rinsed in distilled water, and drained for 1 min before weighing. Cooking yields were calculated from the difference between the mass of noodles before and after cooking and expressed as g H_2O absorbed/g noodle.

Cooking Loss

Noodles from the cooking yield test were dried at 105 ºC in a convection oven and weighed. Cooking losses were computed using equation (4):

$$cooking\ loss\ (\%) = \frac{dried\ initial\ noodle\ wt - dried\ final\ noodle\ wt}{dried\ initial\ noodle\ wt} \times 100 \quad (4)$$

Texture profile analysis

The texture of the noodle samples was measured using the Instron Food Testing Instrument Table Model 1140 (High Wycombe, Bucks, England) fitted with a 50-kg compression cell.

Table 1. Composition of two QPM varieties[a]

Variety	Composition (%)							
	Moisture	Ash	Fat	Fiber	Protein	NFE[b]	Starch	Amylose
SWQ 11	10.37±0.62a	0.35±0.04a	3.22±0.14a	0.35±0.11a	7.62±0.23a	78.23±0.78a	58.97±8.16a	24.76±1.91a
SWQ 15	8.91±0.11b	0.29±0.01a	2.48±0.14b	0.08±0.02b	5.70±0.15b	82.11±0.29b	44.13±6.47b	25.88±3.08a

[a] N = 3. Values in column followed by the same letter are not significantly different at $p < 0.05$. QPM − quality protein maize
[b] NFE − nitrogen-free extract

Table 2. Cooking properties of YAN and QPM noodles

Sample	Cooking Yield[a] (g H_2O absorbed/ g noodle)	Cooking Loss[b] (%)
SWQ 11	2.48±0.08a	3.88±0.03a
SWQ 15	2.54±0.15a	6.79±0.53b
YAN	3.84±0.22b	6.92±0.50b

[a] N = 3. Values in column followed by the same letter are not significantly different at $p < 0.05$.
[b] N = 2. Values in column followed by the same letter are not significantly different at $p < 0.05$.
QPM − quality protein maize, YAN − yellow alkaline noodles

The tests were performed on 13-g cooked and rehydrated noodle samples arranged in parallel layers 10 mm thick using the following parameters: 100 mm/min crosshead speed, 100 mm/min chart speed, and 75% compression. A two-cycle compression of noodle strands was done with a flat-based probe (35 mm diameter) to obtain hardness, resilience, cohesiveness, and gumminess. A cutting test was performed on 5 noodle strands using a Warner-Bratzler probe to obtain cutting stress (Ross 2006). The samples were kept covered with polyethylene film prior to tests to minimize moisture loss. Hardness, cutting stress, and gumminess were reported in kg-force (kg_f).

Sensory evaluation

Twenty untrained panelists from the Institute of Food Science and Technology, University of the Philippines Los Baños were gathered to evaluate the quality attributes of the noodles. The panelists consisted of male and female students and staff members whose ages ranged from 18-60 years old. For each sample (SWQ 11 noodles, SWQ 15 noodles, YAN and CSN) dry noodle batches (65 g) were cooked in boiling water for 3 min, drained, and allowed to cool. For each batch of cooked noodles, 5 g of commercial powdered beef flavor seasoning pack was mixed prior to sensory evaluation. Quality attributes were evaluated using a 7-point category scale. The panelists were asked to evaluate the noodles in terms of color (1 = yellow, 7 = white), chewiness (1 = rubbery, 7 = hard), firmness (1 = soft, 7 = hard), texture (1 = smooth, 7 = coarse), flavor absorbance (1 = weak, 7 = strong), and general acceptability (1 = unacceptable, 7 = acceptable). The panelists were instructed to chew the samples 2-3 times before swallowing. Firmness and texture were evaluated using mastication.

Statistical analysis

All extractions were performed in duplicates and extracts were pooled prior to analyses. Experimental tests were performed in duplicates or triplicates using one-way design. Treatment means were compared using analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) was used as *posthoc* test. Means were considered significantly different at $p < 0.05$.

RESULTS AND DISCUSSION

Kernel and cooking properties

SWQ 11 contained more fat, fiber, protein, and starch than SWQ 15 (Table 1). Based on the amylose content (waxy, normal, high amylose), both corn samples contained normal starch (Shelton and Lee 2000). Tam et al. (2004) reported that normal corn starch samples are good substrates for production of *bihon*-type noodles because they gelatinize sufficiently at boiling temperature of water and demonstrate fast retrogradation. Generally, the starch and amylose contents of normal corn starch approximate those of normal wheat starch (Lineback and Rasper 1988, Guo et al. 2003).

