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Effect of Malting and Fermentation on the Proximate Composition and Sensory Properties of Maize (*Zea mays*) and African Yam Bean (*Sphenostylis stenocarpa*)-Based Tortilla

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ABSTRACT
Four maize flour samples comprising non-malted non-fermented maize (NMNFZ), non-malted fermented maize (NMFZ), malted non-fermented maize (MNFZ), malted fermented maize (MFZ) flour were blended with African yam bean flour to yield test flours consisting of NMNFZB, NMFZB, MNFZB and MFZB with 16g protein/100g flour each. Native maize flour was used as control. The test flours were used for production of tortilla designated as NMNFZBT, NMFZBT, MNFZBT and MFZBT respectively with NT (native tortilla) as control. Proximate composition and sensory attributes of the tortilla products were evaluated using standard methods. Malting and fermentation resulted in apparent increase in protein content of maize from 11.25g/100g solids (NMNFZ) to 11.67g/100g solids (MFZ). Complementation with African yam bean increased the protein content of the test flours. Crude protein values of the tortilla products ranged from 16.27g/100g solids (NMNFZBT) to 21.68g/100g solids (MFZBT). The MFZBT had the lowest carbohydrate content (59.17g/100g solids) while NMNFZBT had the highest value of 68.87g/100g solids. MFZBT had the highest values of 8.75, 1.35 and 5.77g/100g solids for moisture, fibre and ash contents respectively. NMNFZBT had the highest energy value of 1510.11kJ/100g. The flavour of the tortillas improved significantly ($p<0.05$) with MFZBT having the highest overall acceptability mean score (8.30±0.20).

Keywords: African yam bean, fermentation, malting, maize, tortilla

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I. INTRODUCTION

Tortilla is a baked product from the dough of non fermented lime cooked maize grains. Although native to Mesoamerica, tortilla is known and consumed in several other countries of the world [1]. In the traditional method of tortilla production, maize is nixtamalized as a primary processing step. Although tortilla makes significant contributions of calcium, iron, vitamins B_1 and niacin [2], proximate analysis indicates that tortilla contains 42.8% carbohydrates, 5.4% protein, 1.1% fat and 0.8% ash on a dry weight basis [3]. Maize, the base ingredient of tortilla product contains about 9% protein [4] and the protein is poor in quality due to low contents of lysine and tryptophan [5]. Heavy reliance on maize in the diet can lead to malnutrition due to low content and poor quality of its protein. African yam bean seed is a rich source of protein and carbohydrate. The seeds contain about 29% protein [6], which is particularly rich in lysine (up to 9% of the protein which is higher than that of soybean) [7]. The amino acids profile of African yam bean compares favourably with whole hen's eggs with most meeting the daily requirements specified by the Food and Agriculture Organization (FAO) and World Health Organization (WHO) for humans [7].

Protein deficiency is one of the most important causal factors of primary malnutrition. Local production of protein-rich foods is low while purchasing power of average Nigerians is low [8]. According to world hunger and poverty statistics [9], about 239 million out of 925 million protein-deficient malnourished people are in the sub-Saharan Africa. Protein-energy malnutrition is associated with as much as 50-60% of under-five mortality [10]. There is therefore the need for the development of inexpensive and improved quality protein foods. Fortification of maize based diets with alternative protein sources is an adaptable technology even at rural level. African yam bean flour can be utilized as a complementary protein source in carbohydrate-based foods for the undernourished groups. Incorporation of African yam bean flour into maize-based food products such as tortillas will enrich the diets within the domestic eating habits and purchasing power of the target population. Malting and fermentation of cereals are affordable and wildly practiced processing techniques in Africa for generations. Malting liberates most bound nutrients thereby increasing nutrient bioavailability, energy density and acceptability [11]. Fermentation is employed to improve the flavour, texture, palatability and shelf-life of maize-based products [4]. Therefore, malting and fermentation can be employed to improve the nutritional quality of cereal and legumes based food products.

II. MATERIALS AND METHODS

Five kilograms of African Yam Bean (brown cultivar) (*Sphenostylis stenocarpa*) seeds was purchased from Wadata Market, Makurdi. Seven kilograms of yellow maize (TZSR – Y) was purchased from the Benue Agricultural and Rural Development Authority (BNARDA), Makurdi, Benue State. The seeds were cleaned and stored in air-tight low density polyethylene bags until used.

