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NUTRITION AND TEXTURE EVALUATION OF MAIZE-WHITE COMMON BEAN NIÑTAMALIZED TORTILLAS

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**NUTRITION AND TEXTURE EVALUATION OF MAIZE-WHITE COMMON BEAN NIXTAMALIZED TORTILLAS**

Dolores Cuevas-Martínez, Carolina Moreno-Ramos, Enrique Martínez-Manrique, Ernesto Moreno-Martínez and Abraham Méndez-Albores

**SUMMARY**

The effect of white common bean addition on certain nutritional, physicochemical and textural properties of tortillas was determined. The maize-bean blends used were 100:0, 95:5, 90:10, 85:15, 80:20, and 75:25. The blends were processed using the traditional nixtamalization process. As the bean quantity increased in tortillas, higher protein, lysine, and tryptophan contents were registered. At 25% of bean addition, lysine and tryptophan content in tortillas increased from 56 and 36% of FAO profile to 95 and 84%, respectively. It was concluded that tortillas produced with these blends not only improve protein quality but also had similar physicochemical and textural properties of tortillas prepared with maize.

**EVALUACIÓN NUTRICIONAL Y TEXTURAL DE TORTILLAS DE MAÍZ-FRIJOL BLANCO NIXTAMALIZADAS**

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**RESUMEN**

Se determinó el efecto de la adición de frijol blanco sobre ciertas propiedades nutricionales, fisicoquímicas y texturales de tortillas. Las mezclas de maíz-frijol blanco utilizadas fueron 100:0, 95:5, 90:10, 85:15, 80:20, y 75:25. Las mezclas fueron procesadas utilizando el proceso tradicional de nixtamalización. Al aumentar la cantidad de frijol en las tortillas se registraron contenidos mayores de proteína, lisina y triptófano. Con la adición de 25% de frijol, los contenidos de lisina y triptófano aumentaron en 56 y 36% el valor del perfil FAO, hasta 95 y 84%, respectivamente. Se concluye que las tortillas hechas con las mezclas indicadas no solo mejoran su calidad proteica, sino que presentan propiedades fisicoquímicas y texturales similares a las de las tortillas preparadas con maíz.

**Introduction**

Tortillas and beans are the most important protein sources for the Mexican population, providing 70% of the calories and 90% of total protein intake (Pérez et al., 2002; Rosado et al., 2005). Tortillas are traditionally made using the alkaline process called nixtamalization, which consists of cooking grain in abundant water and lime (2-3 l of water per kg of maize processed, with 1-3% Ca(OH)₂) at temperatures near boiling, for 35-70min, with a steeping period of 8-16h. After steeping, the lime cooking solution is decanted, and the grain is thoroughly washed to leave it ready for milling in order to obtain the masa (maize dough) for making the tortillas (Serna-Saldívar et al., 1990). The nixtamalization process enhances the nutritional value of maize by improving protein quality, increasing the calcium and niacin availability and reducing phytic acid levels. Unfortunately, nixtamalization also leads to losses of protein, carbohydrates and vitamins (Figueroa-Cárdenas et al., 2001). Due to this fact, the tortilla industry suffers from a compromise in quality with low protein levels, as well as deficiencies of lysine and tryptophan in the product. Therefore, several studies have been conducted regarding nutrient improvement in tortillas. The amount of protein has been increased by adding soybean (Franze, 1975; Bressani et al., 1979), defatted soybean flour (González-Agramón and Serna-Saldívar, 1988), sorghum (Serna-Saldívar et al., 1988a), cottonseed flour (McPherson and Ou, 1976), germinated corn (Wang and Fields, 1978), spent soymilk residue, and direct lysine and tryptophan enrichment (Waliszewski et al., 2000, 2002), among others. However, such strategies have proven to be expensive or impractical, due to the change in physico-

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Determined were the effect of the addition of phaseolus vulgaris (white bean) on the nutritional characteristics of nixtamalized tortillas. Each experimental unit consisted of 1000g of maize and 600g of bean contained in an attempt to develop practical and economical processes for tortilla production with improved nutritional characteristics.

Materials and Methods

Raw materials

Maize grain (Zea mays L.) of the commercial hybrid AS-900, and white 157 common bean (Phaseolus vulgaris L.) were used, with initial moisture contents of 9.1 and 11.2%, respectively. Moisture content (MC) was determined by drying replicate portions of 5-10g each of whole grain at 103°C for 72h, and percentages calculated on a wet-weight basis.

