European Journal of Nutrition & Food Safety

9(1): 41-51, 2019; Article no.EJNFS.2019.012
ISSN: 2347-5641

Nutrient Composition, Amino Acid Profile and Anti-nutritional Factors of Nixtamalized Maize Flour Supplemented with Sprouted Soybean Flour

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Authors' contributions

The study was carried out in collaboration between authors UEI, BEA and AIE. Author UEI designed the study. The three authors carried out the experimentation and gathered the initial data. Authors BEA and AIE managed the literature searches. Author AIE performed the statistical analysis while author UEI wrote the protocol and the first draft. The three authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2019/46150

Original Research Article

Received 08 December 2018
Accepted 28 December 2018
Published 17 January 2019

ABSTRACT

The high dependence on maize as a staple food in Tropical Africa, coupled with its low nutritive value necessitate investigation on how to improve the nutritional value of maize based foods. The present study was aimed at assessing the effect of supplementing nixtamalized maize flour with sprouted soy bean flour on the proximate composition, mineral content, amino acid profile and anti-nutritional factors in the blends. Nixtamalized maize flour was prepared by cooking maize grains in 1% unripe plantain peel ash solution (pH 10.2), steeped in the cooked solution for 15 h, washed, dried and milled into flour. The flour was supplemented with 0, 10, 20, 30 and 40% sprouted soy flour and analyzed for the aforementioned parameters. The results showed that protein, fat, ash, crude fibre and caloric value increased with increase in soy flour supplementation ranging from 9.26–22.57%, 4.51–10.53%, 1.38–2.06%, 2.14–2.39% and 408.47–434.85 kcal/100 g respectively while carbohydrate decreased from 82.71 – 62.45%. Potassium, calcium, magnesium and zinc contents increased from 267.58 – 286.35mg/100g, 126.93 – 161.03 mg/100 g, 135.71 – 163.81 mg/100 g and 4.52 – 4.85 mg/100 g respectively with soy flour addition. The total amino acids and total essential amino acids increased from 70.55 g/100 g protein and 30.54 g/100 g protein for the control to 87.97 g/100 g protein and 38.98 g/100 g protein for the 40% soy flour supplemented blends respectively. Limiting essential amino acids in both flours were significantly (P = 0.5) improved as a result of soy flour supplementation. Majority of essential amino acid chemical scores were above 100% except for lysine (51.03–66.38%), tryptophan (67.27–95.46%) and threonine

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(80.88 – 99.12%). Soy flour supplemented blends had higher phytate, trypsin inhibitor and tannin contents than the control sample but their values were low and may not have serious effect on nutrient bioavailability. The study clearly shows that nutritional value of nixtamalized maize flour can be improved by supplementing it with sprouted soy flour.

Keywords: Nixtamalized maize flour; sprouted soybean flour; nutrient composition; amino acid profile; anti-nutritional factors.

1. INTRODUCTION

The high consumption of maize products in developing countries including Nigeria has encouraged the development of new processing methods to improve functionality and nutrient quality of maize-based products [1]. Nixtamalization is one of the traditional processes for maize treatment to improve its nutritive quality as well as develop variety in maize processing and utilization. The process involves cooking whole maize grain in alkaline solution for about 30 minutes and steeping the cooked maize in the cooked solution for 12 to 16 hours before washing with water to obtain what is known as nixtamal [1]. The nixtamal can be wet milled to obtain a product known as masa [2] or dried before milling into flour which can be used for various food preparations. In addition to variety introduced in the utilization of maize, nixtamalization has been reported to produce changes in maize such as easy pericarp removal [1,3], partial gelatinization of starches [4], increase in maize amino acid bioavailability [5], increase niacin bioavailability and increase calcium content of the product [1]. Nixtamalization process has also been reported to have beneficial effect in reducing the amount of aflatoxin concentration of the final product [6]. Beside lime, other alkaline solutions that have been used for nixtamalization process include wood ash [7] and potash [8]. There is need to also experiment on other ash solutions such as unripe plantain peel ash solution that is usually used as an alternative to potash in the debittering of *Lasianthera africana* leaf by some rural Ibibio ethnic group in Nigeria.