1.1 Preparation of malted and non-malted maize

Malting of maize was carried out using the method described by [5]. Three kilograms of raw maize grains were washed in 5% saline solution (NaCl) to get rid of microbes. The grains were then steeped in tap water at room temperature ($30\underline{+}2^oC$) at a ratio of 1:3 (w/v grain: water) in a plastic bucket. In other to control natural fermentation, the steep water was changed every 4 hours for a total steeping time of 12h. The grains were then divided into 2 portions. One portion was malted while the second portion was not malted. Malting was achieved by spreading the grains in a single layer on moist jute bags at room temperature ($30\underline{+}2^0C$) for 72h. Distilled water was sprinkled on the grains at 12h intervals. The malted and non-malted grains were each dried in an air draft oven (Genlab Widnes, UK model T12H) at 100^0C to constant weights. The rootlets of the dried malted grains were detached using an attrition mill with a nip of 5mm followed by winnowing.

1.2 Preparation of nixtamalized maize flour (*Masa harina)*

Nixtamalized maize flours (*masa harina*) were produced from the malted and non-malted maize grains respectively using the methods described by [12] with slight modification (drying the nixtamal before milling). This was packaged in low density polyethylene bags, sealed and stored in desiccators.

1.3 Preparation of fermented maize flour

Fermented maize dough was obtained by accelerated natural lactic acid fermentation using the back-slopping method as described by [13]. Essentially, 120.0g each of nixtamalized non malted and malted maize flours were respectively mixed with 80ml of distilled water and subjected to natural fermentation in a covered 500ml glass beaker at room temperature ($30\underline{+}2^oC$) for 24h. At the end of this period, 50% of the fermented mixture was used as starter culture for a new fermentation cycle. During this process, the pH and titratable acidity (an index of lactic acid bacteria activity) were monitored. The fermentation process was continued until the pH of the medium stabilized and remained constant. The fermented concentrates were oven dried at 80^oC (Genlab Widnes U.K. model T12H) and milled to a particle size of 0.5mm (Asiko Al disc attrition mill, Addis Nigeria). The prepared maize flour samples were as follows: Non Malted Non Fermented Maize (NMNFZ), Non Malted Fermented Maize (NMFZ), Malted Non Fermented Maize (MNFZ) and Malted Fermented Maize (MFZ) flours.

1.4 Preparation of African yam bean (AYB) flour

African yam bean flour was prepared as described by [14]. The African yam bean (AYB) seeds were precooked instead of steeping. Two kilograms of cleaned AYB seeds were autoclaved at 90^oC for 40mins and dried in a hot air oven to constant weight. The dried beans were cracked in an attrition mill and winnowed to remove the seed coats. The cracked seeds were then milled into flour and sieved using a 0.5mm mesh sieve. The AYB flour was packed in low density polyethylene bags and stored in a desiccator.

2.5 Flour blends preparation

Four products were formulated by blending the different maize flours produced with the African yam bean flour to obtain 16g protein/100g sample as recommended [15]. The protein levels were obtained by material balancing from the respective proximate compositions of the prepared maize and AYB flours as described by [16]. The four experimental blends were: non malted non fermented maize + African yam bean (NMNFZB), non malted fermented maize + African yam bean (NMFZB), malted non fermented maize + African yam bean (MNFZB) and malted Fermented Maize + African Yam Bean (MFZB). These were used for the production of tortillas and for different analyses.

1.5 Tortilla production

The tortillas were produced as described by [17] (with modifications) from the flour blends using 350g flour, 280ml distilled water, 5ml vegetable oil, 5g salt and 2g baking powder. The batter was allowed to stand for 5 minutes before kneading to stiff dough. The dough was then moulded into balls of about 4cm diameter and wrapped with polyethylene nylon films to keep moist. Each dough ball was placed between two pieces of plastic wrap and pressed (using NORPRO #1063 – Tortilla Press) to form the tortilla which was then cooked over a hot pan for about three minutes on each side until slightly brown. Four tortilla samples (NMNFZBT, NMFZBT, MNFZBT and MFZBT) were obtained. The tortillas were allowed to cool on a tray, packaged in low density transparent polyethylene bags, sealed and stored in air tight plastic containers in a refrigerator.

