



PHYSICOCHEMICAL PROPERTIES OF YELLOW MAIZE-PEANUT FORTIFIED TORTILLAS

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ABSTRACT

In this study, maize grain were cooked and soaked in alkaline (nixtamalization). Nixtamalized maize flour was blended with groundnut (5, 10, 15 and 20%). The proximate composition of the flours and tortillas were evaluated. A range of 3.90-5.26, 6.28-14.31, 4.50-16.20, 1.18-1.22, 2.40-2.64 and 61.73-77.44% was observed for moisture, protein, fat, fibers, ash and carbohydrate contents of the nixtamalized maize flours respectively. Upon the addition of groundnut, the protein and fat content increased. Loose bulk density and packed bulk density of the flours varied from 1.45-1.48 g/mL and 1.61-1.75 g/mL respectively. The water absorption capacities (WAC) of the flours increased while oil absorption capacities (OAC) decreased following the addition of groundnut. Calcium (Ca), potassium (K), magnesium (Mg) and phosphorus (P) content of the flours was observed to increase, while the sodium (Na) content reduced after nixtamalization. The proximate composition of the tortillas made from the nixtamalized flours varied from 9.44 to 11.12 for moisture, 5.40-12.96 for protein, 32.10-42.25 for fat, 4.07-6.16 for fibre, 1.53-1.95 for ash and 33.09-43.98% for carbohydrate content. Sensory evaluation of the tortillas showed that all the fortified samples are favorable compared with the control.

1. Introduction

Tortilla is a major staple food for the Mexican people. It is also a popular snack in the United States (Kawas and Moreira, 2001). Tortilla is an important source of protein for the Mexican population, providing approximately 70% of the calorie and 90% of total protein intake (Rosado et al., 2005). Tortillas are made through the alkaline cooking process called nixtamalization. The process consist of cooking corn grain in abundant water and lime and steeping for 8-16 h (Cuevas-Martínez et al., 2010). Steeped corn is milled to obtain masa, which is then used for making tortillas. Nixtamalization process has been reported to

enhance the nutritional value of maize by improving protein quality, increasing the calcium content and niacin availability (Cuevas-Martínez et al., 2010). Unfortunately, it also leads to losses of protein, carbohydrates fats and vitamins Milán-Carrillo et al., 2004; Figueroa et al., 2001). Several efforts have been made through research to reduce these losses through improved processing methods. For example an optimized processing method of nixtamalization was recently reported (Gutiérrez-Cortez et al., 2013). High quality tortillas were produced by these authors at a reduced cooking temperature (92°C) cooking time (25 min) and steeping time (4 h). Further

superior quality products have been made using enzyme nixtamalization (Sahai and Jackson, 2000). Fortification of nixtamalized maize flour using defatted soybean flour (Gonzales-Agramon and Serna-Saldivar, 1988), direct addition of lysine and tryptophan (Waliszewski et al., 2000), spent soy bean residue (Waliszewski et al., 2002), common bean (Cuevas-Martínez et al., 2010), amaranth flour (Vázquez-Rodríguez et al., 2013), rice bran (Al-Okbi et al., 2014), have been reported. However, to the best of our knowledge, no report exists on the use of groundnut in fortifying nixtamalized maize flour for tortilla production. Groundnut is an excellent source of protein, essential amino acids and minerals (Ayoola et al., 2010). Further, with the growing demand of ready to eat snack in many parts of the world, fortifying nixtamalized maize flour with groundnut may provide variety and increase the choice of consumption among many other snacks. Fortification of nixtamalized maize with legumes for tortilla production may influence nutrient composition, texture and sensory properties. For instance, the protein content of tortilla fortified with common bean (*Phaseolus vulgaris*) was reported to increase by approximately 21% (Cuevas-Martínez et al., 2010). Lysine and tryptophan was also found to increase by 53% and 100% respectively following the addition of common bean. Therefore it is important to investigate the influence of groundnut fortification on nixtamalized maize flour. In this study, the proximate composition, essential amino acids, functional properties, mineral composition, of groundnut - fortified nixtamalized maize flours was determined. The proximate composition, texture and sensory evaluation of the tortillas from the fortified flours were also studied.

