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Comparative Assessment of Changes Induced by Malting on the Proximate Composition and Amino Acid Profile of Three Classes of Sorghum [*Sorghum bicolor* (L.) Moench] Grains

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Abstract

The aim of this study was to investigate the influence of malting on the proximate composition and amino acid profile of locally available sorghum types (local, improved and hybrid). Each sorghum type was subjected to malting after which they were analyzed. The proximate composition of the samples revealed that malting gave rise to the enhancement of protein and crude fibre content while there were reduction in the concentration of fat, ash and carbohydrate. The highest value of protein content was found in the malted Hybrid-A and Hybrid-B with an equal value of 11.45 g/100 g sample while the highest crude fibre content was found in the malted pelipeli (local sorghum type) with a value of 2.54 g/100g sample. Virtually all the amino acids (essential and non-essential) increased in value as a result of the malting process. The total essential amino acids (TEAA) in the malted sorghum grains ranged between 335.5 and 348.1 mg/g protein which fell short of the minimum recommended 35% for the maintenance of optimum human health. The quantity of each amino acid in both unmalted and malted sorghum grains respectively from different classes of the cereal was, to a great extent, not significantly different ($p<0.05$). The amino acid profile therefore serves as an indicator of knowing the extent of complementarity with other protein-rich plant sources in case of using the malted sorghum grains in food formulation.

Keywords: Malting; Proximate composition; Amino acid; Sorghum; Cereal product

Introduction

Sorghum (*Sorghum bicolor* (L) Moench) is a widely grown cereal grain in arid and semi-arid regions of the world, and has been ranked as the fifth most important cereal after wheat, maize, rice and barley [1]. The consumption of sorghum is common among the poorest segment of the population in many countries where it serves as a major source of proteins and calories in the diets of people particularly in Africa [2]. Many traditional food products are obtainable from sorghum grains and these include *ogi, eko*, *kunnu* and *tuwo* [3], fermented beverages such as *mahewu* [4], couscous and dolo [5], *injera*, *kisra* and *ugali* [6], among others. The use of sorghum in the production of traditional weaning food product is an age-long practice in Africa. 'Ogi' is commonly being consumed by infants (as a weaning food) and adults after it has been gelatinized particularly in West Africa [7]. For a weaning food product to be appropriate for feeding a growing child, certain functional properties must be satisfied and these include gelation, water holding capacity, viscosity, pasting characteristics, energy and nutrient density [8,9].

One way of improving the quality of cereal-based weaning food products is through malting of the grains. This essentially serves to reduce the bulkiness of the weaning food and increase the energy and nutrient density [10]. In Africa and Asia, sorghum as a cereal crop has been undergoing series of genetic improvement particularly in the areas of disease resistance, high yielding capability, yield stability and nutrient enhancement, among others [11,12]. The use of newly developed sorghum types is very important so as to know the appropriateness of their utilization particularly in the areas of human and animal feeding.

Therefore, this study was aimed at evaluating the changes induced by malting of locally-available classes of sorghum grains (local, improved and hybrid) on the proximate composition and amino acid profile in the course of producing appropriate weaning food blends.

Materials and Methods

Sources of sorghum grains

Three classes of sorghum grains were used for this study: Local sorghum type (*Pelipeli* and *Kwaya*) obtained from Adamawa Agricultural Development Agency, Yola, Nigeria; Improved sorghum type (SAMSORG-14 and SAMSORG-17) obtained from the Institute of Agricultural Research (IAR), Samaru, Nigeria; and Hybrid sorghum type (Hybrid A and B) sourced from Lake Gerio Research Farm of the River Basin Development Authority (RBDA), Yola, Nigeria. All samples were respectively oven-dried to 8.9-10.2% moisture level at 50°C and then stored in different polyethylene bags at ambient temperature (30 ± 2°C) and 65% relative humidity until required.