Maize (*Zea mays* L.) is one of the most extensively cultivated cereal grain in the world and represents a crucial source of human food, livestock feed, fuel and fibre [9,10]. It is the third most important cereal grain worldwide after wheat and rice [11]. Maize is a basic staple food grain for large parts of the world including Africa, America and Asia [12], and is consumed in many forms such as infant foods, snacks and main dishes [13]. Maize grain contains 65 – 84% starch, 9 – 10% protein, 3 – 5% fat, 3% ash and 2 – 3% fibre [14]. Maize provides many of the B-vitamins and essential minerals but lacks some other nutrients such as vitamin B_{12} and vitamin C, and is, in general, a poor source of calcium, folate and iron [15]. Maize is deficient in lysine and tryptophan, resulting in low nutritional quality protein [14,16]. The consumption of maize-based products without supplementation of high quality protein food could lead to kwashiorkor in infants. Supplementation of maize products with legume flour such as soybean flour would lead to improvement in the nutritional quality of the product since legume is high in lysine and tryptophan that are deficient in maize [5].

Soybean (*Glycine max*) is widely grown in Nigeria for its edible bean which has numerous uses. Soybean contains approximately 40 – 45% protein, 18 – 22% fat and reasonable amount of minerals, vitamins and dietary fibre [17]. The quality of soybean protein can be comparable to that of animal sources such as milk and meat [18] and has been found to be suitable and inexpensive substitute for animal proteins [19]. It is however limiting in methionine and cystine but contains sufficient lysine to overcome the lysine deficiency of cereals [14]. Raw soybean contains high levels of anti-nutritional factors including phytate, trypsin inhibitor, and tannin that can interfere with efficient utilization of some essential nutrients including protein [14,17]. Sprouting is one of the traditional processing methods used to reduce the anti-nutritional factors in soybean and improve its nutritive value [20]. Studies have shown that germination can increase protein content and dietary fibre; reduce tannin and phytic acid contents and increase mineral bioavailability [21]. According to Agrahar and Jha [22], during sprouting, sequences of metabolic changes are triggered, improving the nutritional quality of sprouted legumes and decreasing the anti-nutritional factors such as trypsin inhibitor and phytic acid. Sprouting is effective in reducing flatulence causing oligosaccharides (stachyose and raffinose), and also leads to increase sensory properties [23].

The high dependence on maize as a staple food in Nigeria, coupled with the low nutritive value of the commodity has led to the investigation on simple traditional methods to improve the nutritional quality of maize-based foods. The present study was aimed at assessing the nutrient composition, amino acid profile and anti-nutritional factors of nixtamalized maize flour supplemented with sprouted soybean flour.

2. MATERIALS AND METHODS

2.1 Source of Materials

White maize and soybean were purchased from Itam market in Uyo metropolis of Akwa Ibom State, Nigeria. Unripe plantain peels were obtained from a restaurant in Uyo, Akwa Ibom State, Nigeria.

2.2 Sample Preparation

2.2.1 Preparation of unripe plantain peel ash

The unripe plantain peels were washed, dried, incinerated (550°C), cooled in a desiccator, packaged in air tight container and stored at 4°C for subsequent use.

2.2.2 Preparation of nixtamalized maize flour

The method described by Ocheme and Mikailu [24] was followed in the preparation of nixtamalized maize flour with slight modifications. The authors used 1% lime as alkaline solution while 1% unripe plantain peel ash solution was used in the present study. The maize grains were manually sorted to remove infected grains and other contaminants before washing in potable water. The washed grains (1 kg) were cooked in 1% unripe plantain peel ash solution (pH 10.02) at the ratio of 1:3 (w/v) for 30 minutes and steeped in the cooked solution for 15h at ambient temperature (27°C),drained and the steeped maize washed thoroughly in potable water to remove pericarp and the soaked solution. The grains were dried in a hot air oven (model pp 22 US, Genlab, England) at 60°C for 24 h, cooled, milled using attrition mill, sieved through 425μg mesh screen and packaged in air tight container for subsequent use.