2. Materials and methods

Yellow maize was obtained from a local market in Benin City, Nigeria. Groundnut was purchased from a market in Ilorin and kept at room temperature. All other reagents (food grade) were obtained from the Food processing

laboratory, Department of Home Economics and Food Science, University of Ilorin, Nigeria.

2.1. Alkaline treatment of maize

The optimized method of nixtamalization as described by Gutiérrez-Cortez (2013) was employed in this study. Yellow maize was cooked in 1% calcium hydroxide solution (1:3) at 92°C for 25 minutes. The cooked grains were steeped in the cooking vessel for 4 h at room temperature. The cooking solution was drained off and the treated yellow maize was washed with excess water four times with tap water to remove excess calcium hydroxide. After washing, the maize was dried in an oven at 60°C for 72 h. The dried maize was divided into 5 samples and milled with dried groundnut in ratio 5, 10, 15 and 20% per weight of nixtamalized flour.

2.2. Tortilla production

Tortilla was produced using method described by Salazar (2014) with few modifications. Briefly, nixtamalized flours were reconstituted with enough water in a bowl to produce dough with good consistency. The dough was shaped into cylindrical thin disks (approx. 2mm thickness) using a manual cutter. Frying was done in a deep fat fryer at 190°C until the chips were crispy (approx. 10 mins). Freshly prepared tortilla chips were used for sensory evaluation. Other samples were cooled and kept refrigerated (4°C) until analysis.

2.3. Chemical composition

Proximate composition, amino acid content of flours and tortillas composition were determined according to the official methods of analysis (AOAC, 2000). Carbohydrate was calculated by difference.

2.4. Loose and packed bulk density

Flour samples were gently transferred into 10 mL graduated cylinders that were previously weighed. The bottom of the cylinder was gently tapped on a laboratory bench several times until no further diminution of the sample level was observed after it was filled up to the 10 mL

mark. Bulk density was calculated as the ratio of the bulk weight and the volume of the container (Mpotokwane et al., 2008).

2.5. Oil and water absorption capacity

The oil and water absorption capacities of nixtamalized maize flour were determined by the method described by B. Abbey and G. Ibeh (Abbey and Ibeh, 1988). Briefly, one gram of each sample was weighed into a dry, clean centrifuge tube. Sunflower oil (10 mL) with density of 0.98 g/L was poured into the tube and properly mixed by vortexing. The suspension was centrifuged (Ependorf 5810R, Germany) at 3500×g for 20 min. Supernatant was discarded and the tube with its content reweighed. Gain in weight expressed, as a percentage of oil bound, was calculated as the OAC of the sample. The same procedure was repeated for WAC by replacing oil with water.

2.6. Mineral composition of flours

Flours were digested as described by (Amonsou et al., 2011) and the mineral content of the digest was determined by methods of AOAC (2000).

2.7. Sensory evaluation

Panel members were selected from students and lecturers within the Faculty of Agriculture University of Ilorin (both sexes, 22 to 45 years old). The panel evaluated the products for their sensory qualities (taste, colour, odour, texture and overall acceptability) using a nine-point hedonic scale. 1 and 9 represents dislike extremely and like extremely respectively. Analysis of variance (ANOVA) was performed on the data gathered to determine the significant difference in the samples. The judges were made to wash their mouth with water after evaluating each product. The selection criteria for the panelists were based on the participant interest, taste, colour, aroma, texture perception and overall acceptability were determined, besides that they all declared to enjoy eating tortillas and to consume them on a regular basis.

2.8. Statistical data analysis

All analyses with mean and standard deviations were determined in duplicates. Data were analyzed using the Analysis of Variance (ANOVA) statistical method (Statistical Analysis System version 9.2 program, SAS Inc., (2012), USA.). Means were separated using Duncan's multiple range test. Significant differences were established at $p \leq 0.05$.

