Functional properties and in vitro protein digestibility of fermented sorghum and broad bean (Visia faba L. Major) blended flour

Galal Omer Ahmed Adam¹, Yufei Hua¹, Moses Vernonxious Madalitso Chamba¹² and Mohammed A.A. Gasmalla¹

¹ School of Food Science and Technology, Jiangnan University, China.
² Department of Human Ecology, Domasi College of Education, University of Malawi, Malawi

*Corresponding author: yfhua@jiangnan.edu.cn

ABSTRACT

The fermented sorghum flour paste (ajena), is one of the most common traditional cereal based food products in Africa, especially in Sudan and Ethiopia. It is used as a main ingredient or starting material for other food products. This traditional fermentation biotechnology has recently caught the attention of food scientists trying to improve various properties of the product. In this study, the functional and protein quality properties of naturally fermented blended flour made up of 20% native broad bean and 80% sorghum flours were compared with conventionally fermented sorghum flour. The blended flour increased in protein composition by about 5% from 11.46 to 16.37 after fermentation. The protein quality in terms of in vitro protein digestibility (IVPD) increased from 58.53 % in fermented sorghum flour to 71.93 % in the blended flour. The increased protein, improved (p≤0.05) the functionality of the blended flour as reflected in its better water-absorption capacity, compared to value obtained from fermented sorghum for this functional property. Bulk density and swelling power of the two flours showed no difference. The Mixolab results indicated lower dough stability, elasticity and consistency in the blended flour as compared to non-blended sorghum flour samples. Thus, ajena, with improved nutrition in terms of protein and less elasticity, like those used in cereal based drinks can be processed by blending sorghum and broad bean flours before fermentation.

Keywords: Fermented sorghum flour, blended flour, broad bean, functional properties, protein digestibility.

INTRODUCTION

Sorghum (Sorghum bicolor L. Moench), which belongs to the Gramineae family of crops and the Andropogoneae tribe, is the world’s fourth and Africa’s second major cereal crop. It is mostly grown as a subsistence dry land crop by resource limited farmers under traditional management conditions in semiarid tropic (SAT) regions of the Africa, Asia and Latin America, which are frequently drought-prone and characterized by fragile environments (Reddy et al., 2006, 2008). India grows the largest acreage of sorghum in the world followed by Nigeria and Sudan, and produces the second largest tonnage after the United States of America. In most of the regions of India, it is cultivated both as a rainy- and post rainy-season crop (FAO, 1995). The main industries currently using sorghum are the poultry feed, animal feed, alcohol distilleries and human food.

Despite its low in many nutritional values, sorghum in Africa is processed into a very wide variety of attractive and nutritious traditional foods, such as semi-leavened bread, couscous, dumplings and fermented and non-fermented porridges. It is the grain of choice for brewing traditional African beers. Sorghum is also the grain of 21st century Africa (Taylor, 2003). New products such as instant soft porridge and malt extracts are great successes. In the competitive environment of multinational enterprises, sorghum has been proven to be the best alternative to barley for lager beer brewing.

Sorghum plays a big role in lives of the human and livestock in Africa, especially the northern region, around which it is believed to have originated (Mann et al., 1983; Wendorf et al, 1992). Fermented sorghum flour paste product, locally known as injera in Ethiopia (Belton and Taylor, 2004) and ajena in Sudan, has been one of the major staple foods in these two countries since time in memorial. The Ajena is normally used to make different kinds of human food products such as thin layer bread (kisra), nesha and aseda, just to mention a few.

Lately, fermented sorghum products have caught interest of food scientists in an attempt to develop food products with improved safety, longevity, nutritional and functional properties. In this study therefore, attempt was made to produce an ajena with enhanced nutritional and functional properties by blending sorghum and broad bean (Visia faba, L. Major) flours as starting material. Broad bean is one of the major sources of traditional protein dish among Sudanese and Egyptian local people (Saxena and Nassib,
1989), but very little, if any, has been reported on its use as an ingredient in other food products, especially fermented sorghum. Broad bean, better known as the faba bean, fava bean, horse bean, field bean, tick bean, or open mouth nut, is probably a native to North Africa and Southwest Asia. Broad bean is rich in protein and fibre, and contains notable levels of vitamin A and C, as well as phosphorous and iron. The lipid content of broad bean is very low (1.5%) compared to soybean (21%) (Whittaker and Tannenbaum, 1977). Broad beans contain L-dopa, which is used as a treatment for Parkinson's disease (Carlsson, 1993). Depending on the cultivar, broad bean may contain up to 35% protein (dry basis), the quality of which is comparable to that of soy proteins, except for the tryptophan, methionine and cystine contents. Additionally, it contains fewer anti-nutritional and flatulence factors than soybean (Zee et al., 1988; Marquardt et al., 1975).