All analyses were carried out in triplicates. Tortilla samples were milled using a household blender (Binatone, China, Model BLG-401) prior to use for analyses.

1.6 Determination of proximate composition of the maize flours, flour blends and tortilla samples

Proximate composition was determined using the standard methods of the Association of Official Analytical Chemists [18]. Crude protein was determined by the Kjeldhal method, using 2g of the samples. Crude fat was obtained by exhaustively extracting 5g of sample in Soxhlet apparatus using n-hexane as the extractor. Ash was determined by the incineration of 2g sample in a muffle furnace maintained at 550°C for 5hrs. Moisture content was obtained by heating 2g of sample to constant weight in a crucible placed in an oven maintained at 105°C. The total carbohydrate content was calculated by difference. These analyses were carried out in triplicates.

1.7 Sensory evaluation of tortillas

Sensory evaluation of the tortilla samples was carried out using 15 semi-trained panellists who were students from the Food Science and Technology Department, University of Agriculture, Makurdi. The panellists were served the randomly coded tortilla samples on white disposable saucers lined with white serviettes and clean water was used in between evaluations as a mouth rinse. The samples were evaluated for appearance, taste, aroma, texture and general acceptability using a 9-point Hedonic scale where 1 and 9 represented dislike extremely and like extremely respectively [19].

1.8 Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) and differences among the samples were tested by the least significant difference (LSD) at $p<0.05$.

III. RESULTS AND DISCUSSION

Table 1 shows the effect of malting and fermentation on the proximate composition of maize. The protein content of the malted and fermented maize flours increased from 11.25g/100g solids in NMNFZ to 11.62, 11.65 and 11.67g/100g solids in NMFZ, MNFZ and MFZ respectively, whereas AYB showed a protein content of 26g/100g solids. The increase in protein content due to malting and fermentation could be described as apparent and may be attributed to loss in dry matter and consequent increase in available nitrogen. Crude fat showed a significant ($p< 0.05$) increase and values ranged from 2.74 – 4.24g/100g solids in NMNFZ and MFZ respectively. The increase could be as a result of extensive breakdown of large fat molecules to simple fatty acid units due to the high activities of the lipolytic enzymes which could have resulted in fat increase [20]. The ash content also showed a significant ($p< 0.05$) increase from 1.91g/100g solids in NMNFZ to 3.23g/100g solids in MFZ. The observed higher ash content is an apparent increase since the carbohydrate and fibre decreased with malting and fermentation. The values for carbohydrate decreased from 74.52 to 71.48g/100g solids in NMNFZ and MFZ respectively. The decrease could be due to the utilization of carbohydrate for biochemical activities of germinating seeds [13]. Energy values increased with malting and fermentation. The observed increase could be as a result of the increase in protein and fat contents.

Table 2 shows the proximate composition of blends of maize and African yam bean flour used for tortilla production. Complementation with African yam bean could be regarded be as a process of enrichment since it was used to increase the protein contents of the formulated foods from their initial protein contents of 11.25, 11.62, 11.65 and 11.67g/100g solids for NMNFZ, NMFZ, MNFZ and MFZ respectively (Table 1) to 17.57, 17.59, 17.53 and 17.54g/100g solids for NMNFZB, NMFZB, MNFZB and MFZB respectively (Table 2). Generally the observed increase in values among the tested parameters of the samples in Tables 2 could all be attributed to the complementation with AYB. The decrease in the carbohydrate and fat contents could be due to the low contents in the AYB seeds. Energy values decreased significantly ($P<0.05$) and this may be due to the decrease in fat and carbohydrate contents. Crude fibre content increased with the addition of AYB. Literature revealed that legumes are excellent sources of crude fibre. About 5-6% crude fibre was reported in AYB seeds [21]. Some beneficial effects of legume bean fibre include increase in fecal bulk and fecal moisture, reduction in risk of plasma cholesterol level, improved GI and reduced risk of colon cancer among others [22].