3. Results and discussions

3.1. Proximate composition of groundnut fortified-nixtamalized maize flours

The proximate composition of groundnut fortified-nixtamalized maize flours is shown in Table 1. The protein content of maize flour decreased (approx. 23%) after nixtamalization process (Table 1). Similar reduction in protein content of maize flour following nixtamalization have been reported (Cuevas-Martínez et al., 2010; Milán-Carrillo et al., 2004). However, there was an increase in the protein content following the addition of groundnut. Nixtamalized maize flour (NMF) fortified with 20% groundnut had the highest protein content (14.31%). The protein content of the groundnut-fortified NMF were slightly higher than those reported for nixtamalized maize flour fortified with common bean (Cuevas-Martínez, 2010), and those fortified with bean and amaranth (Gutiérrez-Cortez et al., 2013). Nixtamalization also decreased the fat content of the maize flour. However, the decrease was very minimal (approx. 9%). The decrease in fat content after nixtamalization may be attributed to losses from the pericarp and germ tissues during cooking and washing (Milán-Carrillo et al., 2004); Serna-Saldivar et al., 1990). Moisture, fibre, ash and carbohydrate contents were not significantly affected by nixtamalization.

3.2. Essential amino acids of fortified-nixtamalized maize flours

Leucine was the major essential amino acid (EAA) present in the untreated maize flour (Table 2). The EAA composition of the untreated maize flour is within values reported

in the literature (Andresen et al., 1998). All the EAA was found to decrease after nixtamalization. The highest and lowest decrease was observed for tryptophan (approx. 41%) and lysine (approx. 2%) respectively. A similar decrease in the tryptophan content of nixtamalized maize flour has been reported (Cuevas-Martínez et al., 2010); Rojas-Molina et al., 2008). However, these authors reported approximately 39% and 53% decrease in tryptophan content respectively. The short soaking time (4 h) and low temperature (92°C) employed in this present study may have accounted for the variation observed in comparison with previous findings. According to Rojas-Molina (2008), protein solubility distribution and amino acid localization during nixtamalization may have accounted for the changes in protein quality as reflected by a decrease in the EAA. Upon the addition of groundnut to the nixtamalized maize flour, however, an increase in the EAA was observed. The increase in amino acids may be attributed to the complementary effect of proteins in the groundnut. Similar increase in amino acid content of maize flour after nixtamalization has been reported (Cuevas-Martínez et al., 2010).

3.3. Functional properties of the maize flours

The loose bulk density (LBD) and packed bulk density (PBD) of the flours were not affected by nixtamalization (Table 3). Although there was a slight increase in LBD and PBD following the addition of groundnut, the increase was not significant. Similarly, there was a slight increase in the water absorption capacity (WAC) of the flours after nixtamalization. However, the observed WAC were very much similar among the flours. The increase in the protein content of the fortified flours (Table 1) may have accounted for the slight increase in WAC. This seems plausible since proteins have been reported to contribute to WAC of food materials (Ravi and Susheelamma, 2005). On the contrary, the oil absorption capacity (OAC) of the flours decreased following nixtamalization. Further, the OAC also decreased with increase in the

addition of groundnut flour. This may be due to the relatively high fat content in the flours (Table 1) after groundnut addition. The increase in fat content in the flours may have prevented the flours from absorbing more oil. This may be advantageous in tortilla preparation as the tortilla produced from the fortified nixtamalized maize flour absorbed less oil compared to unfortified samples (Table 5). Similar increase in the WAC of nixtamalized maize following the addition of cowpea has been reported (Afoakwa et al., 2007).

3.4. Mineral composition of the flours

The calcium (Ca), potassium (K), magnesium (Mg) and phosphorus (P) content of the flours was observed to increase after nixtamalization (Table 4). However, the sodium (Na) content reduced for all the flours. The initial increase in the Ca content of the flours prior to the addition of groundnut may be attributed to the absorption of Ca from the lime soaking process by the maize grains. According to Cuevas-Martínez (2010), nixtamalization increases the Ca content of maize flours. Further, calcium ions are reported to be carried by water through the tip cap, germ and pericarp and are mostly retained in the germ (Serna-Saldivar et al., 1990). However, the calcium content of nixtamalized maize flour has been found to depend on the concentration of the lime used, cooking and steeping time (Serna-Saldivar et al., 1991). The further increase in the Ca, K, Mg and P contents of the flours may be attributed to the added groundnut. Groundnut has been reported to be a good source of Ca, K, Mg and P (Ayoola and Adeyeye, 2010).