The upgrading of traditional foods through the inclusion of protein seed meals or other protein rich sources in their preparations has been reported (Ekpenyoung et al., 1977; Plahar et al., 1983; Plahar and Leung, 1983). These extenders have to possess the desirable properties to make them compatible in food formulations (Kinsella, 1976). In the earlier studies (Ahmed et al., 1987; Ahmed and Ramanatham, 1987, 1988), the addition of edible groundnut flour to sorghum meal in a co-fermentation process considerably improved the nutritive value of Sudanese staple thin layer bread. The fermentation process was shown to degrade proteins (Ahmed et al., 1987a) and carbohydrates (Ahmed and Ramanatham, 1984) of sorghum meal as well as of the composite flour. It is based on its attributes, couples with its availability in SAT region of Africa, including Sudan, that broad bean was preferred for this study than soybean.

MATERIALS AND METHODS

Procurement of materials

The white sorghum (Sorghum bicolor, L. Moench) and broad bean (Vicia faba L. Major var. minuta) were obtained from a super market and local market respectively, in Wuxi, Jiangsu province, China. All the chemicals used were of analytical grade.

Sample preparation

Well sorted and cleaned sorghum and dehalled broad beans grains were separately ground into flour to pass through an 80 μm mesh size sieve. Then, samples of 100 g native sorghum (NSF) and a mixture of 80 g NSF and 20 g native broad bean flour (NBF) were each mixed with 100 ml of distilled water and incubated at 37 °C for 24 h, and dried at 40 °C in an open air oven. The fermented samples were then ground again into flour to pass through an 80 μm mesh sieve, to make fermented sorghum flour (FSF) and fermented sorghum-broad bean blended flour (FSBF). The two flours were separately packed in polythene bags and stored at ambient temperature of around 25±2 °C until further analysis.

Proximate composition

Proximate analysis of four different samples was conducted as follows: Crude protein was determined by micro-Kjeldahl method with the common conversion factor of N x 6.25 (AOAC, 2000). Crude oil was extracted by the traditional Soxhlet extraction apparatus and determined according to AOAC (2000) official method. Total ash was analyzed using the conventional method by dry-ashing in muffle furnace at 550 °C. Moisture content was calculated by drying weighed samples for 3 h in an oven at 120 °C (Smith et al., 1966).

Bulk density

Determination of bulk density was conducted according to the method of Okaka and Potter (1979). A 50 g flour sample was put into a 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density was calculated as weight of flour (g) divided by its volume (cm³).

Water absorption capacity

Water absorption capacity of the flour samples were determined by Beuchat (1977) methods. One gram of the flour was mixed with 10 ml of water in a centrifuge tube and allowed to stand at ambient temperature (30±2.00 °C) for 1 h. It was then centrifuged at 10000 rpm, 20 °C for 20 min. The volume of water captured in the sediment was measured by subtracting the volume of water above the sediments from the original volume added to the flour. Water absorption capacity was calculated as ml of water per gram of flour.

Swelling power

The swelling power was determined by the method described by Leach et al. (1959) with modification for small samples. One gram of the flour sample was mixed with 10 ml distilled water in a centrifuge tube and heated at 80 °C for 30 min, continually shaken during the heating period and allowed to cool. The suspension was then centrifuged at 10000 rpm, 25 °C for 20 min. The supernatant was decanted and the weight of the paste taken. The swelling power was calculated as the weight of the paste divided by the original weight of the dry flour.

Dough Property Mixolab

The Mixolab (Chopin, Tripette and Renaud, Villeneuve-la-Garenne, France) was used to study the properties of dough...
made from the each of three flour samples (NSF, FSF and FSBF). A flour sample with known weight and moisture content was placed into the Mixolab analyzer bowl and mixed to obtain dough of 75 g. The water required for the dough to produce a torque of 1.1 nm (C1) was added automatically by the Mixolab system. According to manufacturer instructions, the obtained curve is typically divided into five stages as shown in figure 1. In the first stage (C1), dough-mixing characteristics such as stability, elasticity, and water absorption can be determined. During this stage, an increase in the torque is observed until a maximum is reached. Consistency of the dough decreases with amount of mixing, which is an indication of protein weakening (stage 2, C2). As the temperature of the dough increases, as a result of the increase in block temperature, first a decrease and then an increase in consistency is observed and is attributed to starch gelatinization (stage 3, C3). In stage 4, consistency decreases, attributed to amylolytic activity (C4). Finally, in stage 5, the decrease in temperature causes an increase in the consistency, attributed to gel formation. This stage is also related to the retrogradation of starch.