Kernel composition did not influence the cooking properties of QPM noodles (Table 2). Cooking yields of SWQ 11 and SWQ 15 were statistically equivalent, but were significantly lower than YAN (3.84%) and CSN (5%). Cooking yield is an index of the extent of water absorption of noodles upon cooking. Fardet et al. (1998) explained that the starch-protein matrix in wheat affects the weight increase of pasta because this matrix is involved in the hydration process during cooking. Hydrophilic wheat proteins improve water absorption (Lawton 1992) and corn noodles have fully gelatinized starch. This explains the high cooking yields observed in YAN and CSN. In contrast, the cooking properties of maize nixtamal are more complex. QPM contains hydrophobic tryptophan and basic lysine residues that ionize during nixtamalization, during which starch undergoes partial gelatinization. This supports the notion of increased protein content and bioavailability of niacin (Clark et al. 1977, Rodríguez-Miranda et al. 2011); however, confirmatory *in vitro* and *in vivo* tests need to be conducted. Low-molecular weight proteins, such as globulin and albumin, were reported to leach into the liquor during cooking and steeping (Méndez-Montealvo et al. 2006), but the structure and behavior of the remaining proteins during the washing and noodle processing steps are still unknown. Further, cooking of nixtamalized maize samples increases the water binding capacity (Sefa-Dedeh et al. 2004), but saturation of hydroxy groups with calcium ions effectively reduces water binding sites (Bryant and Hamaker 1997). An alternative alkali, such as sodium hydroxide, could also be used in nixtamalization (Ruiz-Gutiérrez et al. 2012), but changes in the extent of saturation of the hydroxy groups have not yet been reported. The *masa* formed during nixtamalization of QPM in this study was found to be cohesive enough for sheeting and cutting of noodles (Figure 1).

Cooking losses represent high solubility of starch, resulting in turbid cooking water, low cooking tolerance, and sticky mouth feel (Jin et al. 1994). High values are considered undesirable but generally are unavoidable, especially because the added alkali during noodle processing promotes cooking loss (Shiau and Yeh 2001). Cooking losses of 7% to 8% are considered satisfactory for dried noodles (Dick and Youngs 1988). Compared to CSN (15.5%), YAN and QPM noodles showed acceptable cooking losses that could have been influenced by protein content. Lower cooking loss was observed in SWQ 11 noodles (3.88 %) than SWQ 15 noodles (6.79 %) and YAN (6.92 %).

The water absorption capacity of *masa* increases proportionally with lime concentration (Sefa-Dedeh et al. 2004, Mondragón et al. 2004a). When *masa* is further heated to complete gelatinization, followed by a drying process, water solubility may increase but not water absorption (Rodríguez-Miranda et al. 2011). The steeping process in nixtamalization, wherein the kernels are soaked in the cooked liquor, results in annealing of the starch structure (Guzmán et al. 2011, Mondragón et al. 2004b) and may explain low cooking losses. This could explain why both SWQ 11 and SWQ 15 nixtamal yielded comparatively strong noodles that absorbed less water.

Instrumental and sensory attributes

Table 3 shows that the two QPM noodles have similar texture profile parameters. The results suggest that texture parameters are not influenced by differences in starch or protein content (Table 1), in contrast to a related study involving three oriental noodle types (Baik et al. 1994). Noodles made with SWQ 11 (6.90) and SWQ 15 (6.63) have similar hardness values that are significantly higher than that of YAN (4.03) or of CSN (4.0). YAN and CSN exhibited lower hardness values probably due to high water absorption capacities during cooking compared to corn noodle samples (Table 2). Likewise, the force required to cut the noodles was higher for the QPM noodles than either CSN (<0.1 kg_f) or YAN (<0.1 kg_f). This can be explained by the observation that the maximum cutting stress of noodles significantly declines with increasing water absorption levels (Hatcher et al. 1999). Greater hardness associated with noodles prepared from corn nixtamal can be explained as the result of the cross-linking of the hydroxy groups in starch with available calcium ions during alkaline cooking (Bryant and Hamaker 1997). The higher hardness and cutting stress values observed with the QPM noodles suggest extensive cross-links between alkali and starch ions.

Table 3. Instrumental texture parameters of YAN and QPM noodles[a]

Parameters	Sample		
	SWQ 11	SWQ 15	YAN
Hardness (kg_f)	6.90±1.48a	6.63±1.36a	4.03±0.06b
Cutting stress (kg_f)	1.42±0.55a	0.62±0.14a	<0.1
Resilience (Ratio)	0.79±0.14a	0.76±0.10a	0.51±0.11b
Cohesiveness (Ratio)	0.59±0.25a	0.58±0.15a	0.70±0.06a
Gumminess (kg_f)	4.21±2.44a	3.76±0.53a	2.81±0.20a

[a] N = 3. Values in row followed by the same letter are not significantly different at $p < 0.05$.
QPM − quality protein maize, YAN − yellow alkaline noodles

The resilience ratios among all noodle samples were comparable, but a statistically significant difference was observed between QPM noodles (0.8) and the control samples (0.5). The resilience ratio for CSN was 0.50, similar to that of YAN. Resilience ratio is equivalent to the area between the decompression and compression strokes during first bite (Rosenthal 1999). Gluten may explain the resilience of YAN, while comparable values with QPM noodles are presumably due to starch-protein interactions (Guzmán et al. 2009). Recovery from deformation was slightly higher with SWQ 11 noodles than SWQ 15 noodles. This is probably due to a higher protein content of SWQ 11 (7.62%) than SWQ 15 (5.70%). The higher fat content in SWQ 11 (3.22%) compared to SWQ 15 (2.48%) might have also affected the extent of amylose-lipid interactions that arise during nixtamalization (Mondragón et al. 2004a).