3.5. Proximate composition of tortillas

The protein content of the tortillas reduced slightly after frying when compared to the flours (Table 5). This may be attributed to the effect of thermal treatment on nutrients. Tortillas without groundnut addition had the highest reduction in protein content (14%). However, the fortified tortillas had relatively higher protein content than the control. The

protein contents of the tortillas are comparable to those reported for tortillas fortified with common bean (Cuevas-Martínez et al., 2010) and amaranth (Vázquez-Rodríguez et al., 2013). The fat content of the fortified tortilla samples were higher than the control. There was an increase in the fat content compared to the flours. However, tortilla fortified with 5% groundnut (MTG₅) had the highest fat content (42.25%). The higher tendency to absorb more oil as shown by the OAC (Table 2) of this flour may have accounted for the higher fat content of the tortilla. Beyond 5% level of groundnut

addition, the fat content of the tortillas were similar.

The moisture, ash, fibre and carbohydrate content of the tortillas were not very much different. The moisture content (9.44-11.12%) of the tortillas in this study were considerably lower than those reported for tortilla fortified with common bean (Cuevas-Martínez et al., 2010). These authors reported moisture content in a range of 47.11 to 48.16%.

Table 1. Proximate of the groundnut fortified nixtamalized maize flour (g/100g)

Sample	Moisture	Protein	Fat	Fibre	Ash	CHO
A	4.36 ^{ab} ±0.19	8.12 ^b ±0.98	4.50 ^{ab} ±0.32	1.18 ^a ±0.00	2.40 ^a ±0.01	79.44 ^{cd} ±0.64
B	5.26 ^c ±0.34	6.28 ^a ±0.11	4.08 ^a ±0.32	1.19 ^{ab} ±0.00	2.51 ^a ±0.00	80.68 ^d ±0.55
C	4.08 ^a ±0.03	10.34 ^c ±0.26	10.65 ^c ±0.49	1.19 ^{bc} ±0.00	2.54 ^a ±0.01	71.20 ^c ±0.25
D	4.38 ^{ab} ±0.88	10.72 ^c ±0.16	13.00 ^d ±0.00	1.19 ^{bc} ±0.00	2.57 ^b ±0.00	68.14 ^b ±0.32
E	4.79 ^{ab} ±0.27	12.80 ^d ±0.09	14.50 ^e ±0.42	1.20 ^c ±0.01	2.60 ^b ±0.01	64.11 ^{ab} ±0.59
F	3.90 ^a ±0.43	14.31 ^e ±0.26	16.20 ^f ±0.49	1.22 ^d ±0.00	2.64 ^b ±0.00	61.73 ^a ±0.33

Mean±SD. Means with the same superscript are not significantly different (p≤0.05).

CHO: Carbohydrate (calculated by difference)

Table 2. Essential amino acids of nixtamalized maize-groundnut blend (g/100 g)

Sample	Lys	Try	Leu	Iso	Met	Phe	Val	Thr	His
A	3.92	1.92	6.22	3.68	1.92	3.39	4.89	3.92	2.34
B	3.82	1.14	5.43	3.35	1.68	3.09	4.69	3.78	1.72
C	4.46	1.19	8.67	3.42	2.07	3.99	4.90	4.02	2.22
D	4.51	1.25	7.80	3.84	2.12	4.47	5.39	4.09	2.08
E	4.60	1.22	7.90	3.96	2.24	4.83	6.39	5.11	2.11
F	7.68	1.28	8.00	4.01	2.89	5.01	6.53	5.01	2.10

Table 3. Functional properties of nixtamalized maize-groundnut blend

Sample	LBD (g/mL)	PBD (g/mL)	WAC (%)	OAC (%)
A	1.45 ^a ±0.01	1.61 ^a ±0.04	180 ^a ±0.42	215 ^c ±0.46
B	1.46 ^a ±0.02	1.62 ^a ±0.01	205 ^a ±0.64	192 ^{bc} ±0.01
C	1.48 ^{ab} ±0.01	1.64 ^a ±0.01	240 ^a ±0.28	146 ^{abc} ±0.25
D	1.49 ^{ab} ±0.00	1.65 ^a ±0.03	235 ^a ±0.07	128 ^{ab} ±0.13
E	1.48 ^{ab} ±0.01	1.68 ^a ±0.01	230 ^a ±0.14	101 ^a ±0.52
F	1.48 ^{ab} ±0.00	1.75 ^b ±0.01	225 ^a ±0.07	97 ^a ±0.33

Mean±SD. Means with the same superscript are not significantly different (p≤0.05).