2.2.3 Preparation of sprouted soybean flour

Sprouted soybean flour was produced using the method described by Jideani and Onwubali [25] with slight modifications. The soybean seeds were sorting to remove infected seeds and other foreign materials. Sorted seeds (1 kg) were washed, soaked in water (1:4 w/v) at ambient temperature (27°C) for 18h, drained, washed and spread on perforated trays lined with previously sterilized wet cotton cloth and covered with wet muslin cloth. The trays containing the seeds were kept in a dark cupboard away from light and the seeds kept wet by sprinkling with water every 6 h till the end of the sprouting period (48 h). The sprouted seeds were washed and dried in a conventional air oven (model pp. 22 US, Genlab, England) at 60°C for 24 h. The rootlets and hull were removed and discarded while the cotyledons were milled into flour using hammer mill, sieved through a mesh of 425 micrometer aperture screen and packaged in air tight container for subsequent use.

2.2.4 Formulation of nixtamalized maize – sprouted soybean flour blends

The nixtamalized maize flour was blended with sprouted soybean flour at the ratios of 100:00, 90:10, 80:20, 70:30 and 60:40 (maize flour: soybean flour). The 100% nixtamalized maize flour served as the control.

2.3 Methods of Analysis

The crude protein, fat, ash and crude fibre were determined following the methods described in AOAC [26]. The carbohydrate was calculated by difference [27]. Energy value was calculated using Atwater factor formula [28]. Amino acid profile of the samples was determined by the method described by Benitez [29]. The samples for amino acid determination were dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator (Labratorums Technic AG, Model CH – 9230) and loaded into the applied biosystem PTH amino acid analyzer (model 120A PTH, Serial No. 704520, USA). Essential amino acid scores were computed using the FAO/WHO/UNU reference amino acid pattern [30]. The minerals (Ca, K, Mg and Zn) were determined using atomic absorption spectrophotometer (UNICAM, Model 939, UK) as described in AOAC [26]. Phytate determination was done following the method described by Oberleas [31]. The spectro-photometric method was used for trypsin inhibitor determination [32]. Tannin was determined following the method described in AOAC [26].

2.4 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using SPSS version 18 statistical package (SPSS, Inc., USA) software. Means were separated using Duncan's Multiple Range Test (DMRT) at *P*= .05.

3. RESULTS

3.1 Nutrient Composition of Nixtamalized Maize Flour Supplemented with Sprouted Soybean Flour

The proximate composition of nixtamalized maize flour supplemented with 0 – 40% sprouted soybean flour is presented in Table 1.

The result showed that the crude protein, fat, ash, crude fibre and caloric value increased from 9.26 – 22.57%, 4.51 – 10.53%, 1.38 – 2.06%, 2.14 – 2.39% and 408.47 – 434.85 kcal/100 g respectively while the carbohydrate decreased from 82.72% to 62.45%.

The result of mineral content of the samples (Table 1) showed that the potassium, calcium and magnesium contents significantly (*P* = .05) increased from 267.58 – 286.35 mg/100 g, 126.93 – 161.03 mg/100 g and 135.71 – 163.81 mg/100 g respectively while the zinc content insignificantly (*P* = .05) increased from 4.52 – 4.85 mg/100g with increase in the level of soybean flour supplementation.

3.2 Amino Acid Profile of Nixtamalized Maize Flour Supplemented with Sprouted Soybean Flour

The effect of supplementing nixtamalized maize flour with 0 – 40% sprouted soybean flour is presented in Table 2. The result showed that the total amino acids and total essential amino acids for 100% nixtamalized maize flour were 70.55 g/100 g protein and 30.54 g/100 g protein respectively. Both the total amino acids and total essential amino acids increased with increase in sprouted soybean flour supplementation ranging from 75.75 g/100 g protein and 32.88 g/100 g protein for 10% soybean flour supplementation to 87.97 g/100 g protein and 38.98 g/100 g protein for 40% sprouted soybean flour supplementation respectively. Glutamic acid was the highest contributor to the total amino acid content and was followed by leucine. Lysine and tryptophan increased while methionine and cystine decreased with increasing levels of sprouted soybean flour supplementation. The result of computed essential amino acid scores (Table 3) showed that supplementation of nixtamalized maize flour with sprouted soybean flour led to the improvement of the essential amino acid scores.

