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ORIGINAL RESEARCH PAPER

EFFECT OF MALTING CONDITIONS ON THE NUTRITIONAL AND ANTI-NUTRITIONAL FACTORS OF SORGHUM GRIST

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Four grist samples, the same sorghum variety, from a modulated malting condition, were evaluated for nutritional and anti-nutritional factors. A raw grist sample of the same sorghum variety served as control. Results showed mineral elements increasing significantly ($p \leq 0.05$) with increasing steeping and germination periods as follows: Na^+ (123%), K^+ (29.55%), P^{2+} (4.71%), Ca^{2+} (157%) and Mg^{2+} (93.33%). Proximate composition of the samples in relation to the control showed that the total ash and carbohydrate levels decreased significantly ($p \leq 0.05$) by 34.4% and 24.33% respectively. The crude protein also decreased significantly ($p \leq 0.05$) by 28.5% and later increased by 0.10% relatively to the control. The moisture content and crude fibre steadily increased significantly ($p \leq 0.05$) by 37.13% and 72.5% respectively. A highly significant ($p \leq 0.05$) increase of 111.82% in the crude fat of the malted samples over the control was observed. Conversely, the oxalate, tannin, trypsin inhibitor activity (TIA) and phytate levels were significantly ($p \leq 0.05$) reduced by 34.13%, 8.45%, 36.5%, and 66%, respectively with increasing steeping and germination periods. The results suggest that malting, as a processing technique, can be used to effectively enhance the nutritional/organoleptic status of sorghum grist with concomitant reduction in some of its anti-nutritional factors.

Keywords: anti-nutrients, grist, malt, germination, sorghum

Introduction

Sorghum constitutes a significant source of protein, energy and minerals for millions of poor people in Africa and Asia (Kimber, 2000; Yousif and ElTinay, 2001; Elkhier and Hamid, 2008; Mohammed *et al*., 2011). The grain is composed of three main parts: seed coat (pericarp-testa), germ (embryo) and endosperm (storage tissue). The seed coat contains copious amount of polyphenolic compounds which combine with other flavonoids (anthocyanins, anthocyanidins, etc.,) to give it varying colours (Okrah, 2008). The germ fraction of sorghum is rich

in minerals (ash), protein and lipids as well as B-group vitamins: thiamine, niacin, and riboflavin which also occur in the aleurone layer (Pomeranz, 1987; Palmer *et al.,* 1989) while the endosperm consists mainly of starch granules, storage proteins and cell-wall materials (Ogbonna, 2011b).

Sorghum is processed into a variety of traditional foods including fermented and non-fermented products such as unleavened bread, porridges, cookies, cakes, cereal extracts, malted alcoholic and non-alcoholic beverages (Carter and Carpenter, 1981; Rooney and Serna-Saldivar, 1982).

Despite an impressive array of nutrients in sorghum grain, sorghum-based foods have continued to be nutritionally deficient and organoleptically inferior. This is largely due to the presence of anti-nutritional factors (ANF) such as tannin, phytic acid, polyphenol and trypsin inhibitors which bind these food ingredients into complexes making them unavailable for human nutrition (Valencia *et al.,* 1999; Elsheik *et al.,* 2000; Makokha *et al.,* 2002; Mbofung and Fombang, 2003; Gassem and Osman, 2003; Gilani *et al.,* 2005; Idris *et al.,* 2007). For instance, the presence of these anti-nutritional factors limits the digestibility of proteins and carbohydrates by inhibiting their respective proteolytic and amylolytic enzymes (Yoon *et al.,* 1983; Knuckles *et al.,* 1998; Yagoub, 2003; Mohammed *et al.,* 2011). They equally determine the bioavailabilty of divalent mineral elements which play key roles as enzyme stabilizers, transport co-factors in metabolic pathways and other key physiological functions. Specifically, sorghum tannins which are condensed polymeric polyphenols (proanthocyanidins) are capable of binding non-haem iron (Fe) and form complexes with proteins (Emmanbux and Taylor, 2003; Melaku *et al.,* 2005), to inhibit enzymes of the digestive system (Price and Butler, 1980; Ogunkoya *et al.,* 2006). Similarly, phytic acid (myoinositol hexaphosphate), present in most plant materials as phytate salt, is the main phosphorus store in mature seeds. Its association with proteins chelates metal ions (Alemu, 2009) to form protein-mineral-phytate complexes which are highly insoluble at the physiological pH of human intestine (Khertapaul and Sharme, 1997; Sandberg and Andlid, 2002).

Several methods have been generally adopted to improve the nutritional and organoleptic qualities of cereal-based foods. These include: genetic modification, amino-acid fortification, supplementation or complementation with protein- rich sources and processing techniques which include malting, milling and fermentation (Chavan and Kadam, 1989, Ugwu and Oranye, 2006; Mohammed *et al*., 2011). Others are steaming, pressure-cooking, flaking, puffing or micronization of the cereal starch which increase its digestibility (McNeil *et al*., 1975; Harpers, 1975). Taylor and Robbins (1993) identified malting as the most inexpensive traditional processing technique for the elimination of the nutritional impediments of sorghum-based foods. Malting is a biotechnological technique which involves the controlled germination of a cereal grain which aims at activating enzyme systems that catalyze the hydrolysis of polymerized reserved food materials, notably, proteins, starches and cell-wall substances, thus, extracting fermentable materials (MacLeod, 1977; Ogbonna, 2011a).