The gumminess and cohesiveness values of the QPM noodle samples were statistically equivalent and were comparable to those of CSN and YAN. Cohesiveness is related to the strength of the internal bonds that make up the food sample (Guo et al. 2003), while gumminess is the energy required to disintegrate a semisolid food until it is ready for swallowing. Mathematically, cohesiveness is the ratio of the positive force areas between the second and first compression strokes, while gumminess is the product of cohesiveness and hardness (Rosenthal 1999). The QPM noodles were significantly firmer than either YAN or CSN, but the compressive force during second bite was slightly lower. As a result, gumminess values were similar across all samples although values were slightly higher for QPM noodles. Besides tortillas, products made with alkaline-cooked corn have a firm structure (Rodríguez-Miranda et al. 2011). However, the cohesive structure of the *masa* allows sheeting and cutting, similar to noodle processing. To improve the texture properties of the noodles, the alkaline cooking time may be shortened (Guzmán et al. 2009).

The results of sensory evaluation (Table 4) showed that the QPM noodles differed from YAN in all the attributes tested. The noodles were also compared with CSN to determine if the presence of starch would yield similar results in the sensory characteristics. Compared to QPM noodles, CSN seasoned with the

Table 4. Sensory attributes of YAN and QPM noodles[a]

Attribute [b]	Sample		
	SWQ 11	SWQ 15	YAN
Color	3.45±1.28a	3.35±1.27a	5.40±0.99b
Firmness	4.95±1.43a	5.45±1.23a	2.65±1.35b
Chewiness	4.80±1.54a	5.30±1.30a	2.40±1.31b
Texture	4.65±1.31a	4.60±1.23a	1.80±0.70b
Flavor Absorbance	3.50±1.64a	3.55±1.79a	4.85±1.90b
General Acceptability	3.30±1.53a	3.25±1.41a	6.35±0.93b

[a] Values in row followed by the same letter are not significantly different at $p < 0.05$.
[b] N = 20.The anchors for each attribute on the scales were as follows: color (1 = yellow, 7 = white), firmness (1 = soft, 7 = hard), chewiness (1 = rubbery, 7 = hard), texture (1 = smooth, 7 = coarse), flavor absorbance (1 = weak, 7 = strong), and general acceptability (1 = unacceptable, 7 = acceptable)
QPM − quality protein maize, YAN − yellow alkaline noodles

flavor packet was found to be more yellow (color score = 2.85), softer (firmness score = 2.25), more rubbery (chewiness score = 3.20), and smoother (texture score = 1.85). It also had a stronger flavor (flavor absorbance score = 4.55) and was found to be more acceptable (general acceptability score = 5.25). The difference in color between the QPM noodles and CSN might be attributed to nixtamalization, which allows the formation of a yellowish product even when white maize is used (Sefa-Dedeh et al. 2004). More than the presence of starch in both corn-based noodles, data suggest that the presence of components in the nixtamal influenced the final noodle characteristics. The panelists found the texture of YAN as smooth as CSN and smoother than the QPM noodles. The difference in magnitude among the scores was also greatest in texture than in any other sensory attribute. This implies that texture appears to be the most crucial factor in deciding the acceptability of the QPM noodles. Instrumental measures of food texture can be compared to sensory results to determine if human perception of food texture is approximated by simulated mastication. Correlation analysis between hardness (Table 3) and food firmness (Table 4) reveals a linear relationship (r = 0.96). However, instrumental parameters indicative of the second bite (cohesiveness and gumminess) do not appear to simulate oral processing parameters (such as chewiness), and measurement methods to approximate mastication may need to be improved. The texture of noodles processed from *masa* may be further improved by decreasing the noodle firmness. This can be achieved by shortening the nixtamalization times or adding hydrocolloids such as proteins and polysaccharide-based gums.

CONCLUSIONS

Alkaline-cooked QPM was processed into noodles with acceptable cooking properties and comparable flavor absorbance compared to CSN and YAN. Kernel composition was not a significant factor in the cooking and sensory properties of the processed noodles. The two QPM samples had different proximate compositions and starch contents but equivalent amylose contents. The results of cooking tests and sensory tests, as well as the instrumental measurement of texture, were similar for both samples. The results showed that amylose content might be a better indicator of noodle properties than starch content. Both the alkaline cooking and noodle making processes will be modified to improve consumer acceptability. Changes in the physical and thermal properties of the noodles during retrogradation and rehydration will also be explored to enhance the noodle quality and increase the food uses of QPM.

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CONFLICTS OF INTEREST

There are no conflicts of interest in this study.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

This study represents a portion of the undergraduate thesis of Ms. Bibat. Dr. del Rosario supervised the conduct of the proximate, starch and amylose analyses. Dr. Mopera measured the kernel characteristics of the maize varieties used in this study. Dr. Collado developed the nixtamalization process and served as the project leader in the funded study. Dr. Flores developed the process for making noodles from nixtamal and supervised the study.

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