Malting of sorghum grains

Malting was done by using the modified method of Beta et al. [13]. One kilogramme of grains from each sorghum type was respectively steeped in water at 30 ± 2°C inside a plastic bowl for 20 h. The water in the bowl was being replaced with fresh one at 4-hourly interval to discourage fermentation. After steeping, the grains were immersed in 2% sodium hypochlorite solution for 10 min and then rinsed five times

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with excess water. The grains were finally spread on damped jute bags for germination at 30 ± 2°C, 95% RH, for five days in a germinating chamber. The germinated grains were eventually dried in a forced-air oven at 50°C for 24 h. The dried malt was cleaned and the roots and shoots were removed manually using a corrugated, rubber surface; and then kept in a plastic container for subsequent use.

Determination of proximate composition of dried malted sorghum grains

The proximate composition of dried malted grains from each sorghum type was determined by evaluating the moisture content through drying of the ground sample in an oven (Model No. DHG-910.1SA, Sanfa, China) at 130 ± 1°C to constant weight [14]. Protein content was determined by multiplying total nitrogen, estimated by micro-Kjeldahl method, by 6.25 factor [14]. Fat content was determined by ether extraction in a Soxhlet extraction tube. Ash content was measured by heating the sample in a muffle furnace at 55°C for 24 h [14]. Crude fibre was evaluated by subjecting the sample to an initial defatting, boiling of defatted sample under reflux, drying and final incineration in muffle furnace at 55°C for 2 h followed by cooling [14]. Carbohydrate content was calculated by difference.

Evaluation of amino acid profile of sorghum grains

Ground sorghum sample (malted or unmalted) to be analyzed for amino acid composition was hydrolyzed with 6 M HCI in vacuo at 110°C for 24 h. Thereafter, the sample was dried in a vacuum chamber with a NaOH trap. The dried samples were solubilized in pH 2.2 citrate buffer and injected into an automated Amino Acid Analyzer (Beckman 6300, CA) for analysis. Norleucine was used for the internal standard. Sulphur-containing amino acids, cystine and methionine were determined after a pre-hydrolysis oxidation with performic acids [15] while tryptophan content was determined after alkaline hydrolysis [16]. The contents of different amino acids recovered are presented as mg g-1 protein and are compared with the FAO/WHO reference pattern [17].

Statistical analysis

All data generated in this study were from triplicate determinations. In each determination, a mean value and standard deviation were calculated. Analysis of variance (ANOVA) was also performed and separation of the mean values was by Duncan's Multiple Range Test at $p<0.05$ using Statistical Package for Social Scientists (SPSS) software, version 16.0.

Results and Discussion

Effect of malting on the proximate composition of sorghum grains

The proximate composition (dry weight basis) of malted sorghum grains of different classes is presented in Table 1. The moisture content of the unmalted grains was significantly ($p<0.05$) higher than the malted counterparts across all sorghum classes. The moisture content of the unmalted grains ranged between 9.01 and 10.17 g/100 g sample while that of the malted ranged between 8.91 and 9.97 g/100 g. The lower moisture content of the malted grains could be attributed to the subsequent drying operation carried out on the grains after germination so as to prevent microbial growth [18].

The protein content of the malted sorghum grains was observed to be significantly higher than that of the unmalted sorghum grains. The protein content of the malted grains ranged between 9.39 and 11.45 g/100 g sample. The protein level of malted Hybrid-A was particularly the highest (11.45 g/100 g sample) among the samples though not significantly different ($p<0.05$) from that of malted Hybrid-B (11.42 g/100 g sample). The enhancement of protein concentration in the malted sorghum grains could be attributed to the metabolic processes occurring during grain germination which, most probably, had led to the mobilization of storage nitrogen of the grains to produce the nutritionally high quality protein needed by the developing radicle and plumule for their growth [19].