In this paper, the effect of a modulated malting condition on the nutritional and anti-nutritional factors of sorghum grist is reported.

Materials and methods

Source of Materials

An improved white sorghum variety (ex-Kwara), used in this study was obtained from the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, Nigeria. All chemicals used in this study are of analytical grade.

Preparation of samples

The sorghum grains were sorted manually, cleaned and divided into four lots (samples) and modulated as follows:

- Sample A: steeped for 8 hours; germinated for 24 hours and kilned at 50^{o}C for 3 hours.
- Sample B: steeped for 16 hours; germinated for 48 hours and kilned at 50^{o}C for 4 hours.
- Sample C: steeped for 24 hours; germinated for 72 hours and kilned at 50^{o}C for 5 hours.
- Sample D: steeped for 48 hours; germinated for 96 hours and kilned at 50^{o}C for 5 hours.

During the steeping process, the steep liquor was changed every 4 hours and the samples air-rested for 15 minutes.

Malted samples were deculmed, milled with a manual laboratory knife-edge hand mill and sifted through a 0.75mm mesh to generate fine malted sorghum grist. The raw sorghum grist produced using the same milling process served as control. Finally, the samples and control were analysed for nutritional and anti-nutritional factors, using recommended standard procedures.

Determination of nutritional factors

The nutritional factors in both the control and malted samples were determined as follows:

- ***Mineral elements***

Calcium and magnesium content of the test samples were determined by the versenate EDTA complexiometric titration method; phosphorus, by the molybdoranadate (yellow) spectrophotometry method (James, 1995), while potassium and sodium were determined using a flame photometer (Onwuka, 2005).

- ***Proximate composition***

Moisture content was determined using the gravimetric method, crude protein by the micro kjedahl method, crude fibre using the Weende method (James, 1995); ash (AOAC, 1984); crude fat by the continuous solvent extraction method, and carbohydrate using the estimation by difference method (Pearson, 1976).

Determination of anti-nutritional factors

The anti-nutritional factors in both samples and control were examined as follows:

Oxalate (Onwuka, 2005); tannin, by the Folin Denis spectrophotometric method (Pearson 1976); trypsin inhibitor activity (TIA) by the Kakade method (Amtfield *et al.,* 1985) and phytate using methods described by Davies and Reid (1975).

Statistical analyses

Means and standard deviation (S.D.) of factors examined were calculated. The effects of steeping, germination and kilning periods on the nutritional and anti-nutritional factors of sorghum grist were resolved by Analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT) and Least Significance Difference (LSD) were also applied to separate and show means that differed significantly (Kelly and Onyeka, 1992). Significance was accepted at $p \leq 0.05$.

Results and discussion

Mineral analyses

The mineral composition of the samples increased above the values of the control with increasing steeping and germination periods. The results indicated that sodium increased by 123%, potassium 29.55%, phosphorus 45.71%, calcium 157% and magnesium 93.33% (Figure 1).

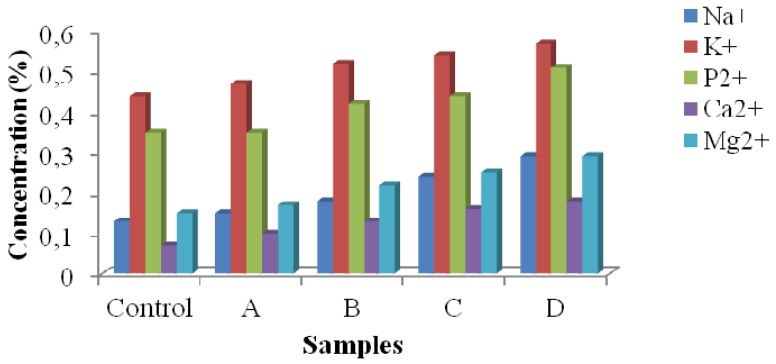

Figure 1. Mineral composition of the control and malted samples

Thus, malting improved the content of both the major and trace mineral ions. This observation may be a result of proportional increment in the content of the minerals possibly as a result of enzyme solubilisation and leaching of the anti-nutritional factors binding them through leaching (Idris *et al.* 2005; Alemu, 2009).