3.3 Effect of Sprouted Soybean Flour Supplementation on Anti-nutritional Factors in Nixtamalized Maize Flour

The effect of sprouted soybean flour supplementation on some anti-nutritional factors

Table 1. Nutrient composition and caloric value of nixtamalized maize – sprouted soy flour blends (dry matter basis)

Parameters	Blending ratios (NMF:SSF)				
	100:00	90:10	80:20	70:30	60:40
Crude Protein (%)	9.26^{e}±0.08	12.08^{d}±0.05	16.43^{c}±0.10	18.92^{b}±0.04	22.57^{a}±0.06
Fat (%)	4.51^{e}±0.02	6.03^{d}±0.00	7.68^{c}±0.06	9.22^{b}±0.20	10.53^{a}±0.03
Ash (%)	1.38^{c}±0.05	1.52^{b}±0.02	1.78^{b}±0.04	1.92^{a}±0.03	2.06^{a}±0.10
Crude Fibre (%)	2.14^{a}±0.11	2.19^{a}±0.09	2.26^{a}±0.13	2.31^{a}±0.08	2.39^{a}±0.12
Carbohydrate (%)	82.71^{a}±0.03	78.18^{b}±0.06	71.85^{c}±0.04	67.63^{d}±0.10	62.45^{e}±0.04
Caloric Value (kcal/100 g)	408.47^{e}±0.10	415.31^{d}±0.08	422.24^{c}±0.11	429.18^{b}±0.05	434.85±0.08
Potassium (mg/100 g)	267.58^{c}±0.08	271.87^{b}±0.20	275.14^{b}±0.14	280.72^{a}±0.09	286.35^{a}±0.15
Calcium (mg/100 g)	126.93^{e}±0.13	134.61^{d}±0.11	143.08^{c}±0.09	150.36^{b}±0.21	161.03^{a}±0.13
Magnesium (mg/100 g)	135.71^{e}±0.15	142.05^{d}±0.07	148.63^{c}±0.11	156.49^{b}±0.16	163.81^{a}±0.06
Zinc (mg/100 g)	4.52^{a}±0.21	4.61^{a}±0.14	4.68^{a}±0.10	4.77^{a}±0.09	4.85^{a}±0.10

Values are means ± SD (standard deviation) of triplicate determinations. Means on the same row with different superscripts are significantly different at P = .05. NMF = nixtamalized maize flour; SSF = sprouted soybean flour

Table 2. Amino acid profile of nixtamalized maize – sprouted soy flour blends (g/100 g protein)

Amino acids	Blending ratios (NMF:SSF)				
	100:00	90:10	80:20	70:30	60:40
Leucine	7.68^{d}±0.02	9.02^{c}±0.05	9.51^{b}±0.04	9.87^{b}±0.01	10.71^{a}±0.01
Lysine	2.96^{c}±0.05	3.18^{b}±0.03	3.45^{a}±0.05	3.53^{a}±0.08	3.85^{a}±0.08
Isoleucine	2.95^{c}±0.01	3.11^{c}±0.02	3.57^{b}±0.10	3.80^{b}±0.03	4.03^{a}±0.03
Phenylalanine	3.81^{c}±0.02	4.08^{b}±0.08	4.19^{b}±0.02	4.43^{a}±0.10	4.97^{a}±0.10
Tryptophan	0.74^{c}±0.04	0.76^{c}±0.01	0.79^{c}±0.06	0.81^{b}±0.04	1.05^{a}±0.04
Valine	3.68^{d}±0.02	3.74^{c}±0.04	3.80^{c}±0.05	4.08^{b}±0.02	4.50^{a}±0.02
Methionine	1.48^{a}±0.05	1.44^{a}±0.02	1.39^{b}±0.04	1.36^{b}±0.05	1.30^{b}±0.05
Proline	3.86^{d}±0.03	4.57^{c}±0.04	4.97^{b}±0.02	5.00^{b}±0.03	5.28^{a}±0.03
Arginine	4.04^{c}±0.01	4.22^{c}±0.05	4.47^{b}±0.01	4.73^{b}±0.04	5.51^{a}±0.04
Tyrosine	3.10^{c}±0.03	3.27^{c}±0.03	3.61^{b}±0.02	3.80^{a}±0.06	3.96^{a}±0.06
Histidine	2.20^{c}±0.06	3.04^{b}±0.06	3.13^{b}±0.04	3.27^{a}±0.01	3.32^{a}±0.01
Cystine	1.39^{a}±0.04	1.37^{a}±0.02	1.34^{a}±0.10	1.29^{b}±0.03	1.24^{b}±0.03
Alanine	3.94^{c}±0.10	4.21^{c}±0.03	4.32^{b}±0.08	4.51^{b}±0.02	5.01^{a}±0.02
Glutamic acid	12.84^{d}±0.05	13.03^{c}±0.01	13.32^{b}±0.03	13.61^{b}±0.05	14.00^{a}±0.05
Glycine	2.61^{c}±0.02	3.02^{b}±0.11	3.35^{b}±0.04	3.47^{a}±0.02	3.66^{a}±0.02
Threonine	2.75^{b}±0.01	2.91^{b}±0.04	3.00^{a}±0.02	3.20^{a}±0.04	3.37^{a}±0.04
Serine	3.51^{b}±0.03	3.67^{b}±0.02	3.70^{b}±0.03	3.97^{a}±0.00	4.21^{a}±0.00
Aspartic acid	7.01^{c}±0.06	7.11^{c}±0.05	7.23^{b}±0.02	7.60^{b}±0.03	8.00^{a}±0.03
TAA	70.55^{e}±0.02	75.75^{d}±0.06	79.14^{c}±0.02	82.33^{b}±0.05	87.97^{a}±0.05
TEAA	30.54^{d}±0.01	32.88^{c}±0.03	34.43^{b}±0.04	36.17^{b}±0.02	38.98^{a}±0.02
TEAA/TAA (%)	43.29	43.41	43.51	43.93	44.31