Tortilla-making process

The traditional nixtamalization process was used. Each experimental unit consisted of 1000g of maize-bean blend (100:0, 95:5, 90:10, 85:15, 80:20, 75:25) mixed with 3 l distilled water and 15g of lime (99% calcium hydroxide). The blends were cooked in a covered aluminum pan for 55min and steeped 16h at room temperature (22 ±1°C). The steep liquor was removed, and the cooked maize was washed with 4l of tap water to remove excess lime and pericarp tissue. The nixtamal (cooked grain) was stone-ground to a MC of ~59%. The masa was flattened into thin disks of 12.5cm diameter and 1.2mm thickness using a commercial tortilla roll machine (Casa González, Monterrey, NL, Mexico). Tortillas were baked on a griddle at 270±5°C for 17s on one side, 55s on the other side, and again 17s on the first side. The temperature was measured with a non-contact portable infrared thermometer Fluke-572 (Fluke, Melrose, MA, USA). Tortilla puffing was evaluated subjectively by using scores of 1-3, where 1= little or no puffing (0–25%), 2= medium puffing (25–75%), and 3= complete puffing (75–100%). Rollability was evaluated by rolling a tortilla over a 1cm diameter tube, quantifying the extent of breaking using a scale of 1 to 3, where 1= tortillas with no breaking; 2= a partial breaking at the center and edges of the tortilla; and 3= completely flattened tortillas.

Physicochemical analysis

The pH was determined according to the 02-52 AACC method (AACC, 2000). Tortillas were subjected to surface-color analysis with a MiniScan XE model 45/0-L colorimeter (Hunter Associates Laboratory, Reston, VA, USA). The colorimeter was calibrated with a white porcelain plaque (L= 97.02, a= 0.13, b= 1.77). Readings were made in triplicate at four positions at 90° with respect to each other. Three derived functions (ΔE, chroma, and hue value) were computed from the L, a, and b readings, as:

\[ ΔE= [(ΔL)^2 + (Δa)^2 + (Δb)^2]^{1/2} \]

Chroma= (a^2 + b^2)^1/2

Hue angle= arctan (b/a)

Tortilla texture

The texture of the tortilla (tensile strength and cutting force) was evaluated using the Texture Analyzer TA-XT2 (Texture Technologies Corp., Scarsdale, NY, USA). Texture was evaluated immediately after preparation. To avoid loss of water and temperature, tortillas were kept at 40°C inside polyethylene bags. For tensile strength evaluation, a piece of tortilla in the form of a test条 (8.7×3.75cm at each end, and 1.5cm wide at the thinnest part) of the central part of the tortilla was cut and placed in retention clamps TA-96. The test was carried out at 2mm·s^-1, and pincers were opened 15mm until the tortilla piece was broken. To measure the cutting force, a piece of tortilla with the same form was cut using the blade TA-90 at 2mm·s^-1 and a cutting depth of 10mm.

Protein, lysine and tryptophan content

The 960.52 micro-Kjeldhal official method of the AOAC (2000) was used to determine the protein content in tortilla flours (N×6.25). Amino acid analysis was performed by reversed phase-high performance liquid chromatography (RP-HPLC, Model 510, Waters Associates, Milford, MA, USA). Samples (100mg) were hydrolyzed under nitrogen at 110°C with 2ml of 6N HCl for 24h. The acid was removed by rotary evaporation. For tryptophan analysis, samples were hydrolyzed at 140°C with 3ml of 4N Ba(OH)_2 for 8h, then neutralized with 12N HCl to a pH of 7. After filtration, 25μl were used for derivatization with phenylisothiocyanate and derivatized samples were analyzed in a Waters Nova-pak C18 column. 
(5µm, 3.9×150mm). Amino acid analysis was conducted in triplicate for each sample.