The fat content of the malted sorghum grains was significantly lower ($p<0.05$) than that of the unmalted grains. The malted grains had fat content that ranged between 2.32 and 3.78 g/100 g sample while that of the unmalted counterparts ranged between 2.42 and 3.91 g/100 g sample. The depletion in the fat content of the malted sorghum grains may be attributed to a possible hydrolysis of lipid and oxidation of fatty acids taking place during germination of the grains [20]. Similarly, the energy required for grain metabolic activities during germination and growth might have been supplied by fat and carbohydrate thereby leading to their depletion [21].

The crude fibre of the malted sorghum grains was significantly higher ($p<0.05$) than that of the unmalted counterparts ranging between 0.43 and 2.54 g/100 g sample. The crude fibre of *pelipeli* (local sorghum type) was particularly higher than that of others which may be attributed to differences in the genetic make-up of the grains [22]. Similarly the enhancement of crude fibre content in the grains through

Parameter	Classes of sorghum grain											
	Local type				Improved sorghum type				Hybrid sorghum type			
	Unmalted *Pelipeli*	Malted *Pelipeli*	Unmalted *Kwaya*	Malted *Kwaya*	Unmalted SAMSORG-17	Malted SAMSORG-17	Unmalted SAMSORG-41	Malted SAMSORG-41	Unmalted Hybrid-A	Malted Hybrid-A	Unmalted Hybrid-B	Malted Hybrid-B
Moisture content	10.01 ± 0.08^{bc}	9.96 ± 0.06^{c}	10.17 ± 0.03^{a}	9.97 ± 0.07^{c}	9.21 ± 0.05^{ef}	9.02 ± 0.06^{g}	10.11 ± 0.05^{ab}	9.71 ± 0.06^{d}	9.01 ± 0.09^{g}	8.91 ± 0.07^{h}	9.11 ± 0.08^{f}	8.92 ± 0.08^{h}
Protein	8.85 ± 0.04^{j}	9.55 ± 0.02^{g}	9.23 ± 0.08^{i}	9.39 ± 0.04^{h}	9.53 ± 0.09^{g}	9.91 ± 0.08^{f}	10.23 ± 0.06^{e}	10.44 ± 0.09^{d}	11.32 ± 0.08^{bc}	11.45 ± 0.06^{a}	11.28 ± 0.06^{c}	11.45 ± 0.06^{a}
Fat	3.64 ± 0.09^{cd}	3.57 ± 0.06^{d}	3.91 ± 0.06^{a}	3.83 ± 0.02^{b}	3.05 ± 0.04^{e}	2.98 ± 0.06^{f}	2.65 ±0.05g	2.56 ± 0.08^{h}	2.42 ± 0.03^{i}	2.38 ± 0.04^{j}	2.49 ± 0.09^{i}	2.37 ± 0.05^{j}
Crude fibre	2.48 ± 0.09^{a}	2.54 ± 0.05^{a}	2.31 ± 0.09^{b}	2.51 ± 0.08^{a}	0.41 ± 0.02^{i}	0.53 ± 0.03^{h}	0.92 ± 0.09^{g}	1.18 ± 0.08^{f}	1.63 ± 0.07^{d}	1.76 ± 0.08^{c}	1.33 ± 0.09^{e}	1.44 ± 0.05^{e}
Ash	2.45 ± 0.07^{cd}	2.39 ± 0.05^{d}	2.67 ± 0.03^{a}	2.44 ± 0.04^{d}	2.36 ± 0.09^{de}	2.05 ± 0.06^{h}	2.25 ± 0.04^{f}	2.02 ± 0.07^{h}	2.31 ± 0.05^{e}	2.19 ± 0.09^{fg}	2.56 ± 0.07^{ab}	2.26 ± 0.04^{f}
Carbohydrate	82.6 ± 1.3^{b}	82.0 ± 0.8^{b}	81.9 ± 1.1^{bc}	81.8 ± 0.8^{bc}	84.7 ± 1.1^{a}	84.5 ± 1.3^{a}	84.0 ± 0.8^{a}	83.8 ± 1.2^{a}	82.3 ± 0.7^{b}	82.2 ± 1.1^{b}	82.5 ± 0.8^{b}	82.4 ± 0.6^{b}

Results are mean values of triplicate determinations ± standard deviation. Mean value within the same row having the same letter are not significantly different at $p<0.05$.