Values are means ± SD (standard deviation) of duplicate determinations. Means on the same row with different superscripts are significantly different at P = .05. TAA = total amino acids. TEAA = total essential amino acid; NMF = nixtamalized maize flour; SSF = sprouted soybean flour

Table 3. Essential amino acid scores of nixtamalized maize – sprouted soy flour blends (%)

Essential amino acids	Blending ratios (NMF:SSF)					*FAO/WHO (1985) Reference Value (g/100 g Protein)
	100:00	90:10	80:20	70:30	60:40	
Leucine	116.19	136.46	143.87	149.32	162.03	6.61
Lysine	51.03	54.83	59.48	60.86	66.38	5.80
Isoleucine	105.36	111.07	127.50	135.71	143.93	2.80
Phen. + Tyro.	109.68	116.67	123.81	130.63	141.75	6.30
Trypotophan	67.27	69.09	71.82	73.64	95.46	1.10
Valine	105.14	106.86	108.57	116.57	128.57	3.50
Met. + Cyst.	114.80	112.40	109.20	106.00	101.60	2.50
Threonine	80.88	85.59	88.24	94.12	99.12	3.40

** Reference amino acid pattern of pre-school children (2 – 5 years) (FAO/WHO/UNU, 1985). Phen = phenylalanine; Tyro. = tyrosine; Met = methionine; Cyst. = cystine; NMF = nixtamalized maize flour; SSF = sprouted soybean flour*

Table 4. Anti-nutritional factors of nixtamalized maize – sprouted soy flour blends

Anti-nutrients	Blending ratios (NMF:SSF)				
	1 00:00	90:10	80:20	70:30	60:40
Phytate (mg/g)	0.76^{e}±0.09	0.89^{d}±0.20	1.06^{c}±0.11	1.18^{b}±0.15	1.31^{a}±0.08
Trypsin inhibitor (TIU/mg)	0.03^{e}±0.21	0.14^{d}±0.15	0.59^{c}±0.32	1.20^{b}±0.18	1.74^{a}±0.16
Tannins (mg/g)	0.24^{d}±0.30	0.30^{c}±0.24	0.38^{c}±0.08	0.46^{b}±0.10	0.57^{a}±0.15

Values are means ± SD (standard deviation) of triplicate determinations. Means on the same row with different superscripts are significantly different at P = .05. NMF = nixtamalized maize flour; SSF = sprouted soybean flour

in nixtamalized maize flour is presented in Table 4. The result showed that the nixtamalized maize flour had the lowest contents of phytate, trypsin inhibitor and tannins. Supplementation of maize flour with 0 – 40% sprouted soybean flour resulted in significant (*P* = .05) increases in the phytate, trypsin inhibitor and tannins ranging from 0.76 mg/g, 0.03 TIU/mg and 0.24 mg/g in the 100% nixtamalized maize flour to 1.31 mg/g, 1.74 TUI/mg and 0.57 mg/g respectively in the blend with 40% soy flour addition.