Tryptic inhibitor, phytic acid and tannins

Tryptic inhibitor activity was determined using the method of Kadake et al. (1974), from the decrease in the rate in which trypsin hydrolyzes BApNA (N-alpha-benzoyl-DL-arginine p-nitroanilide). Briefly, the ground sample was stirred in 0.01N NaOH for 1h, and aliquots were used for the analysis. Tryptic inhibitor activity was expressed as trypsin units inhibited, one trypsin unit being arbitrarily defined as an increase of 0.01 absorbance unit at 410nm·ml⁻¹ of the reaction mixture under the described conditions. Phytic acid was extracted in 0.5M nitric acid by shaking at room temperature for 3h and determined spectrophotometrically at 512nm, as described by Davies and Reid (1979). Tannin content was also estimated with a spectrophotometer (Beckman Coulter, DU-530) at 760nm, using the Folin-Denis reagent after extraction with 1% hydrochloric acid in methanol (method 952.03; AOAC, 2000).

Statistical analysis

The experiment was conducted as a completely randomized design. The experimental conditions were carried out with three replicates. Data was assessed by analysis of variance (ANOVA), and comparisons of means were performed according to the Dunnet test using SAS (1998). A significance of α = 0.05 was used to distinguish significant differences between treatments.

Results and Discussion

Table I shows some physicochemical and textural properties of tortillas obtained through the traditional nixtamalization process. No statistical differences were observed in those properties in tortillas prepared with the maize-bean blends. Moisture content (MC) ranged from 47.11 to 48.16%, and the pH values from 8.95 to 9.32. These values are similar to those reported by other researchers (Saldana and Brown, 1984; Serna-Saldívar et al., 1988b; Méndez-Albores et al., 2004a, b). In nixtamalized products, the lime concentration represents an important factor in color, odor, flavor, shelf life and texture characteristics; when the lime content is not sufficient to give the characteristic alkaline flavor, the tortillas are rejected by consumers. Likewise, if this compound is in excess, tortillas become stringent and are also rejected. However, with some maize genotypes, a high concentration of lime could be used (3% wt/wt), which leads to a yellowish end-product and also extends the shelf-life of the tortillas.

The tortilla color was not affected by the addition of bean to the maize (Table I). All treatments had the same lime concentration of 1.5% (wt/wt), and consequently the tortillas presented a yellowish color, as shown by the ΔE values near 35. Moreover, the inclusion of different ratios of white bean did not significantly affect the L, chroma and hue in tortillas as shown in Table I. Changes in the color of tortillas were directly attributed to the amount of lime retained during the cooking and washing of the nixtamal. Lime content affects the tortilla color even when tortillas are produced from white maize grains, and the color intensity is closely related to carotenoid pigments, flavonoids, and pH. However, the development of color during the alkaline cooking is more complex, considering that the calcium hydroxide reacts with the different pigments found in the maize grain and interferes with browning reactions such as caramelization and Maillard reactions (Gómez et al., 1987).

Table I also shows some quality and textural properties of tortillas. Tortilla puffing was not significantly affected. All tortillas evaluated presented a value of 3, which indicates complete puffing (75-100%). A good puffing is presented when two layers are formed in the tortilla; these layers, produced during the cooking process, are impermeable, retaining the steam that gives rise to the puffing during heating. Moreover, all tortillas evaluated presented a good rollability, with a value close to 1, defined as no breaking; therefore, tortillas were also considered within the acceptable margins of quality, presenting a soft texture and rolled without breaking.

As to the texture, tortillas made with maize presented tense properties (measured in Newtons) of 1.11N; and no significant differences were observed between control tortillas and tortillas prepared with the maize-bean blends. Also, regarding the cutting force, no significant differences were observed, the average values were 7.9N for tortillas made with the blends as well as for tortillas made with maize alone. These texture values are similar to those reported in tortillas produced with high moisture content in stored maize grain (Méndez-Albores et al., 2003). In general, tortillas prepared from maize alone or from blends were stretchable, elastic, and resistant to tearing and cracking. However, a shelf-life study is needed to determine if storage time causes changes in tortilla texture (tensile strength or cutting force).