Table 3 shows the proximate composition of tortillas from maize complemented with African yam bean flour. This table indicates some changes in the proximate composition of tortillas produced from the blends of maize and AYB when compared with the raw materials in Table 2. The observed higher protein content in the malted and fermented tortilla samples than in raw samples is similar to that previously reported by other workers [23, 24], and it was attributed to losses of soluble carbohydrates during washing of the cooked maize. In this study, other processes, malting, fermentation and complementation with AYB could cause changes in the composition of the tortilla during heat processes.

Mean sensory scores (Table 4) of the tortillas showed that malting and fermentation processes as well as the addition of African yam bean flour did not adversely affect the sensory characteristics of the tortillas. Generally, a mean score of 7 and above representing "like moderately" was obtained for the appearance, taste, aroma, and texture parameters for all the tortilla products. The MFZBT had the highest score of 8.30 (like very much) for overall acceptability and was significantly ($P<0.05$) different from the other products. Similar findings [4, 25] on good organoleptic characteristics of malted and fermented maize based products have been reported.

IV. CONCLUSION

Malting and fermentation of maize with the addition of AYB have been used to prepare acceptable tortillas which could be used as part of breakfast cereals or snacks. The addition of AYB implies that the final products have potentials for improved protein quality beneficial to its consumers.

Table 1 Effect of Malting and Fermentation on the Proximate Composition of Maize and African Yam Bean Flours

Nutrient (g/100g solid)	NMNFZ	NMFZ	MNFZ	MFZ	AYB	LSD
Dry matter	92.3^{a}±0.06	92.35^{a}±0.09	92.35^{a}±0.13	92.36^{a}±0.14	89.98^{b}±0.00	1.50
Moisture	8.34^{a}±0.07	8.28^{a}±0.04	8.28^{a}±0.02	8.27^{a}±0.02	11.14^{b}±0.05	0.10
Crude protein	11.25^{a}±0.05	11.62^{b}±0.04	11.65^{b}±0.05	11.67^{b}±0.02	26.04±0.06	0.20
Crude fat	2.74^{a}±0.06	3.98^{b}±0.01	4.09±0.01	4.24^{d}±0.03	3.11^{e}±0.02	0.10
Crude fibre	1.27^{a}±0.02	1.17^{b}±0.02	1.12^{c}±0.01	1.15^{b}c±0.02	2.04^{d}±0.02	0.05
Ash	1.90^{a}±0.01	3.23^{b}±0.02	3.22^{b}±0.02	3.19^{b}±0.02	3.08^{c}±0.01	0.10
Carbohydrate (fibre free)	74.50^{a}±0.02	71.72^{b}±0.02	71.64^{c}±0.02	71.48^{d}±0.03	54.59^{e}±0.01	0.05
Energy (kJ/100g)	1544.17^{a}±0.27	1550.56^{b}±0.94	1553.87^{c}±0.27	1557.19^{d}±0.26	1472.14^{e}±0.16	3.00

Values are means ± standard deviations of triplicate determinations. Means with the same superscripts within the same row are not significantly different ($p>0.05$).
NMNFZ: Non malted non fermented maize flour NMFZ: Non malted fermented maize flour
MNFZ: Malted non fermented maize flour MFZ: Malted fermented maize flour
AYB: African yam bean flour LSD: Least significant difference

Table 2 Proximate Composition of Blends of Maize and African Yam Bean Flour used for Tortilla Production

Nutrient (g/100g solid)	NMNFZB	NMFZB	MNFZB	MFZB	LSD
Dry matter	91.12^{a}±0.06	91.05^{a}±0.07	91.50^{b}±0.14	91.45^{b}±0.06	0.09
Moisture	9.75^{a}±0.05	9.83^{a}±0.04	9.29^{b}±0.01	9.35^{b}±0.04	0.20
Crude protein	17.57^{a}±0.02	17.59^{a}±0.01	17.53^{a}±0.04	17.54^{a}±0.02	0.08
Crude fat	2.14^{a}±0.03	2.65^{b}±0.10	3.25^{c}±0.04	3.30^{c}±0.02	0.40
Crude fibre	1.21^{a}±0.04	1.25^{ab}±0.02	1.29^{b}±0.02	1.37^{c}±0.02	0.08
Ash	3.45^{a}±0.03	4.80^{b}±0.05	5.33^{c}±0.03	5.81^{d}±0.05	0.45
Carbohydrate (fibre free)	65.88^{a}±0.08	63.88^{b}±0.07	63.31^{c}±0.02	62.63^{d}±0.05	0.50
Energy (kJ/100g)	1482.85^{a}±0.89	1468.87^{b}±0.78	1480.96^{c}±0.16	1471.60^{d}±0.63	1.00