Proximate composition

The influence of malting conditions on the proximate composition of the control and malted samples are shown in Table 1. The moisture content increased significantly ($p \leq 0.05$) by 37.13% which is a normal indication of rapid water uptake by a viable grain expected during steeping. This hydration process activated a wide array of enzyme systems which hydrolysed and solubilised food reserves

during germination. The crude protein showed an initial significant decrease of 28.53% before a later increase of 0.1%. This may be due to the fact that storage nitrogen reserves may have been mobilized during sprouting after hydrolysis by proteolytic enzymes (which digest the macromolecular proteins into the more easily assimilable peptides and amino acids) to play a role in the synthesis of its cellular materials for the rapidly growing roots and shoots during germination.
The carbohydrate content of the malted samples decreased significantly ($p \leq 0.05$) by 24.33% from that of the control. This significant decrease could be attributed to metabolism. The carbohydrates may have been digested into simple sugars by amylolytic enzymes which are rapidly taken up by the growing embryo to serve as its energy source during germination (Elkhier and Hamid, 2008). The total ash content of the malted samples decreased significantly ($p \leq 0.05$) by 34.38% from that of the control. This may be due to the incorporation of mineral elements into cell constituents during the germination process.

Table 1. Proximate composition of control and malted samples*

Sample	Proximate composition				
	Moisture (%)	**Crude protein (%)**	**Carbohydrate (%)**	**Crude fibre (%)**	**Crude fat (%)**
Control	12.20±0.02^{e}	10.20±2.40^{a}	70.70±3.50^{a}	2.00±0.01^{a}	3.30±0.02^{b}
A	13.70±0.00^{d}	10.20±1.30^{a}	66.40±4.01^{a}	2.21±0.01^{b}	6.99±0.25^{a}
B	14.27±0.05^{c}	7.30±0.93^{b}	62.10±3.25^{b}	2.84±0.05^{e}	6.46±0.23^{a}
C	15.63±0.10^{b}	7.29±1.05^{c}	57.80±2.91^{b}	3.41±0.02^{d}	5.93±0.17^{b}
D	16.73±0.08^{a}	10.21±2.00^{d}	53.50±1.52^{c}	3.45±0.01^{e}	5.40±0.22^{c}

*Values are means of triplicate determinations ± S.D.
^{abc}Means with different superscripts on the same column are significantly different at $p \leq 0.05$.

Mineral ions play vital roles in metabolism as enzyme stabilizers and transport cofactors. The crude fibre content of the malted samples increased significantly ($p \leq 0.05$) by 72.5% during the malting period compared to the control. Crude fibre consists mainly of cellulose, lignin and hemicellulose (Eggum et al., 1981). This increase could be attributed to increased bran matter and the building of dry matter during the growth and development (germination) of the plant. A highly significant ($p \leq 0.05$) increase of 111.82% in the crude fat levels of the malted samples over the control was observed at first and later decreased significantly ($p \leq 0.05$) by 22.75%. This suggests that there was a change in the crude fat content during the malting stage which may be due to its proportional increase as a result of decrease in the other food reserves like carbohydrates.

Anti-nutritional factors

Table 2 reflects the levels of the anti-nutritional factors in both the control and malted samples. The levels of the anti-nutritional factors in the malted samples decreased significantly ($p \leq 0.05$) with increasing steeping and germination periods indicating the occurrence of some form of modification during the malting process. Oxalate decreased by 34.13%, tannin by 8.45%, trypsin inhibitor activity by 36.5%

while phytate dropped by 66%. Leaching during steeping was suspected to have contributed in the reduction of some of the anti-nutritional factors considering a change in colour of the steep water. Others such as phytate may have been significantly affected by the endogenous enzymes such as phytases activated during germination. Phytases degrade phytate into inorganic phosphorus and inositol and its intermediate forms (Idris et al., 2005). This was confirmed by Valverde *et al*., (1994) who reported that the germination of lentils greatly reduced phytate content compared to soaking and cooking.

Table 2. *Anti-nutritional factors' level of control and malted samples*[*]

Sample	Anti-nutritional factors			
	Oxalate (%)	**Tannin (%)**	**Trypsin inhibitor (%)**	**Phytate (%)**
Control	12.60±2.50[a]	39.15±2.20[a]	6.30±0.10[a]	1.50±0.19[a]
A	12.30±1.82[b]	37.64±2.15[b]	5.80±0.30[b]	0.78±0.15[b]
B	11.30±2.65[c]	37.38±3.12[c]	5.20±0.21[c]	0.68±0.09[c]
C	9.40±3.01[d]	36.09±2.64[d]	4.10±0.16[d]	0.60±0.13[d]
D	8.30±2.73[e]	35.84±3.22[e]	4.00±0.25[e]	0.51±0.05[e]

[*]Values are means of triplicate determinations ± S.D.
[abc]Means with different superscripts on the same column are significantly different at $p \leq 0.05$.

Calcium is released from oxalate complexes and iron from protein-tannin complexes (Emmanbux and Taylor, 2003; Melaku *et al.,* 2005). The rate of reduction depended on the age of the malt. However, the rate of reduction in tannin was less than that of phytate possibly because while phytate is degraded by malt enzymes, tannins are only leached out (Idris et al., 2005; Reichert *et al.,* 1980; Sandberg, 2002; Ugwu and Oranye, 2006). Hence, the combined effects of the physical and enzymatic actions on the sorghum grain during malting dramatically decreased the concentration of anti-nutritional factors in the malted sorghum grist.

Conclusions

The results obtained from this study confirmed that malting as a processing technique can be used to effectively enhance the nutritional status of sorghum-based foods while reducing their anti-nutritional factors.

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