![Figure 1: The typical Mixolab™ standard curve](image)

**In vitro protein digestibility**

In vitro protein digestibility (IVPD) was determined by the method of Saunders et al. (1973) with some modifications. A sample (0.2 g) was placed in a 50 ml centrifuge tube, 15 ml of 0.1 M HCl containing 1.5 mg pepsin were added, and incubated at 37 °C for 2 h. The suspension was then neutralized with 3 ml 0.5 M NaOH and treated with pancreatin solution [4.0 mg in 7.5 ml 0.2 M phosphate buffer pH 8.0 containing Thymol (25 mg per 250 ml phosphate buffer)]. The mixture was then incubated at 37 °C in a gently shaken water bath for 24 h. After incubation, the reaction was stopped with 10 % trichloroacetic acid (10 ml) and centrifuged at 5000 rpm for 20 min at room temperature. Nitrogen in the supernatant was determined by micro Kjeldahl method (AOAC, 2000). Digestibility was calculated using the formula: Protein digestibility (%) = N in supernatant - enzyme N / N in sample.

**Statistical analysis**

The triplicate sample data were analyzed and the figures averaged. Differences were assessed for significance at p ≤ 0.05 by analysis of variance (ANOVA) using Duncan’s multiple-range test, by SAS analytical software (SAS Institute Inc., Cary, NC, USA), version 8.1.

**RESULT AND DISCUSSION**

**Proximate analysis**

The proximate composition of the four different samples (NSF, NBF, FSF and FSBF) in terms of crude protein, ash, moisture and crude oil were determined and the results are presented in table 1. From the results it can be observed that comparatively, all compositions, except moisture were relatively higher in fermented sorghum-broad bean blended flour (FSBF) sample than in the initial fermented sorghum flour (FSF). Crude protein was higher by about 42.84 %, ash (57.89 %) and oil (14.52 %), while moisture was 47.60 % lower in FSBF than in FSF. This is not surprising, considering the similar situation observed when comparing the initial starting material (NSF and NBF). Thus, the variation is attributed to the presence of broad bean flour. This scenario is very likely to be affected by the ratio of sorghum to broad bean flours. Although the moisture and the rest of the compositions are affected by the extent of sample drying, the fact that both flours were dried under the same conditions clears the doubt. The decrease in the moisture composition may have a significant bearing on water absorptions capacity, resulting into more water needed in order to produce dough of a particular thickness and consistency.

**Bulking density**

The bulk density and the pasting properties of the both flour were studied. The Bulk density is a measure of heaviness of a flour sample. The results showed no significant difference (p ≤ 0.05) between the fermented blended flour (0.65 ± 0.01 g/ml³) and the fermented sorghum flour (0.64 ± 0.00 g/ml³) in this property. The bulk density is very important in preparation of food for special people such as manual workers and infants. Fermentation has been reported as a very useful traditional method for the preparation of low-bulk weaning foods (Desikachar, 1980). The similarity in low-bulk density values between the two samples indicates the possibility of using the new flour product even for the preparation of weaning food, just as it is currently the case with fermented sorghum flour.
Table 1: Proximate composition for FSF and FSBF

<table>
<thead>
<tr>
<th>Sample</th>
<th>Protein (%)</th>
<th>Ash (%)</th>
<th>Moisture (%)</th>
<th>Oil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSF</td>
<td>13.25 ± 0.19</td>
<td>0.58 ± 0.16</td>
<td>12.00 ± 0.24</td>
<td>1.64 ± 0.03</td>
</tr>
<tr>
<td>NBF</td>
<td>29.30 ± 0.72</td>
<td>2.88 ± 0.03</td>
<td>11.69 ± 0.10</td>
<td>2.23 ± 0.96</td>
</tr>
<tr>
<td>FSF</td>
<td>11.46 ± 1.08</td>
<td>0.57 ± 0.06</td>
<td>12.00 ± 0.22</td>
<td>1.24 ± 0.27</td>
</tr>
<tr>
<td>FSBF</td>
<td>16.37 ± 0.67</td>
<td>0.90 ± 0.07</td>
<td>8.13 ± 0.19</td>
<td>1.42 ± 0.12</td>
</tr>
</tbody>
</table>

*Values are means of triplicate tests.

