Textural, chemical and sensorial properties of maize tortillas fortified with nontoxic Jatropha curcas L. flour

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ABSTRACT

Hunger and malnutrition still affecting part of the Mexican population, for whom the tortilla is a staple food. However, maize tortillas are high in calories but deficient in proteins; therefore, studies have been conducted to fortify tortillas, with protein-rich nonconventional sources. This study examines the physicochemical and rheological characteristics of dough and maize tortillas fortified with nontoxic Jatropha curcas flour. Fortified maize doughs were prepared with 0%, 5%, 10%, 15% and 20% J. curcas nontoxic flour, which contains 55% protein. Tortillas were made and their chemical profile and tortilla quality were quantified and subjected to sensorial analysis. Rheological characteristics of dough were slightly modified but the protein in the tortillas increased 10.8% with treatment T20. They did not change in color, were soft, and consumer acceptance was not affected. It is concluded that nontoxic J. curcas flour is an excellent option for increasing the protein value of tortillas.

INTRODUCTION

The Food and Agriculture Organization of the United Nations (2000) declares that ‘all persons have the right to sufficient healthy nutritious food and not suffer hunger’. Ingesting food that is not sufficient in quantity or quality causes malnutrition, which is associated with physiological disorders. Mexico is a country where malnutrition or undernutrition exists (Encuesta Nacional de Salud y Nutrición (ENSANUT), 2012), and therefore, alternatives for reducing this condition should be pursued. One alternative is fortifying food, which consists of supplementing it with the nutrients it lacks (vitamins, proteins and minerals) (Figueroa et al., 2001).

Approximately 95 million inhabitants of Mexico consume 127 kg maize tortillas/year per capita (Stylianospolou, 1999; Vázquez & Amaya, 2010). Unfortunately, the maize protein is deficient in lysine and tryptophan, as well as in micronutrients such as iron, zinc and vitamins (Vázquez & Amaya, 2010), which are essential for human nutrition. Poverty and high population growth rate have led to unsuitable diets and more dependence on the tortilla. For this reason, flours from some crops have been incorporated to fortify it. The flour obtained from the nontoxic ecotype (absence of phorbol esters) Jatropha curcas L. seed could be an excellent alternative.

Today, J. curcas seed is used to produce biofuels from its oil; the seed have about 18–30% protein and oil (35–48%); however, the residual cake contains more than 50% protein of good quality and can be used in human nutrition (Martínez, Martínez, Makkar, Francis, & Becker, 2010). In vitro digestibility of its defatted flour is 78%, which increases up to 88% after a heating process. The levels of essential amino acids except lysine in Jatropha meal are very close to the FAO/WHO reference pattern (Martínez, Siddurajju, Francis, Davila, & Becker, 2006). No reports in the literature were found on the uses of J. curcas flour as supplement to flours made from wheat and
maize grains, which are deficient in essential amino acids (Vázquez & Amaya, 2010). However, defatted soybean (Glycine max L.) flour has been used in concentrations of 4% and 5% to improve nutritive and sensorial quality of tortillas (Figueroa et al., 2001). Cuevas, Moreno, Martínez, Martínez and Mendoza (2010) examined the addition of white beans (Phaseolus vulgaris L.) on certain nutritional, physicochemical and textural properties of tortillas, while Amador (2009) tested the effect of adding soybean and amaranth (Amaranthus hipochondriacus) flour to improve tortilla quality and protein content. In this study, the rheological, chemical and sensorial properties of flour made from nixtamalized maize with the addition of defatted nontoxic J. curcas flour and the tortillas made with those flours mixtures were analyzed.

Materials and methods

Flours

Jatropha flour was made from seeds of an edible nontoxic ecotype produced in the state of Veracruz, México. The seed coat was manually removed, ground with a Cyclotec mill and sifted through a No. 80 mesh in order to obtain even sized flour particles. The cake was defatted immediately with hexane in a Soxhlet extractor for 16 h at 68°C to remove the oil. The maize flour used was from the commercial Maseca™ brand, made with nixtamalized maize.

Formulation of fortified treatments

Maize flour and J. curcas flour were mixed in the following rations: 100:0 (T0, control treatment), 95:5 (T5), 90:10 (T10), 85:15 (T15) and 80:20 (T20).

Proximal chemical analysis

Percentages of protein, lipids, ash, moisture and fiber were quantified by triplicate in J. curcas flour (whole and defatted), maize flour and tortillas made from the treatment formulations. Protein, by the Kjeldahl method, using digester (Digestive System 61007 digester) and distilled Kjeltec 1002 (Distilling unit system Tecator) manual operation (AOAC method 2.057) 15; lipids by extraction with petroleum ether in an extractor Goldfish (AOAC method 7.062) 15; ash, by carbonization and subsequent samples calcined at 550°C to constant weight (AOAC method 14.006) 15; moisture, by circulation oven drying air at 90°C to constant weight (AOAC method 14.003) 15 (AOAC, 2010).