4. DISCUSSION

4.1 Nutrient Composition of Nixtamalized Maize – Sprouted Soybean Flour Blends

The incorporation of sprouted soybean flour into nixtamalized maize flour influenced the nutrient composition of the blends (Table 1). The protein content of nixtamalized maize flour obtained in the present study (9.26%) was within the range (8 – 11%) reported by Rendon et al. [33] for corn tortilla. The value was higher than 8.31% reported by Hassan [34] but lower than 9.33%, 9.36%, 9.43% and 10.62% reported by Hussein and Al-Okbi [35], Pappa et al. [7], Trevino – Majia et al. [5] and Hussein et al. [36] respectively for nixtamalized maize flour. As expected, supplementation of nixtamalized maize flour with sprouted soybean flour (0 – 40%) resulted in significant (P = .05) increase in the protein content with increasing levels of soy flour supplementation. The increase in protein content with soy flour supplementation could be attributed to higher content of protein in soybean flour than in maize flour. This observation is in agreement with reports by other authors on soy flour supplemented blends [37,38,39]. This improvement in protein content with soy flour supplementation is of nutritional significant in a country like Nigeria where many people and especially children, can rarely take adequate foods with high protein content because of cost [40]. Products made from the fortified nixtamalized maize flour could be used to alleviate the problem of protein – energy malnutrition that is still prevalent in most of our communities.

The observed significant (P = .05) increase in fat content with increasing levels of soy flour supplementation could be attributed to higher fat content in soy flour than in nixtamalized maize flour. It has been reported that maize contains 3.5% fat [14] while soy bean contains 18-12% fat [17]. The result of the present study is in agreement with reports by other authors on soy supplemented flour blends [37,38,39]. Fat in food is usually the highest contributor of energy in the body and also serves as carriers of fat soluble vitamins [14]. Soybean oil is high in polyunsaturated fatty acids including linoleic and linolenic acids that are not produced in the body and are required for human health [41]. However, higher fat content in the flour may pose a problem in shelf life resulting in auto-oxidation and rancid flavour development [14].

The ash content of a food sample is an index of the mineral element of such food. The ash content recorded for nixtamalized maize flour (1.38%) was slightly higher than 1.37%, 1.35% and 1.32% reported by Pappa et al. [7], Hussein and Al-Okbi [35] and Hassan [34] respectively. The value was however lower than 2.50% reported by Hussein et al. [36] for corn tortilla. The observed increase in ash content with increased levels of soy flour supplementation is an indication that the sprouted soybean flour contained higher mineral elements than the nixtamalized maize flour. Similar increases in ash content of composite flour as a result of soy flour incorporation have been reported by other authors [37,38,39,42].

The recorded insignificant (P = .05) increase in crude fibre content with increasing levels of soy flour supplementation could be attributed to higher fibre content in sprouted soybean flour (3.08%) than in nixtamalized maize flour (2.14%). Similar observations have been reported by other authors [37,38,39,42]. The presence of high dietary fibre in food products is essential owing to its ability to facilitate bowel movement (peristalsis), bulk addition to food and prevention of constipation [43]. It has been reported that increased dietary fibre consumption could lead to significantly lower risk of obesity, type2 diabetes, coronary heart disease and some cancers [44,45].

Contrary to the trend recorded for crude protein, fat, ash and crude fibre contents, the carbohydrate content of the blends significantly (P = .05) decreased with increase in the level of soy flour supplementation ranging from 82.71% for the control sample to 62.45% for the blend that contained 40% soybean flour. The decrease in carbohydrate content with soy flour supplementation could be attributed to lower carbohydrate content in soybean flour than in nixtamalized maize flour. Germinated soybean flour was reported to contain 16.71% carbohydrate [46] while 83.94% was reported as the carbohydrate content in nixtamalized maize flour [7]. Similar observations as obtained in the present study have been reported by other researchers [37,38,39,42].

