Iron Bioavailability and Organoleptic Properties of Sorghum and White Bean Noodles

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Abstract: The objective of this study was to produce iron fortified noodles that are made from natural sources. The fortification vehicle used was sorghum flour whereas the iron fortificant was white bean flour added in amounts of 10, 30 and 50% to sorghum flour. The investigated variables were the ratio of sorghum to white bean flour; pre-gelatinized flours (drum dried and extruded) and guar gum while the emulsifier added was kept constant. Investigated parameters were the iron content and its bioavailability, as well as the functional properties (cooking weight, cooking time, cooking loss and texture) of the noodles. Results showed that the content of white bean in the noodles had a direct influence on the iron content and bioavailability. Iron content and bioavailability was higher with the higher the amount of white bean added. Additionally, the iron content and bioavailability was affected by the addition of guar gum and the pregelatinised flours. Iron content of noodles decreased with the increase of guar gum content while the addition of white bean pregelatinised flour showed an increase in the iron content and bioavailability. On examination of the functional properties, the 50% white bean noodles gave the best results in terms of texture, cooking loss, cooking time and cooking weight. Cooking time, cooking weight and cooking loss were comparable to that of durum wheat noodles. Noodles prepared with 50% white bean flour and pregelatinized flours (extruded or drum dried) received the best rankings in the sensory evaluation. The result of this study showed that the higher the amount of white bean added, the superior was the noodle quality, therefore fulfilling the requirements of the objectives i.e. good quality noodles with high iron content and bioavailability.

1. Introduction

Iron Deficiency Anaemia (IDA) affects approximately two billion people worldwide (WHO, 2002). Iron is considered as the only nutrient deficiency that high and low income countries have in common (Hambraeus, 1999). The prevalence of anaemia is 50 %, 25 % and 10 %
for South Asia and Africa, Latin America and industrialized countries of Europe respectively (Hurrell, 1997).

Sorghum is considered as the main sources of energy, protein, vitamins and minerals for millions of people in semi arid tropics of Asia and Africa. It is consumed mostly by the poor and unprivileged sectors of the society and is known collectively with millet as ‘poor people’s crop’ (FAO, 1995). Durum wheat or common wheat are used in the production of pasta products (Rooney and Salvidar, 1991). In pasta production the flour has to form an extensible, elastic and cohesive mass with water. Sorghum is inferior to wheat as it has no gluten and its gelatinisation temperature is higher than wheat (FAO, 1995). Yeast leavened products are difficult to obtain from sorghum flour as it does not contain viscoelastic gluten. A range of products have been produced from sorghum and wheat composite flour. Burger (1998) succeeded in producing pasta from 100 % sorghum. Cakes and biscuits have also been made from composite sorghum and wheat flour; however there is deterioration in product quality with increase in sorghum (FAO, 1995).

White beans (Phaseolus vulgaris) are very good sources of proteins and a good source of iron (Reyes-Moreno and Paredes-Lopez, 1993).

The aim of this study was to produce sorghum fortified noodles which will serve some of the functions of fortification of foods, which include, maintenance of nutritional quality, improvement of keeping quality and stability, enhance attractiveness. This in addition to bearing in mind the cost of the end product. Use of staple foods will help in the decrease of the prevalence of IDA without high increase in the cost of the fortified flour.

2. State of the Art

Sorghum variety, Dabar, and white bean purchased from the local market. They were first cleaned using a grain magnetic cleaner and sifter. After cleaning, dabar and the white bean were milled using a Pin mill. Then the milled flours of the two raw materials were packed in plastic bags, closed tightly and stored at 4 °C for further use. White bean and sorghum were further processed for the production of pregelatinised flour and in order to improve the bioavailable iron. White bean was used as a fortificant in an unprocessed form, extruded and drum dried form.

The experimental design for the main trials for noodle production was a 2³ Screening test with 3 center points (Table 1). The variables were sorghum and white bean flour, pregelatinised flours (extruded sorghum [ES], extruded white bean [EWB], drum dried sorghum [DDS], drum dried white bean [DDWB] and roasted sorghum [RS]) and guar while the emulsifier added was kept constant. The experimental design 2³ (11 runs with three center points) was carried out with each of the five
pregelatinised flours respectively and in duplicate i.e. 55 different recipes were produced twice. In all the experiments the dough mass was constant at 500 g.