Table 1: Proximate composition (dry weight basis) of malted sorghum grains of different classes (g/100 g sample).

malting may be due to a possible build-up of dry matter in the grain during germination which might have led to crude fibre increase [21].

The decrease in the ash content of malted sorghum grains were observed and it ranged between 2.02 and 2.39 g/100 g sample while that of the unmalted grains ranged between 2.25 and 2.67 g/100 g sample. The significant decrease in the ash content of the malted grains may be due to possible leaching of minerals during the initial steeping of grains thereby accounting for such reduction [23]. It had similarly been observed that a considerable loss of mineral could occur through leaching when food grains/seeds are soaked [24].

The carbohydrate content of malted sorghum grains was observed to be lower than that of the unmalted counterparts and it ranged between 81.8 and 84.5 g/100g sample while the carbohydrate content of the unmalted grains ranged between 81.9 and 84.7 g/100g. No significant differences ($p<0.05$) were observed in the values. The utilization of carbohydrate for energy and growth during germination may be implicated for lower carbohydrate level in the malted grains [23]. It had earlier been observed that during malting, the grains undergo an incomplete natural germination process which usually leads to enzymic degradation of endosperm cell wall, release of starch granules from the matrix of the endosperm in which they are embedded, and increased physiological activities thereby causing the utilization of food reserves for energy and growth [25]. However, the effectiveness of the degradation had been observed to be dependent on the prevailing temperature of malting and germinating duration [26,27].

Amino acid profile of sorghum grains as influenced by malting

Tables 2A and 2B show the essential and non-essential amino acid profiles of sorghum grains respectively as influenced by malting. Virtually all the amino acids were observed to have higher concentration in the malted grains than the unmalted counterparts. This may be attributed to the increased metabolic activities in the grains during germination. Earlier observations had indicated that when sorghum grain underwent germination, increased activities of amylases and proteases were observed thereby leading to breakdown of carbohydrate and proteins respectively. As a result, malt samples contain free simple sugars and amino acids released during germination [27,28].

The total essential amino acid (TEAA) values of the malted sorghum grains ranged between 335.5 and 348.1 mg/g protein (Table 2A). These values are close to the 35% recommendation for the maintenance of optimum human health [29]. The implication of this value is that the malted sorghum may serve as a good source of essential amino acids to maintain optimum health condition. Specifically, the ranges of values of the essential amino acids in the malted sorghum grains include threonine (32.1-33.6 mg/g protein), methionine (22.4-24.7 mg/g protein), phenylalanine (45.6-48.1 mg/g protein), lysine (17.2-18.9 mg/g protein), and tryptophan (8.7-9.7 mg/g protein). All these values, however, fell short of the recommended FAO/WHO requirement pattern [17] of 34, 25, 63, 58 and 11 mg/g protein for threonine, methionine phenylalanine, lysine and tryptophan respectively. The essential amino acids in the malted sorghum grains that satisfied the recommended FAO/WHO requirement pattern are valine (44.2-48.9 mg/g protein), leucine (124.6-130.3 mg/g protein) and isoleucine (35.7-38.4 mg/g protein). The extent of amino acids production during the germination stage had been observed to be dependent on the type and variety of cereal grain involved [30]. It was also observed that the quantity of each amino acid in both unmalted and malted sorghum grains respectively from different classes of the cereal was, to a great extent, not significantly different ($p<0.05$).