Energy value of a product is important to assess its impact on human health especially if it is to be marketed in health sensitive consumer group. The protein, fat and carbohydrate constituents contributed to the calculated caloric value of the samples with fat as the major contributor (9 kcal/g) while protein and carbohydrate have about 4 kcal/g. This explains why the composite flour blend with 40% soy flour addition which had the highest fat content exhibited the highest caloric value and the control sample with the least fat content also exhibited the least caloric value.

Minerals are essential nutrients that are needed to facilitate proper functioning of certain organs in the body. Potassium was the most abundant mineral present in the nixtamalized maize flour and was followed by magnesium (Table 1). Similar observations have been reported by other researchers [7,47]. The values for potassium (267.58 mg/100 g) and magnesium (135.71 mg/100 g) obtained in the present study were lower than the ranges of 378.70 – 423.78 mg/100 g for potassium and 194.81 – 212.95 mg/100 g for magnesium reported by Pappa et al. [7] for maize masa. The potassium content was however within the range (246.7 – 275.7 mg/100 g) and magnesium was within the range of 130.00 – 137.60 mg/100 g reported by Bressani et al. [6] for nixtamalized maize tortilla. The calcium content of the control sample (126.93 mg/100 g) was lower than the range of 129.1 – 144.9 mg/100 and the value of 141.00 mg/100 g reported by Bressani et al. [6] for maize tortilla and Hussein et al. [36] for nixtamalized corn flour respectively. The recorded calcium value was however higher than 72.48 – 92.99 mg/100 g reported by Pappa et al. [7] for maize masa. The zinc content for the 100% nixtamalized maize flour (control) was lower than 7.10 – 9.58 mg/100 g reported by Pappa et al. [7] for maize masa. The observed significant (P = .05) increases in potassium, calcium and magnesium contents and insignificant (P = 0.5) increase in zinc content with increasing levels of sprouted soybean flour supplementation could be attributed to their higher values in soybean flour than in nixtamalized maize flour. The result of the present study is in agreement with the report by Khan et al. [48] for wheat-soy flour blends and flat bread prepared from the blends. The intake of potassium is required in relatively large amount in the body because it functions as an important electrolyte in the nervous system and has been shown to have a powerful, dose-dependent inhibitory effect on sodium sensitivity [49]. Magnesium is important for bone health; is needed as a co-factor for numerous reactions in the body and is also essential for nerve and muscle conductivity [50]. Calcium plays important role in blood clotting, muscle contraction and in certain enzymes in metabolic processes [50]. High amount of potassium, calcium and magnesium have been reported to reduce blood pressure in humans [51]. Zinc is involved in cellular growth and differentiation. Zinc deficiency causes impaired growth, immune dysfunction, increased morbidity and mortality, adverse pregnancy outcomes and abnormal neurobehavioral development [52].

4.2 Amino Acid Profile of Nixtamalized Maize Flour Supplemented with Sprouted Soy Flour

Amino acids are component subunits of protein. They play a vital role both as building blocks of proteins and as intermediates in metabolism [50]. All amino acids in food have different role that help the body to grow and function normally. However, essential amino acids are of main concern as they are not synthesized in the body and must be supplied in adequate amount through diets. The significantly (P = .05) increases in both the total amino acids and total essential amino acids with increasing levels of soy flour supplementation (Table 2) could be due to the fact that the protein in soybean is higher in quantity and quality than maize grains. According to Farzana and Mohajan [53], amino acid profile of soybean is excellent amongst plant proteins. Awadalkareem et al. [54] similarly reported of the improvement of amino acid profile of sorghum flour as a result of supplementation with soybean protein concentrate.

Essentially, the quality of protein food is nutritionally judged by its protein content and the number and amounts of essential amino acids it contains. As expected, as the sprouted soybean flour increased, higher levels of lysine and tryptophan and lower levels of methionine and cystine than found in 100% nixtamalized maize flour were recorded (Table 2). This could be due to the fact that soybean has higher lysine and tryptophan than maize grain but is limited in methionine and cystine [14]. Similar observation was reported by Khan et al. [42]. Rawat et al. [55] similarly observed an increase in protein and lysine contents of chapattis containing soy meal. The implication of the result is that consumers of products made from soy flour supplemented blends would derive protein of better nutritional quality than consumers of products made from 100% nixtamalized maize flour.