Values are means ±standard deviations of triplicate determinations. Values with common superscript within a row are not significantly different ($p> 0.05$).
NMNFZB= Non malted non fermented maize + African yam bean NMFZB = Non malted fermented maize + African yam bean MNFZB = Malted non fermented maize + African yam bean
MFZB = Malted fermented maize + African yam bean LSD: Least significant difference

Table 3 Effect of Malting and Fermentation on the Proximate Composition of Tortilla from maize Complemented with African Yam Bean Flour

Nutrient (g/100g solid)	NMNFZBT	NMFZBT	MNFZBT	MFZBT	NT	LSD
Dry matter	92.37^{a}±0.02	92.30^{a}±0.10	92.07^{b}±0.05	91.95^{b}±0.06	91.47^{c}±0.03	0.20
Moisture	8.26^{a}±0.02	8.34^{a}±0.03	8.61^{b}±0.05	8.75^{c}±0.02	9.33^{d}±0.03	0.10
Crude protein	16.27^{a}±0.02	17.62^{b}±0.02	18.03^{c}±0.03	21.68^{d}±0.03	10.69_{e}±0.04	0.40
Crude fat	2.11^{a}±0.02	3.73^{b}±0.02	3.23^{c}±0.05	3.28^{c}±0.02	2.61^{d}±0.04	0.30

Crude fibre	1.09^{a}±0.04	1.24^{b}±0.03	1.29^{bc}±0.04	1.35^{cd}±0.04	1.43^{d}±0.02	0.10
Ash	3.40^{a}±0.02	4.72^{b}±0.04	5.30^{c}±0.05	5.77^{d}±0.02	4.61^{e}±0.02	0.10
Carbohydrate (fibre free)	68.87^{a}±0.02	65.53^{b}±0.05	63.54^{c}±0.47	59.17^{d}±0.37	71.34^{e}±0.16	1.50
Energy (kJ/100g)	1510.11^{a}±0.61	1497.09^{b}±0.94	1492.47^{c}±0.08	1482.26^{d}±0.44	1476.76^{e}±0.66	3.55

Values are means ±standard deviations of duplicate determinations. Values with common superscript within a row are not significantly different (p> 0.05).

NMNFZBT= Non malted non fermented maize + African yam bean tortilla NMFZBT = Non malted fermented maize + African yam bean tortilla MNFZBT = Malted non fermented maize + African yam bean tortilla

MFZBT = Malted fermented maize + African yam bean tortilla NT= Native tortilla

Table 4 Mean Sensory Scores of Maize and African Yam Bean-Based Tortillas

Attribute	NMNFZBT	NMFZBT	MNFZBT	MFZBT	NT	LSD
Appearance	7.20^{ab}±0.10	7.50^{ac}±0.10	7.00^{b}±0.10	6.80^{b}±0.10	7.70^{c}±0.30	0.50
Taste	7.60^{a}±0.30	7.60^{a}±0.40	7.60^{a}±0.10	7.50^{a}±0.10	7.60^{a}±0.10	0.20
Aroma	7.60^{a}±0.10	7.70^{a}±0.30	7.70^{a}±0.20	7.90^{a}±0.10	7.50^{a}±0.20	0.50
Texture	7.70^{a}±0.10	7.50^{a}±0.20	7.70^{a}±0.10	7.70^{a}±0.30	7.70^{a}±0.50	0.30
General Acceptability	6.30^{a}±0.20	5.90^{b}±0.10	6.60^{a}±0.10	8.30^{c}±0.20	5.80^{b}±0.10	0.35

Means with the same superscripts within the same row are not significantly different (p<0.5).

NMNFZBT: Non malted non fermented maize +African yam bean NMFZBT: Non malted fermented maize + African yam bean MNFZBT: Malted non fermented maize+ African yam bean MFZBT: Malted fermented maize+ African yam bean NT: Native Tortilla LSD: Least significant difference

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