Protein content was reduced after the nixtamalization process. Protein content in raw maize was 94.80g·kg⁻¹ db (dry basis), and when nixtamalized, protein was reduced to 91.53g·kg⁻¹ db (Table II). This reduction of 3.5% is consistent with the reported losses in proteins due to the process, which are in agreement with the results obtained by other researchers (Saldana and Brown, 1984; Serna-Saldívar et al., 1988b). The protein content in the blends was slightly lower than that of maize alone, indicating a reduction of the protein content due to the addition of bean. The protein content in the blends ranged from 91.53 to 93.92g·kg⁻¹ db. The protein content of the blends was also reduced due to the addition of bean, which is richer in carbohydrates than maize. The protein content of the blends ranged from 89.76 to 91.61g·kg⁻¹ db, which is lower than that of maize alone. The protein content of the blends was also reduced due to the addition of bean, which is richer in carbohydrates than maize.
with previous reports, which indicate that protein is lost during tortilla elaboration (Bressani, 1990; Milan-Carrillo et al., 2004). Regarding the amino acid content, lysine and tryptophan were also reduced in maize tortillas in 9.62 and 52.61%, respectively (Table II). Mora-Avilés et al. (2007) reported that lysine and tryptophan content in quality protein maize (QPM) were reduced in 8% after lime treatment, while in regular maize they were reduced 25 and 15%, respectively. Rojas-Molina et al. (2008) reported reductions of 36 and 32% in the total lysine and reactive lysine, as well as 38.7% for tryptophan content during traditional nixtamalization of QPM (H-368C). These differences in amino acid reductions are attributable to the conditions used during the nixtamalization process, such as lime concentration, temperature, cooking and steeping time (Bressani, 1990; Serna-Saldivar et al., 1990). Also, the protein solubility distribution and the essential amino acids location could partially explain the protein quality changes observed during nixtamalization (Rojas-Molina et al., 2008). On the contrary, the quantity and quality of the protein in tortillas prepared with maize-bean blends evidently increase (Table II).

Tryptophan, an amino acid highly sensitive to the thermal-alkaline treatment, can be considered the first limiting amino acid of maize nixtamalized tortillas (3.45g·kg⁻¹ protein), the second limiting amino acid being lysine (30.63g·kg⁻¹ protein), covering 36 and 56% of the FAO/WHO requirements (FAO/WHO/UNU, 1985). However, as a result of the inclusion of the bean, there were significant increases in trypsin and lysine content in maize-bean tortillas. As expected, as the bean content increased, higher levels of those amino acids were registered, without affecting the physicochemical or textural properties of tortillas (Table II). Tortillas produced with the blend 75:25 presented 51.84 and 8.04g·kg⁻¹ protein of lysine and tryptophan, respectively; which represents 95 and 84% of FAO profile.

Table III summarizes the anti-nutritional factors found in raw maize, raw bean, and tortillas elaborated with the maize-bean blends. As expected, raw bean had the highest trypsin inhibitor activity, presenting a value of 13.6 units/mg sample, as well as phytic acid (2.4%) and tannin content (0.25%). Reductions on these anti-nutritional were observed, to various extents, depending on the maize-bean ratio processed. About 90-96% trypsin inhibitor, 46-54% phytic acid, and 16-20% tannin content were reduced upon nixtamalization. These results are consistent with the findings of other studies that reported a reduction in tannins and other antinutrients upon cooking legumes (Sharma and Sehgal, 1992; Singh, 1993; Rehman and Shah, 2005; Siddhuraju and Becker, 2005). In general, the decrease in the levels of these antinutrients, particularly of trypsin inhibitor, might also be due to thermal degradation and denaturation, as well as to the formation of insoluble complexes (Kataria et al., 1989, Siddhuraju and Becker, 2001).

A major challenge for many Latin American countries is to ensure that sectors of society that consume tortillas as a principal energy and protein source improve their diet quality. Consequently, in countries where white common bean is available, its use is recommended during the nixtamalization process for up to 25% for tortilla enrichment.

**TABLE II**

<table>
<thead>
<tr>
<th>Component</th>
<th>FAO requirement</th>
<th>Raw grains</th>
<th>Maize-bean ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lysine</td>
<td>54.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tryptophan</td>
<td>9.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean of three replicates + standard error. Mean values with same letter in the same row are not significantly different (Dunnet>0.05). 
Protein content in g·kg⁻¹ (dry basis). Amino acids are expressed in g·kg⁻¹ of protein.

**TABLE III**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Phytic acid (%)</th>
<th>Tannins (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>100-0</td>
<td>91.53±0.29a</td>
</tr>
<tr>
<td>Bean</td>
<td>95-5</td>
<td>100.53±0.46c</td>
</tr>
<tr>
<td></td>
<td>90-10</td>
<td>110.27±0.92c</td>
</tr>
<tr>
<td></td>
<td>85-15</td>
<td>80-20</td>
</tr>
</tbody>
</table>

**REFERENCES**


Davies NT, Reid H (1979) An evaluation of the phytate, zinc, cop-