Table 2: Mixolab results for FSF and FSBF

<table>
<thead>
<tr>
<th>Mixolab stages</th>
<th>Time (min)</th>
<th>Torque (nm)</th>
<th>Dough temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FSF</td>
<td>FSBF</td>
<td>FSF</td>
</tr>
<tr>
<td>C1</td>
<td>1.63</td>
<td>22.02</td>
<td>0.27</td>
</tr>
<tr>
<td>C2</td>
<td>15.10</td>
<td>23.18</td>
<td>0.04</td>
</tr>
<tr>
<td>C3</td>
<td>17.77</td>
<td>29.72</td>
<td>0.74</td>
</tr>
<tr>
<td>C4</td>
<td>21.20</td>
<td>31.73</td>
<td>0.32</td>
</tr>
<tr>
<td>C5</td>
<td>45.05</td>
<td>45.03</td>
<td>4.26</td>
</tr>
</tbody>
</table>

C4 to C5 torque increase (%) = 1231.25 - 31.45

*Values are means of triplicate tests.
Water absorption capacity

The addition of broad bean flour significantly increased (p ≤0.05) the water absorption capacity from 1.07 ± 0.02 g/g in FSF to 1.21 ± 0.05 g/g in FSBF, representing 13.08% increase. These findings are similar to those reports by Ahmed and Ramanatham (1988), where an increase was also observed in fermented sorghum and groundnut composite meal. The water absorption capacity is very important in determining the amount of water needed for a specific extent of gelatinization and dough thickness. Higher absorption capacity is desirable for making thicker gruels. Generally, sorghum flour has a higher water binding capacity than flours of higher protein materials such as raw fluted pumpkin seed (Giami and Bekebain, 1992).

Swelling power

The swelling power correlates with gruel solid content. The results for both fermented flours were compared and there was no significant difference between them (FSF = 4.37 ± 0.69; FSBF = 4.91 ± 0.16). The sight increase in swelling power in FSBF indicates a slightly higher content of amorphous material than in FSF. It is noted that the water absorption capacity is directly proportional to swelling power, when the water absorption capacity increases, the swelling power also increases.

Dough property by Mixolab

Mixolab determines a comprehensive qualitative profile of the flour and plots, in real time, the torque (expressed in nm) produced by the passage of the dough between two kneading arms when submitted to both shear stress and a temperature constraint (Dhaka et al., 2012). In this study the results given by the Mixolab, as pasting properties of the flour samples, are shown in tables 1. At almost the same moisture content of 26.16±22 for FSF and 25.23±19 for FSBF, stability and viscosity of the two doughs differed widely. Stability dropped from 1.33 min. in FSF to 0.63 min. in FSBF, while viscosity declined from 6.00 to 1.00, respectively, where as amylase showed the same value (9.00) in both fermented flour samples. In normal situation (standard curve) at stage C5, the decrease in dough temperature, results in the increase in torque (figure 1), signifying increase in dough consistency due to gel formation. From table 1, it can be observed that from C4 to C5 the FSF showed great amount of increase in torque (by 1231.25%), indicating much higher dough consistency compared to the 31.45% observed in FSBF.

The differences in dough stability, viscosity and consistency observed between the two fermented flour samples, may be attributed to the relatively reduced starch composition in the FSBF, which is responsible for gelatinization when it retrogrades. The similarity in the amylase values indicates that amylolytic activity may not be the major reason for the differences.

Mixolab results

In vitro protein digestibility

In vitro protein digestibility (IVPD) has been reported to closely relate to true digestibility, and is normally used as a more quick and convenient alternative. In this study, after natural fermentation of the two samples, IVPD increased from 58.53 ± 0.33% in sorghum flour to 71.93 ± 2.49% in the blended flour. These results are considerably higher compared to those reported by Fadlallah et al. (2010) in the similar study, where they supplemented the sorghum flour with chickpea flour. The differences in IVPD in fermentation studies between low and high tannin sorghum cultivars have been reported (Romo-Parada et al. 1985; Cummins, 1971). Thus, the difference with those reported, may be attributed to the difference in the cultivars and legume used. The increased IVPD indicates that the protein in the FSBF may be more available for the body’s nourishment than that of FSF.

Conclusion

An Ajena with improved protein composition and digestibility can be prepared by blending the native sorghum and broad bean flours before the fermentation process. Some functional properties associated with this kind of ajena product do not differ much with the conventional one. Those that differ have other applications in different the preparation of other food products. With regard to the nutritional problems, which is pandemic to most of the developing countries, such as those in many African and Asian regions, it is imperative for food scientist to actively engage in studying even the seemingly basic traditional foods, which form integral part of the local people’s diet, regardless of whether yields industrial economic benefit or not, in order to improve the nutritional status of the people. Use of supplementation of sorghum flour with broad bean may be a more convenient and cheaper option in countries like Sudan, Egypt and Ethiopia, and other Asian countries, where it is readily available and is already an integral part of their local population’s diet.

Acknowledgement

The authors would like to thank all the students and support staff of the Vegetable Protein laboratory, School of Food Science and Technology, Jiangnan University for all the support rendered during this study.

REFERENCES


Pakistan Journal of Food Sciences (2013), Volume 23, Issue 1, Page(s): 10-16