### Table 1: 2³ Screening test for noodle production

<table>
<thead>
<tr>
<th>Run</th>
<th>White bean [%]</th>
<th>PGF** [%]</th>
<th>Guar [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>2</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>+1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>+1</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>6*</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
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<td>+1</td>
</tr>
<tr>
<td>11*</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
</tbody>
</table>

* Center points  
** Pregelatinized flours (extruded sorghum, extruded white bean, drum dried sorghum, drum dried white bean)

Iron Analysis: Ferrozine technique was used to analyse the iron content. The methodology in the original technique was wet ashing of the sample and then determination of iron through the reaction of the colorimetric reagent known as Ferrozine. However during the wet ashing processing, foaming of the samples resulted. Therefore, in this study the samples were subjected to dry ashing in accordance to AACC Method (1995) and the colorimetric technique was carried out in the same manner as cited in the literature. The iron content in the dry ashed samples is measured after the addition of reagents and the absorbance is read in a spectrophotometer at 562nm. The result interpolated in a calibration curve and compared with a reference standard.

Bioavailable iron Determination: Modified Miller technique (Kapsokofalou and Miller, 1991) was used. An in-vitro method where there is simulation of gastrointestinal digestion followed by the measurement of soluble iron of low molecular weight. The homogenised foods are digested by pepsin at pH 2 under controlled temperature. The dialysis bags were then inserted and the pH adjusted to the intestinal levels. Digestion was then continued with the addition of pancreatin. The iron from the digested sample which diffused through the dialysis bag was used as an indicator of available iron.
Functional properties Determination: Cooking time was determined by boiling 25 g of noodles in 300 ml of tap water without the addition of salt was boiled in a 500 ml beaker. The noodles were cooked until they were firm as over cooking results in mushy pasta. The noodles were removed and pressed between two perplex plates every 30 sec. This procedure was carried out until the desired firmness is attained and no white core was visible which determined that the cooking time was reached. The cooking time was recorded for each sample in duplicate.

Cooking loss: Cooking loss is defined as the percentage of noodles that is lost in the cooking water. During the cooking of noodles some parts of it disintegrated in the water. The cooked noodles were sieved and the cooking water was collected in a beaker. The beaker was placed in a drying oven to evaporate the water. The residue was weighed and the cooking loss was calculated as follows:

\[
\text{Cooking loss [%]} = \frac{A1 - A2}{M} \times 100
\]

A1 = mass of full beaker [g]  
A2 = mass of empty beaker [g]  
M = mass of noodle [g]

Cooking weight: The noodles were cooked as described and the cooking weight was calculated as follows:

\[
\text{Cooking weight [%]} = \frac{\text{Mass of cooked noodles [g]}}{\text{Mass of raw noodles [g]}} \times 100
\]

Noodle production: Noodles were produced on a laboratory scale. An important factor in noodle production is the moisture content. The exact amount of water to be added to the flour is calculated with respect to the moisture contents of the dough components. The final dough will be in a flaky and crumbly condition i.e. not one complete piece. The condition of the dough determines the state of the resultant noodle: moist dough results in soft noodles where as dry dough produces brittle and splintered noodles. Therefore the amount of water to be added is crucial for the production of good quality noodles.

The amount of water required to be added to the flour:

\[
W = \frac{MD \times WD - MG \times WG - MU \times WU - ME \times WE - (MD - MG - MU - ME) \times WF}{1 - WF}
\]

W = water content to be added [ml]  
MD = mass of dough [g]  
WD = moisture content of dough [%]  
MG = mass of gelatinised flour [g]
WG = moisture content of gelatinised flour [%]
MU = mass of Guar [g]
WU = moisture content of Guar [%]
ME = mass of emulsifier [g]
WE = moisture content of emulsifier [%]
WF = moisture content of flour [%]

Sensory evaluation of fortified sorghum noodles was conducted different formulations as described by test sheet prepared by Schoenlechner (2001).

### 2.1 Literature Review

Iron is an essential micronutrient and forms an integral part of haemoglobin. It is required for the transport of oxygen and carbon dioxide in the blood. It is also an essential component of several critical tissue enzymes that are important for energy production and enzymes involved in the immune system (Craig, 1994). O’Dell (1984) defined bioavailability as the proportion of the total nutrient in a food, meal or diet that is utilized for normal body functions. The valance, solubility and the degree of complex formation of iron affect its bioavailability.

Strategies for combating IDA include therapeutic supplementation (direct measure), iron fortification of common foodstuffs, dietary improvement through nutrition education and public health measures (indirect measures) (Oliveria et al., 1996).