Textural properties

Dough texture profile

Texture of doughs (mixture of flours with distilled water) resulting from the treatment formulations was measured with a Brookfield CT3 2SK texture analyzer following the protocol described by Martinez et al. (2001). The accessories used were a bar with a 1/2-in. sphere tip; test conditions were 25 kg load cell, distance 10 mm s⁻¹, test rate 1 mm s⁻¹ and pretest rate 2 mm s⁻¹. All the analyses were carried out by triplicate.

Tortilla quality

Flour treatments formulations were mixed with distilled water until soft dough was obtained for making tortillas approximately 12 cm in diameter with a manual tortilla press (Lenin, Mexico). Tortillas were cooked on a 280°C grid- dle for 15 s on one side (to form the thin layer), 25 s on the other side (to form the thick layer), and flipped once more to inflate. They were cooled to 27°C and stored in Ziploc™ plastic bags as described by Arámbula, Méndez, González, Gutiérrez and Moreno (2001) to evaluate the following characteristics:

Puncture or perforation test on tortillas

This test was performed in triplicate with a Brookfield CT3 25K texture analyzer, following the method proposed by Bejosano, Joseph, Lopez, Kelekci and Waniska (2005). The accessory was a bar with a stainless steel 1/2-in. sphere tip. Test conditions were 50 mm distance from the puncture base. The tortilla was placed between two perforated plates, leaving an area 40 mm in diameter and in the middle where the bar that made contact. The force applied was that which was necessary to cause the tortilla to break.

Rollability and inflate

Three whole tortillas were taken at random 30 min after baking, which were rolled manually into a tube 2 cm in diameter and the degree of breakage was quantified (Bedolla & Rooney, 1984). A scale of 1 to 5 was used 1 = no breakage, 2, 3, 4 and 5 = 25%, 50%, 75% and 100% breakage, respectively. Inflate was quantified during baking at 280°C under the scale: 1 = 100% inflated, 2 = 50% inflated and 3 = no inflate.

Color assessment

Color of doughs and tortillas was measured with a Hunter Lab reflection colorimeter, which was calibrated with a white porcelain plate. Readings were taken directly on the central part of the doughs and tortillas (Figueroa et al., 2001) by triplicates. For the color scan, luminosity was considered, ranging from white to black, a* in red (+values) and green (−values) tones, b* in yellow (+values) and blue (−values) tones.

Sensory evaluation

Fifty untrained panelists (consumer-like) from the student and worker population of the Colegio de Postgraduados, Campus Tabasco and the Universidad Popular de la Chontalpa, México carried out the sensorial evaluation. A 7-point hedonic scale was used by panelists to express how much they liked or disliked five coded tortilla samples, following the methodology of Anzaldúa (2005). The test was conducted 10 min after baking the tortillas.

Statistical analysis

Data were processed with Statistical Analysis System software (version 9.0.; SAS Institute Inc., Cary, NC, USA), under the completely randomized model, and the means were compared with the Tukey test (p = 0.05).
The analysis of variance and means comparison analysis revealed significant differences in the four traits analyzed among the three flours (Table 1). The moisture content was higher in the maize flour than in both nontoxic J. curcas flours. Protein content was 8.01% in maize flour and 24.5% in non-defatted J. curcas, which increases to 55.01% when the oil was removed. These protein values coincide with those reported for maize of 8–11% (Rendón, Ortiz, Solorza, & Trujillo, 2012) and for whole and defatted J. curcas seed and flour (Martínez et al., 2010). Flour tortillas with added J. curcas showed a slight increase in lipid content compared with the control; however, although this increase is not statistically significant favors the formation of amylose–lipid complexes, thus reducing retrogradation starch, and hardening of the same, providing smoother, coupled with the high content of moisture that presented the same, giving it a longer shelf life, the same behavior was observed by Vázquez-Carrillo et al. (2014) in tortillas obtained from corn hybrids. The high ash (10.4%) content present in defatted meal of J. curcas is important, because these minerals provide nutritional properties beneficial to health and their incorporation into foods would result in a major contribution in this case tortillas, which have low levels of minerals. Humans and other vertebrates need large amounts of calcium for construction and maintenance of bone and normal function of nerves and muscles. Phosphorus is also essential for acid–base balance, bone and tooth formation. Red blood cells cannot function properly without iron in hemoglobin, the oxygen-carrying pigment of red blood cells. Iron is also an important component of the cytochromes that function in cellular respiration. Magnesium, copper, selenium, zinc, iron, manganese and molybdenum are important cofactors found in the structure of certain enzymes and are indispensable in numerous biochemical pathways (Soetan, Olaiya, & Oyewole, 2010).

