

Production and Determination of Bioavailable Iron in Sorghum and White bean Noodles

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ABSTRACT

The objective of this study was to find innovative approaches for the production of iron fortified noodles that are natural and economically feasible. The functional food was produced using different combinations. The investigated variables were the ratio of sorghum to white bean flour, pre-gelatinized flours (drum dried or extruded) and guar gum addition 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 of the study showed that the content of white bean in the noodles had a direct influence on the iron content and bioavailability. As expected, the iron content and bioavailability was higher 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.

Key words: Sorghum, White bean, Iron, Fortification, Noodles.

INTRODUCTION

Iron Deficiency Anaemia (IDA) affects approximately two billion people worldwide (WHO, 2008). 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' (Rooney *et al* , 1991). 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 (Rooney *et al* , 1991).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. 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 is to find innovative approaches for the production of 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.

MATERIALS AND METHODS

Dabar sorghum (a low tannin Sudanese Sorghum bicolor (Linn) Moench) and white bean were 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 pregelatinized 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. 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.

Determination of Total Iron Content

Millers Ferrozine technique was used to analyse the iron content in the different noodle samples. The methodology (Millers Ferrozine

technique) in the original procedure was performed by initially wet ashing the sample and iron was determined through the reaction of the colorimetric reagent known as Ferrozine. However, during the wet ashing procedure, foaming of the samples occurred and therefore the method needed to be modified. In this study the samples were dry ashed to replace wet ashing in the original method. Dry ashing was carried out using the AACC Method (1999) 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.

Determination of Bioavailable Iron

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.

Measurement of 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:

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

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:

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

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

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).

RESULTS AND DISCUSSION

Iron content on pregelatinized sorghum and white bean

The iron content in the raw sorghum was 2.69 mg/100g dm and white bean was 12.53 mg/100g dm. The iron content in extruded sorghum and extruded white bean was 3.01 mg/100g dm and 13.02 mg/100g dm respectively. Theoretically, the iron content in any raw material does not change when subjected to processing however there is a possibility that the increase in the iron content was due to contamination iron from the extruder. The slight increase in the iron content in

Production of Noodles

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 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:

the flours produced by extrusion cooking may be attributed to the presence of contamination iron due to the high shear force exhibited during processing. Alonso *et al.*, 2001, reported that extrusion cooking increased the iron content in beans and this he explained by the contamination iron from the extruder.

Iron bioavailability of pregelatinized sorghum and white bean

Raw sorghum had an iron bioavailability of 16.2 %. Iron bioavailability of extruded sorghum ranged from 39.5 % to 37 % therefore extrusion cooking improved the bioavailability in sorghum extrudates by 21 to 23 %. Bioavailable iron in raw white bean was 38.7 % whereas white bean extrudates iron bioavailability ranged from 53.7% to 57.3 %. The increase of iron bioavailability due to extrusion cooking of white beans was approximately 20 %. These results agree with the findings of Ummadi *et al.* (1995) who reported that extruded legumes exhibited higher iron dialyzability than boiled legumes. Extrusion reduced the phytic acid content in legumes from 66 to 79 % to 20 to 50 %. Tannin content also decreased by 31 to 76 % compared to raw legumes. Food processes which involve heat treatment degrade phytates in plants to lower forms of inositol phosphates which induce an increase in iron solubility due to the formation of

small soluble iron complexes (Sandberg *et al.*, 1989). Alonso *et al.* (2001), reported that extrusion cooking significantly increased the iron bioavailability due to the decreasing of phytic acid content by 21.4%, the condensed tannins by 83.8% and polyphenols by 45.9%. Kevisto *et al.* (1986) reported that extrusion of cereals lead to a decrease in mineral absorption, which was attributed to the destruction of phytase and a consequent increase of phytate concentration. On the other hand, mineral decomplexation from phytates and phenols during extrusion counterbalances the negative effect of loss of endogenous phytase. Fapojuwo *et al.* (1987) reported that extrusion cooking improved digestibility of proteins from 45 % to 74.6 % and improvement in protein digestibility significantly increases iron bioavailability. Results of this study show that iron bioavailability increased by extrusion cooking probably due to the degradation of phytates.

Iron content in fortified sorghum noodles

On analysis of the results, the noodles prepared with 50 % white bean had a higher iron content whereas the noodles with 10 % white bean had the lowest contents of iron. Addition of guar gum and pregelatinized flours significantly affected the iron content in the noodle samples. The higher the guar gum used, the lower was the iron content. In the case of pregelatinised flours (PGF), noodles prepared with sorghum PGF flours had a lower iron content than white bean (PGF). This shows that the addition of white bean increased the iron content in sorghum noodles. Noodles prepared from the fortified flour using the extruded sorghum (ES), drum dried sorghum (DDS) and drum dried white bean (DDWB) had higher iron content than the roasted sorghum (RS). This increase in the iron content may be due to contamination iron from the hot extruder during extrusion cooking and from the drum drier. The lowest increase in the iron content was in roasted sorghum noodles. There was significant difference at the 95 % confidence level (ANOVA) between the different samples with 30% and 50% white bean. The 10 % and the 50 % white bean noodles also had significant difference between their respective samples. The higher the amount of white bean, pregelatinized or non-pregelatinized, added to the noodles the higher the iron content. Highest increase in the iron content

was in the noodles prepared with pregelatinized white beans .

Bioavailable iron in fortified sorghum/white bean noodles

In noodles prepared with pregelatinized sorghum flour and 10 % white bean, iron bioavailability increased by 17.6 %. Iron bioavailability increased to 58.43 % in noodles fortified with 50 % white bean. The degree of increase in iron bioavailability was also dependent on the amount of guar and type of pregelatinized flour (sorghum or white bean) used. The higher the amount of guar and extruded sorghum PGF used, the lower was the increase in bioavailable iron. Roasted sorghum and drum dried sorghum did not increase iron bioavailability when compared to the other noodle recipes using the pregelatinized white bean. The best results were obtained from extruded white bean. The noodles prepared from the recipes using 50% extruded white bean showed 71.16 % bioavailable iron i.e. 55 % improvement in iron bioavailability when compared to raw sorghum (16.2 % bioavailable iron). Drum dried white bean showed similar results to extruded white bean noodles and the highest increase was seen in the 50 % drum dried white bean noodles (61.8 %). Iron bioavailability increased in all noodle recipes except in 2 recipes using roasted sorghum PGF. The recipes that used 10 % white bean and high guar content had a decrease in the bioavailable iron. The higher guar content counteracted the effect of the white bean therefore there was no improvement in iron bioavailability. 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 negligible improvement in bioavailable iron, 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 namely texture, bite resistance, cooking time and cooking loss. Results showed 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, the higher the bite resistance. However, the bite resistance in all sorghum/white bean noodles was lower than durum wheat noodles. There was no significant difference in the cooking loss between the different 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 an average cooking time for durum wheat noodles. Sensory evaluation was carried out for noodles that had a gave the best functional properties, good iron content and bioavailability. Noodles prepared with 50 % white bean showed the best results. In all the three recipes produced with the 5 different pregelatinized flours, 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.

CONCLUSION

Noodles recipes were established using a 2³ experimental design. The content of white bean in the noodles had a direct influence on the iron content and bioavailability. Increase in the addition of white bean to the noodle recipes resulted in a higher 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.

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