WHO listed the strategies for the prevention and control of IDA as follows:

1. Dietary diversification: This is through the food-to-food fortification.
2. Iron supplementation: Administration of iron supplements
3. Food fortification: With inorganic compounds
4. Public health measures

Effect of processing techniques on iron content and bioavailability Hurrell (1997) stated that some food processing techniques decrease the inhibitory effect of phytic acid on mineral absorption. Industrial processing may cause reasonable phytate loss. Lomarbi-Boccia and Carnovale (1995) reported that when meals were freeze dried and drum-dried bioavailable iron content was reduced by 7.0 % and 7.4 % respectively from the original iron content.

Common or white beans (*Phaseolus vulgaris*) are grain legumes that belong to the family *Fabaceae (Leguminosae)*. Legumes are widely grown and consumed around the world. Common beans were known to be the
native of the New World basically in Central Mexico and Guatemala. The Spaniards and Portuguese brought them to Europe and from there to Africa and other parts of the Old World. They are now widely cultivated in the tropics, subtropics and temperate regions.

White beans are very good sources of proteins (16–40 %), carbohydrates (50–60 %) and relatively good sources of Vitamins (thiamine, riboflavin, niacin, Vitamin B6, Folic acid) dietary fibre (14–19 %), minerals (calcium, iron, copper, zinc, potassium, phosphorous and magnesium and free unsaturated fatty acids (Reyes-Moreno and Paredes-Lopez, 1993).

Lomardi et al. (1995) reported that in white beans the iron content in the hull was 7.5 % and in the cotyledon 92.5 %. White beans iron has a high dialyzability (57.7 %). Cooking improved iron dialyzability to 62.4 %. Iron in the hull had higher dialyzability than the cotyledon iron. Cooking also improved iron dialyzability by 54 %. Protein digestibility also has a direct affect on iron dialyzability i.e. undigested or partially digested protein negatively influence iron availability (Hurrell et al., 1989).

Lomardi et al. (1994) reported that protein digestion and peptide composition modify iron availability from legumes. Although tannins are present in Phaseolus vulgaris, the white variety and in terms of bioavailability, the percentage of bioavailable iron was from 50-70 %. Iron content of Sudanese white bean is 7.5 mg / 100g DM (Sudan Food Composition Tables, 1999).

2.2 Results and Discussion
Iron content in fortified sorghum noodles: Results show that the 50 % white bean noodles gave higher values for the iron content. The 10 % white bean noodles presented the lowest contents of iron. The effect of guar and pregelatinised flours also affected the iron content. The higher the guar used, the lower was the iron content. In the case of pregelatinised flours (PGF), the use of sorghum PGF flours, showed a lower iron content whereas the use of white bean pregelatinised flours resulted in an increase in the iron content. This shows that the white bean content had a direct influence on the iron content whether it was a fortificant or as pregelatinised flours. Noodles prepared from the fortified flour with the extruded sorghum (ES) and drum dried sorghum (DDS) and drum dried white bean (DDWB) had higher results than the roasted sorghum (RS) due to contamination iron. 10 % white bean noodles showed iron content lower than the iron content in raw sorghum (2.67 mg). This was due to the effect of the low fortification level. The negative increase was more apparent in roasted sorghum than in the other noodle preparations. Statistically in the 30 % white bean noodles, there was significant difference at the 95 % confidence level (ANOVA) between the samples and there was no homogeneity (Multiple range test). The 10 % and the 50
% white bean noodles also had significant difference between their respective samples. Iron content improvement was higher in 30 % and 50 % white bean fortification and Pregelatinized flours (PGF). The 10 % white bean and its combination with roasted sorghum did not give satisfactory results in terms of iron content. This was in the recipes that had 10 % white bean and high guar content.

These results show that noodles prepared with different fortification levels of white improved the iron content with varying degrees. The 10 % white bean fortification gave negative results in some recipes whereas the 30 % and 50 % white bean fortification levels gave the best results and therefore fulfil the aims of the study.