### Table 1. Chemical composition of flours from different sources.

| Flours       | Moisture (%) | Ashes (%) | Protein (%) | Lipids (%) |
|--------------|--------------|-----------|-------------|------------|
| Corn         | 9.00 ± 0.07   | 0.93 ± 0.06 | 8.01 ± 0.01  | 4.00 ± 0.10   |
| Non-defatted J. curcas | 5.5 ± 0.15  | 4.29 ± 0.07  | 24.5 ± 0.06  | 33.52 ± 0.05  |
| Defatted J. curcas | 6.4 ± 0.10   | 1.04 ± 0.05  | 55.01 ± 0.06  | 1.44 ± 0.01   |

Means with the same letter in each column are not statistically different (Tukey, p < 0.05).

### Results and discussion

#### Proximal chemical analysis of flours

The doughs resulting from the formulations of flour mixtures showed differences in all textural properties (hardness, adhesiveness, cohesiveness), except elasticity (Table 2). Hardness and adhesiveness tended to decrease up to 0.83 and 0.9 when 5–15% J. curcas flour was added to the maize flour, while cohesiveness increased 0.4 with 5–10% J. curcas flour, respectively. A decrease in hardness is attributed to the increase in protein content due to J. curcas flour, which confers capacity to absorb more water and thus makes the dough softer (Salinas, Castillo, Vázquez, & Buendia, 2011). The values obtained are found in the acceptable range (2.06–5.19 N) for maize tortillas dough made from landraces (Rangel et al., 2014).

Decreased adhesiveness is also associated with the capacity of the dough to absorb water (Ramírez & Ortega, 1994) which increased with the addition of protein-rich flour. It is important to point out that making tortillas requires less adhesiveness for a less sticky dough, but it should be sufficient to adhere slightly to the rollers that press out the dough in the tortilla machine (Antuna et al., 2008). Dough that does not adhere does not have the consistency suitable for cutting the tortilla, and too sticky dough cannot form a tortilla that can be placed on the griddle (Arambula et al., 2001). For this reason, ideal dough is balanced in terms of adhesion and cohesion, which is achieved when the dough can absorb the necessary quantity of water (Flores, 2004; Rodriguez, Fernández, & Ayala, 2005). Increased cohesiveness, which is the capacity of the molecules to remain united, is closely linked to adhesiveness which gives the dough firmness (Rodríguez et al., 2005). It should be mentioned that although the parameters of adhesiveness and cohesiveness are important to determine tortilla quality, none of the several published studies on texture establish values for good quality maize dough (Arámula, Méndez, González, Gutiérrez, & Moreno, 2004; Salinas et al., 2010). A study with doughs made from landrace reported a range of adhesiveness of 0.27–0.59 N as suitable for producing tortillas (Arámula et al., 2001).

The elasticity values (13.06–13.09 mm) indicate that dough with ideal hydration for making tortilla was obtained, since values above 8 mm are considered acceptable (Arámula et al., 2004). The values of our study indicate that the doughs are softer and stretch more before breaking (Salinas et al., 2010).
Proximal chemical analysis of the tortillas

In the proximal chemical analysis, the characteristics of the tortillas made with the analyzed flour formulations increased significantly, except for lipid content (Table 3). When the formulation was 20% J. curcas flour, there were increases in moisture content 3.76%, protein 6.20%, ash 1.38% and fiber 1.18%, relative to the control.

The increase in moisture was possibly due to the increase in protein content, which allows retention of more water (Salinas et al., 2011). The moisture values are within the range (35–50%) reported for tortillas, depending on the conditions of nixtamalization and maize variety (Agama et al., 2004). Moisture in the 20% J. curcas flour was in the range (47.11–48.16%) reported for tortillas fortified with white beans (P. vulgaris L.) (Cuevas et al., 2010).

The highest protein increase (6.20%) was obtained when the dough had 20% J. curcas flour, similar to tortillas fortified with 4% soybean (G. max L.) flour (Figueroa et al., 2001) and with 5–20% whole chia seeds (Salvia hispanica L.) (Rendón et al., 2012). The ash increases are likely due to the minerals that J. curcas seeds contain (calcium, magnesium, potassium, among others) (Toral, 2008) and are similar to those in tortillas fortified with 20% amaranth (A. hipochondriacus) flour (Islas, Rendón, Agama, Tovar, & Bello, 2007).