Essential amino acid scores presented in Table 3 revealed that majority of the scores were above 100% except for lysine that ranged from 51.03% for the control sample to 66.38% for the 40% soy flour supplemented blend, tryptophan that ranged from 67.27% for the control to 95.46% for the 40% soy flour supplemented blend and threonine which ranged from 80.88% for the control to 99.12% for the 40% soy flour supplemented blend. Comparison of the essential amino acid composition of the present study with the reference values of FAO/WHO/UNU [30] showed that majority of the essential amino acids of the soy flour fortified blends would meet the recommended range of amino acid required for children 2 – 5 years and adults.

4.3 Anti-Nutritional Factors of Nixtamalized Maize Flour Supplemented with Sprouted Soy Flour

Cereals and legumes are rich in minerals but the bioavailability of these minerals is usually low due to the presence of anti-nutritional factors such as phytate, tannin and trypsin inhibitor [56]. Soaking, boiling and sprouting are among the traditional processing methods usually employed to reduce or eliminate these anti-nutritional factors in foods. The low levels of phytate, tannin and trypsin inhibitors recorded for nixtamalized maize flour in the present study (Table 4) could be due to the fact that the maize grains were cooked in alkaline solution, steeped in the cooked solution for 15h and dried before milling into flour. Cuevas-Martinez et al. [56] had earlier reported that about 90 – 96% trypsin inhibitor, 46 – 54% phytic acid and 16 – 20% tannin contents were reduced upon nixtamalization. The phytate content obtained for nixtamalized maize flour (0.76 mg/g) was within the range (0.70 – 0.93%) reported by Queiroz et al. [57] for flours from five maize genotypes. The value was slightly lower than 0.80% and 0.85% reported by Cuevas-Martinez et al. [56] for nixtamalized maize product and Olapado et al. [58] for white maize flour respectively. Phytates are known to form complexes with protein and minerals such as calcium, iron, zinc and magnesium thereby making them biologically unavailable [59,60].

The very low level of trypsin inhibitor recorded for the nixtamalized maize flour (0.03 TUI/mg) might be due to the thermal degradation and denaturation since it is heat labile [56]. Cuevas-Martinez et al. [56] however reported that trypsin inhibitor could not be detected in nixtamalized maize tortilla. Trypsin inhibitor usually inhibit proteolytic activity of the digestive enzyme, trypsin, and consequently reduce bioavailability of amino acids and hence growth [61]. The tannin content in the nixtamalized maize flour (0.24 mg/g) was within the range of 0.14 – 0.33% reported by Pikuda and Ilelaboye [62] for maize ogi. The value was higher than 0.11% reported by Olapado et al. [58] for white maize flour but lower than 0.44 mg/g reported by Bintu et al. [63] for fermented maize flour. Tannins are naturally occurring plant polyphenols. Their main characteristic is to bind and precipitate protein thereby interfering with its digestion and absorption [62]. The observed increases in phytate, tannin and trypsin inhibitor contents in the composite flour blends with increasing levels of soy flour supplementation could be attributed to their higher content in soy flour than in nixtamalized maize flour. It is important to note that despite the increases in the anti-nutrients with increase in sprouted soy flour addition, their values in all the samples were low and may not have serious adverse effect on bioavailability of the nutrients.

5. CONCLUSION

The present study has shown that sprouted soybean flour could be used to improve the nutrient contents and amino acid profile of nixtamalized maize flour. Limiting essential amino acids in both nixtamalized maize flour and sprouted soybean were improved as a result of soy flour supplementation. Although phytate, trypsin inhibitor and tannin increased with increase in soy flour supplementation, their values in all the flour blends were still low and may not have serious adverse effect on nutrient bioavailability. It is evident from the result that consumers of products made from soy flour supplemented blends may derive better nutritional value than the consumers of products from 100% nixtamalized maize flour. Further work is recommended to assess the storage stability of the flour blends, acceptability of products made from the blends and nutrient bioavailability of the samples.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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