Table 4. Mineral composition of nixtamalized maize-groundnut blend (mg/g flour)

Sample	Calcium	Magnesium	Sodium	Potassium	Phosphorus
A	169.74	94.87	749.14	984.18	462.72
B	342.19	144.14	531.62	1024.49	584.41
C	356.99	183.19	468.44	1113.13	638.86
D	368.37	218.89	472.31	1126.36	612.91
E	383.41	217.94	475.37	1129.46	610.75
F	386.39	217.97	476.39	1129.52	609.24

Table 5. Proximate composition of tortillas (g/100g)

Sample	Moisture	Ash	Protein	Fat	Fibre	CHO
MTG ₀	11.12 ^b ±0.5	1.60 ^b ±0.10	5.40 ^a ±0.10	32.10 ^a ±1.10	5.80 ^b ±0.01	43.98 ^b ±0.12
MTG ₅	9.58 ^a ±0.19	1.60 ^b ±0.00	9.41 ^b ±0.12	42.25 ^c ±0.09	4.07 ^a ±0.02	33.09 ^a ±0.10
MTG ₁₀	9.44 ^a ±0.23	1.85 ^c ±0.05	9.77 ^b ±0.41	38.40 ^{bc} ±0.40	4.47 ^a ±0.02	36.07 ^a ±0.14
MTG ₁₅	9.90 ^a ±0.05	1.95 ^c ±0.00	11.84 ^c ±0.11	35.83 ^a ±0.09	5.75 ^b ±0.05	34.73 ^a ±0.15
MTG ₂₀	9.63 ^a ±0.19	1.53 ^b ±0.03	12.96 ^c ±0.22	34.40 ^a ±0.21	6.16 ^c ±0.01	34.32 ^a ±0.32

Mean with the same superscript are not significantly different ($p \leq 0.05$).

CHO: Carbohydrate (calculated by difference)

MTG₀= Maize tortilla with no groundnut

MTG₅= Maize tortilla fortified with 5% groundnut

MTG₁₀= Maize tortilla fortified with 10% groundnut

MTG₁₅= Maize tortilla fortified with 15% groundnut

Table 6. Mean sensory scores for tortillas

Sample	Taste	Colour	Aroma	Texture	Overall acceptability
MTG ₀	5.80 ^a	6.55 ^a	5.65 ^a	6.25 ^a	6.30 ^a
MTG ₅	6.85 ^{ab}	7.00 ^a	6.20 ^a	6.70 ^a	6.80 ^a
MTG ₁₀	7.20 ^b	6.65 ^a	6.15 ^a	6.55 ^a	6.75 ^a
MTG ₁₅	6.65 ^{ab}	6.00 ^a	6.10 ^a	6.45 ^a	6.60 ^a
MTG ₂₀	6.45 ^{ab}	6.30 ^a	6.20 ^a	6.05 ^a	6.25 ^a

Means with the same superscript are not significantly different ($p \leq 0.05$).

The drying temperature and duration of the nixtamalized maize flour may have accounted for the difference. In this study the nixtamalized maize flour was dried prior to tortilla production. The lower moisture content of the tortillas may indicate better keeping quality.

3.6. Sensory evaluation of tortillas

The mean sensory scores of the tortillas are very much similar (Table 6). The ratings for taste colour, aroma texture and overall acceptability showed that the incorporation of groundnut to nixtamalized maize flours had no significant effect on the tortillas. Although, tortillas made from nixtamalized maize flour fortified with 5% groundnut had the highest rating for overall acceptability, the ratings

compared to other tortilla samples were very much similar. This suggests that the inclusion of groundnut to nixtamalized maize flours did not significantly alter the sensory attributes of tortilla.

4. Conclusions

Fortification of nixtamalized maize flour produced acceptable tortillas.

There was an improvement in the protein and fat content of the nixtamalized maize flours. Amino acid content also improved following the addition of groundnut. The flours exhibited good oil absorption capacity which moderated the absorption of oil during frying. Up to 20% addition of groundnut flour did not affect the sensory properties of the tortillas. Fortification of nixtamalized maize flour with

groundnut should therefore be encouraged. Studies on in-vitro digestibility and sorption isotherms of the groundnut fortified tortillas may be investigated. The latter may give useful information in the design of packaging materials for the product.

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