From nutritional point of view, the presence and adequacy of amino acids in human diets play significant roles in the health status of such individual [31]. Adequate methionine in human diet has been implicated to be a major donour in the methyl group to affect deoxyribonucleic acid (DNA) and protein methylation in cells [32]. Similarly, leucine has been identified to be an activator of mammalian target of rapamycin which is designed towards the stimulation of protein synthesis and inhibition of intracellular proteolysis [33]. High arginine

Amino acid	Classes of sorghum grain												FAO/WHO (1991) requirement pattern
	Local type				Improved sorghum type				Hybrid sorghum type				
	Unmalted *Pelipeli*	Malted *Pelipeli*	Unmalted *Kwaya*	Malted *Kwaya*	Unmalted SAMSORG-17	Malted SAMSORG-17	Unmalted SAMSORG-41	Malted SAMSORG-41	Unmalted Hybrid-A	Malted Hybrid-A	Unmalted Hybrid-B	Malted Hybrid-B	
Threonine	31.2 ± 0.5^{e}	33.3 ± 0.7^{a}	32.6 ± 0.8^{abcd}	33.5 ± 0.5^{a}	31.6 ± 0.5^{de}	32.1 ± 0.7^{bcde}	33.1 ± 0.6^{ab}	32.8 ± 0.3^{abc}	32.7 ±0.6^{abcd}	33.6 ± 0.7^{a}	31.7 ± 0.8^{cde}	32.9 ± 0.2^{ab}	34
Valine	43.5 ± 0.7^{f}	44.2 ± 0.8^{ef}	45.2 ± 0.5^{cde}	46.3 ± 0.7^{bc}	47.1 ± 0.7^{b}	48.9 ± 0.6^{a}	44.6 ± 0.8^{def}	46.2 ± 0.7^{bc}	44.6 ± 0.7^{def}	45.6 ± 0.6^{cd}	45.5 ± 0.7^{cde}	47.3 ± 0.9^{b}	35
Methionine	21.3 ± 0.3^{d}	22.4 ± 0.5^{cd}	23.4 ± 0.6^{abc}	24.7 ± 0.9^{a}	22.6 ± 0.6^{c}	24.2 ± 0.8^{ab}	23.5 ± 0.9^{abc}	24.5 ± 0.9^{a}	22.4 ± 0.9^{cd}	24.1 ± 0.9^{ab}	23.1 ± 0.5^{bc}	24.6 ± 0.3^{a}	25†
Leucine	124.2 ± 1.7^{d}	126.3 ± 1.9^{cd}	125.6 ± 1.5^{d}	124.6 ± 2.2^{d}	132.1 ± 1.5^{a}	130.3 ± 2.1^{ab}	126.4 ± 1.7^{cd}	127.1 ± 2.3^{bcd}	125.3 ± 1.8^{d}	127.2 ± 2.1^{bcd}	129.3 ± 1.8^{abc}	130.2 ± 2.2^{ab}	66
Isoleucine	34.4 ± 0.5^{g}	35.7 ± 0.8^{ef}	36.2 ± 0.8^{def}	37.1 ± 0.4^{bcd}	35.5 ± 0.7^{ef}	37.4 ± 0.7^{abc}	35.9 ± 0.7^{ef}	38.1 ± 0.2^{ab}	35.2 ± 0.3^{fg}	36.6 ± 0.2^{cde}	36.1 ± 0.9^{def}	38.4 ± 0.7^{a}	28
Phenylalanine	45.5 ± 0.5^{d}	46.8 ± 0.4^{bc}	44.3 ± 0.4^{e}	47.4 ± 0.6^{ab}	46.5 ± 0.4^{bc}	47.4 ± 0.6^{ab}	48.2 ± 0.8^{a}	46.2 ± 0.4^{cd}	46.9 ± 0.4^{bc}	45.6 ± 0.4^{d}	46.9 ± 0.3^{bc}	48.1 ± 0.3^{a}	63‡
Tryptophan	8.2 ± 0.3^{de}	9.6 ± 0.4^{a}	7.5 ± 0.3^{f}	8.8 ± 0.2^{bcd}	8.4 ± 0.4^{de}	9.7 ± 0.7^{a}	8.1 ± 0.4^{de}	9.4 ± 0.2^{ab}	8.5 ± 0.2^{cde}	9.1 ± 0.2^{ab}	7.9 ± 0.4^{ef}	8.7 ± 0.4^{cd}	11
Lysine	16.2 ± 0.7^{de}	17.2 ± 0.3^{bcd}	17.2 ± 0.7^{bcd}	18.3 ± 0.8^{ab}	18.1 ± 0.2^{ab}	17.5 ± 0.8^{bc}	17.2 ± 0.7^{bcd}	18.9 ± 0.8^{a}	15.6 ± 0.5^{e}	17.2 ± 0.6^{bcd}	16.4 ± 0.6^{cde}	17.9 ± 0.6^{ab}	58
Total essential amino acid (TEAA)	324.5	335.5	332	340.7	341.9	347.5	337	343.2	331.2	339	336.9	348.1	