The reduced fiber content could be due to the low fiber of defatted J. curcas flour, which oscillates between 5% and 9% (Martínez et al., 2010). Fiber increases of up to 25% were reported in tortillas fortified with whole chia seed (Salvia hispanica L.) (Rendón et al., 2012). However, values similar to ours are reported for tortillas formulated with 4% soybean flour (Figueroa et al., 2001). It is concluded that the highest content of protein was obtained with the formulations with 15% and 20% J. curcas flour and that the most desirable percentage for improving tortillas nutritionally is 20%.

Tortilla quality

Tortilla quality, in terms of hardness, rollability and inflate, was significantly different among treatments (Table 4). Tortilla hardness decreased more than 50% when 15% J. curcas flour was added. The same percentage of flour doubled up rollability, but it was necessary to add 20% of this flour to detect an increase in tortilla inflate.

Hardness, measured by the puncture test, is associated with starch retrogradation, which begins as soon as the tortilla cools. The starch polymers amylose and amylopectin are directly involved. The former has a faster retrogradation process because of its linear, highly polar formation, which reduces its capacity to retain water and causes partial shrinkage of the starch (Almeida & Loyd, 1996; Salinas et al., 2011).

This process is altered when J. curcas flour is added; because of its high protein content, the water retention capacity increases, therefore preventing the tortilla from becoming rigid and hard (Salinas et al., 2011).

The rollability value of one indicates no breakage when tortillas are rolled, and therefore, the maize flour used meets this parameter. The addition of J. curcas flour modified this characteristic when it was more than 15% of the formulation, increasing softness that caused up to 25% breakage. This change is associated with the increase in water retention, which reached values above 40% because of the high protein content in J. curcas flour (Martínez et al., 2010).

Water in the tortillas evaporates during baking and inflates it and forms a blister (Salinas et al., 2011). All of the tortillas (100%) made from maize flour inflated. When the dough had 20% J. curcas flour, inflatedness reduced to an intermediate value. The high protein content in the 20% J. curcas flour formulation may have made inflation more difficult.

Jatropha also slightly modified the parameters that define tortilla color. Luminosity (L) oscillated between 77.87 and 78.47 and the samples that tended more toward white were those with 10% J. curcas flour (data not shown). The very small changes in the a* and b* values indicate that the tortillas tended slightly toward a yellow tone, which was not significantly different from the negative control. This is associated to the Maillard reaction that starts when the dough is cooked, increasing the yellow tone in the resulting tortilla (Martínez et al., 2010). However, it has been demonstrated that the addition of soybean, amaranth and bean flours in proportions of 5–20% tends to modify the color and produce darker tortillas, affecting luminosity (Figueroa et al., 2001; Güemes, Peña, Jiménez, & Dávila, 2008). This did not occur with the addition of J. curcas flour.
Sensorial evaluation

The panelists that participated in the sensorial evaluation responded differentially to the treatments (Figure 1). The highest frequencies (approximately 91%) were found in the parameters ‘I like it very much’, ‘I like it’ and ‘I like it a little’. These responses reflected the small difference in flavor between the tortillas fortified with *J. curcas* flour and those made with 100% maize flour (Figure 2(a)).

The treatments that were most liked were the control tortilla (7.29%), followed by treatments T5, T10 and T20 (all 6.93%) (Figure 2(b)). The positive characteristics of the tortillas, according to the panel, were good odor and color; in terms of flavor, they did not perceive differences. Treatment T15 was the most accepted in the category ‘I like it very much’ with 25%. These results corroborate that the tortillas analyzed in this study possess the attributes of good quality associated with dough texture. This is contrary to results of other studies in which nonconventional flours were added (Rendón et al., 2012; Vázquez & Amaya, 2010).

Acceptable proportions of *J. curcas* flour in the dough formulations were up to 15%. This was corroborated with chemical and rheological analyses. However, panelists in the sensorial evaluation found that the 20% proportion was not different from the control, indicating its acceptance. It is important to point out that previous studies with percentages of 30, 50 and 100 *J. curcas* flour produce products that are not sensorial accepted by consumers (data not published).

Overall, the addition of *J. curcas* flour to maize flour modified slightly the rheological properties of the dough without a negative effect on the elaboration of tortillas; however, the protein content in the tortilla increased up to 6.2% with no change in color and sensorial properties, which could contribute to improve the nutrition of people who consume them.

Conclusions

The defatted meal may be used as a substitute for food fortification, this in relation to its protein content. Using *J. curcas* for tortilla fortification increased protein content when *Jatropha* flour substituted 20% of the flour without...
affecting rheological and sensory properties, resulting in 91% consumer acceptance. Therefore, Jatropha flour is recommended to enhance nutrition in the preparation of various food products.

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No potential conflict of interest was reported by the authors.

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