Bioavailable iron in fortified sorghum noodles: In the noodles prepared with extruded sorghum PGF, the bioavailability improved by 17.6 % in 10 % white bean fortification up to 58.43 % in 50 % white bean fortification. The degree of improvement was dependent also on the amount of guar and pregelatinised flour used. The higher the guar and extruded sorghum PGF used, the lower was the increase in bioavailable iron. The same applies to drum dried sorghum. Roasted sorghum showed the least improvement in bioavailable iron when compared to the other noodle recipes using the other PGFs. The best results were obtained from extruded white bean PGF. The noodles prepared from the recipes using EWB PGF showed up to 71.16 % bioavailable iron i.e. 55 % improvement in iron bioavailability when compared to raw sorghum (16.2 % bioavailable iron). The highest increase was seen in the 50 % white bean noodles. Drum dried white bean PGF also showed similar results to extruded white bean RGF noodles and the highest increase was seen in the 50 % white bean noodles (61.8 %).

Statistically in the 30 % white bean noodles iron bioavailability; there was significant difference at the 95 % confidence level (ANOVA) between the samples. The 10 % and the 50 % white bean noodles also had significant difference between their respective samples. Iron bioavailability increased in all of the noodle recipes except in 2 recipes using roasted sorghum PGF. This was in the recipes that had 10 % white bean and high guar content. The high guar content counteracted the effect of the white bean therefore there was a no improvement in the iron bioavailability. The 30 % white bean fortification showed good results in all the recipes. The best results were from the noodles prepared from 50 % white bean and white bean PGF which showed the highest increase in bioavailable iron.

In terms of PGF, the sorghum PGF showed slight difference in bioavailable iron content, the lowest improvement was with roasted sorghum. In the case of white bean PGF extruded white bean gave better results due to the higher iron content in the sample. Noodles prepared with 50 % white bean and extruded white bean PGF gave the best results.
Influence of addition of white bean flour on functional properties of noodles: Generally the white bean fortification gave positive results in terms of the functional properties of noodles. From the results it can be observed that the addition of white bean had a significant effect on the bite resistance of noodles in all the different recipes. The higher the percentage of white bean added, the higher the bite resistance. However the range of the increase was within the average level when compared to durum wheat noodles. In comparison to all the other texture parameters, the bite resistance was the most criteria that was affected by the white bean fortification level. There was no significant difference in the cooking loss between the noodle recipes. The percentage of cooking loss was comparable to that of durum noodles. There was also no significant difference between the different recipes on the cooking time. The range of cooking was from 9 – 12 mins. and that can also be considered as a normal cooking time for durum wheat noodles.

Sensory evaluation was carried out for noodles that had a good quality number and cooking properties and they were selected in accordance to the results obtained from the functional properties. The noodles selected must in the end have good iron content and bioavailability, good functional characteristics and must also be desirable to the consumer. Noodles prepared with 50 % white bean showed the best results. In all the three recipes produced with the 5 different PGF, the noodles prepared with the PGF from extruded white bean and drum dried white bean gave the best results, whereas roasted sorghum PGF gave showed least acceptance. However from the comments the roasted sorghum noodles had a exotic taste that appealed to some of the panellists.

2.3 Conclusion
Noodles recipes were established using a $2^3$ experimental design. The content of white bean in the noodles had a direct influence on the iron content and bioavailability. The higher the amount of white bean added, the better was the iron content and bioavailability. In all the recipes, the 50 % white bean noodles gave the best results for the iron content and bioavailability. The iron content and bioavailability was also affected by the addition of guar and pregelatinised flours. Iron content of noodles decreased with the increase of guar content likewise the addition of sorghum pregelatinised flours also showed a decrease in the iron content and bioavailability whereas white bean pregelatinised flours resulted in increased levels of iron content and bioavailability. Noodles prepared with extruded sorghum gave higher results than the drum dried sorghum noodles in terms of iron content and bioavailability whereas there was no increase in the iron content and bioavailability in noodles prepared with pregelatinised roasted sorghum. Noodles prepared with extruded white
bean gave similar results to those produced with drum dried white bean. In all noodle recipes, the highest increase was seen in the 50% white bean noodles.

On examination of the functional properties, the 50% white bean noodles gave the best results in terms of texture, cooking loss, cooking time and cooking weight. Sensory evaluation of the noodles showed that the noodles prepared with the 50% white bean and extruded and drum dried white bean gave the best results.

This result fulfils the aim of the study in that the noodles prepared with the high fortification level gave the best result and therefore when consumed can help in the eradication of iron deficiency anaemia and can serve as a good alternative to gluten free pasta for celiac disease patients.

References


WHO: Guidelines for the control of iron deficiency in countries of the Eastern Mediterranean, Middle East and North Africa. (www.who.sci.eg).