Values are means ± standard deviations. Mean value within the same row having the same letter are not significantly different at $p<0.05$.
†Methionine+Cystine;
‡Phenylalanine+Tyrosine.

Table 2(a): Essential amino acid profiles of malted sorghum grains of different classes (mg/g protein).

Amino acid	Classes of sorghum grain												FAO/ WHO (1991) require-ment pattern
	Local type				Improved sorghum type				Hybrid sorghum type				
	Unmalted *Pelipeli*	Malted *Pelipeli*	Unmalted *Kwaya*	Malted *Kwaya*	Unmalted SAMSORG -17	Malted SAMSORG -17	Unmalted SAMSORG -41	Malted SAMSORG -41	Unmalted Hybrid-A	Malted Hybrid-A	Unmalted Hybrid-B	Malted Hybrid-B	
Histidine	3.2 ± 0.3^{ef}	4.2 ± 0.2^{bcde}	4.5 ± 0.6^{abcd}	5.5 ± 0.4^{a}	3.6 ± 0.4^{cdef}	4.8 ± 0.6^{ab}	3.6 ± 0.7^{cdef}	4.7 ± 0.9^{ab}	3.5 ± 0.5^{def}	4.8 ± 0.7^{ab}	3.1 ± 0.2^{f}	4.6 ± 0.5^{abc}	
Arginine	37.4 ± 0.8^{f}	38.2 ± 0.9^{def}	39.1 ± 0.5^{abcd}	40.2 ± 0.7^{a}	38.5 ± 0.6^{cdef}	39.6 ± 0.4^{abc}	38.2 ± 0.4^{def}	39.9 ± 0.8^{ab}	37.6 ± 0.5^{f}	38.9 ± 0.8^{bcde}	37.8 ± 0.6^{ef}	38.9 ± 0.5^{bcde}	
Aspartate	68.1 ± 0.7^{g}	70.1 ± 0.6^{cdef}	69.2 ± 0.8^{efg}	69.0 ± 0.2^{fg}	71.3 ± 0.5^{b}	73.1 ± 0.7^{a}	69.2 ± 0.6^{efg}	70.3 ± 0.7^{bcde}	69.8 ± 0.7^{def}	71.2 ± 0.9^{bc}	69.2 ± 0.4^{efg}	70.6 ± 0.2^{bcd}	
Glutamate	198.2 ± 1.4^{c}	202.6 ± 2.3^{ab}	199.5 ± 2.4^{abc}	201.7 ± 1.7^{abc}	198.8 ± 1.7^{bc}	200.5 ± 2.3^{abc}	201.4 ± 1.9^{abc}	203.3 ± 1.8^{a}	198.1 ± 2.2^{c}	199.6 ± 1.8^{abc}	202.3 ± 2.3^{ab}	201.6 ± 1.8^{abc}	
Serine	44.2 ± 0.6^{d}	45.7 ± 0.8^{abc}	46.2 ± 0.7^{abc}	46.0 ± 0.6^{abc}	45.4 ± 0.7^{abcd}	46.8 ± 0.8^{a}	45.3 ± 0.9^{bcd}	44.8 ± 0.5^{cd}	45.9 ± 0.7^{abc}	46.6 ± 0.9^{ab}	44.8 ± 0.9^{cd}	45.7 ± 0.9^{abc}	
Proline	82.4 ± 0.7^{e}	84.3 ± 0.7^{cd}	83.6 ± 0.8^{de}	85.9 ± 0.8^{b}	84.2 ± 0.8^{cd}	86.4 ± 0.9^{ab}	83.4 ± 0.5^{de}	85.6 ± 0.3^{b}	85.6 ± 0.9^{b}	87.2 ± 0.7^{a}	83.7 ± 0.8^{d}	85.1 ± 0.3^{bc}	
Glycine	27.5 ± 0.4^{g}	28.4 ± 0.9^{efg}	29.2 ± 0.4^{bcde}	29.0 ± 0.4^{cde}	28.5 ± 0.4^{def}	29.8 ± 0.7^{abc}	29.4 ± 0.3^{bcde}	30.1 ± 0.2^{ab}	29.5 ± 0.5^{bcd}	30.7 ± 0.5^{a}	27.8 ± 0.6^{fg}	29.3 ± 0.7^{bcde}	
Alanine	86.2 ± 0.9^{d}	88.1 ± 0.5^{ab}	87.2 ± 0.7^{bc}	88.9 ± 0.2^{a}	88.3 ± 0.7^{ab}	89.2 ± 0.9^{a}	87.5 ± 0.9^{bc}	88.8 ± 0.4^{a}	86.5 ± 0.9^{cd}	88.1 ± 0.4^{ab}	87.4 ± 0.4^{bc}	88.2 ± 0.4^{ab}	
Tyrosine	35.1 ± 0.5^{ef}	36.8 ± 0.4^{c}	34.6 ± 0.9^{f}	35.8 ± 0.5^{de}	37.8 ± 0.4^{b}	38.7 ± 0.5^{ab}	36.7 ± 0.2^{c}	38.5 ± 0.6^{ab}	39.1 ± 0.2^{a}	38.2 ± 0.6^{ab}	36.2 ± 0.2^{cd}	37.9 ± 0.6^{b}	
Total non-essential amino acid (TNAA)	582.3	598.4	593.1	602	596.4	608.9	594.7	606	595.6	605.3	592.3	601.9	
Total amino acid (TEAA+TNAA)	906.8	933.9	925.1	942.7	938.3	956.4	931.7	949.2	926.8	944.3	929.2	950	

Values are means ± standard deviations. Mean value within the same row having the same letter are not significantly different at p<0.05.

Table 2(b): Non-essential amino acid profiles of malted sorghum grains of different classes (mg/g protein).

level is significant because of its beneficial influence on cardiovascular health, attributed to hypocholesterolemic effects of arginine-containing diets [34]. The combination of some nutritionally non-essential amino acids (arginine, glutamate, glycine and proline) has been implicated to play important roles in animal system and these include the regulation of gene expression [35], transportation of nutrients and metabolism of animal cells [36] and stimulation of anti-oxidative responses [37], among others. Similarly, the regulation of neurological development and function has been attributed to a collective role of tryptophan, tyrosine, alanine and serine [38,39].

Therefore, the presence of all these amino acids in the malted sorghum grains investigated in this study, though not in adequate quantity, will serve as a pointer to what extent the malt could be supplemented with other protein-rich plant sources such as legumes.

Conclusion

The conclusion that can be drawn from this study is that subjecting sorghum grains of different types to malting would lead to variations in the induced changes to both the proximate composition and amino acid profile. The malting process led to the enhancement of protein and crude fibre content while reduction was observed in fat, ash and carbohydrate content. The effect of malting on the amino acid profile was such that virtually all amino acids were enhanced by the process though some were produced at higher concentration that others. The recommended FAO/WHO requirement pattern for most of the essential amino acids was not met by the malted sorghum grains investigated.

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