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Household food processing methods to enhance iron and zinc bioavailability in formulated haricot bean and maize complementary food

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This study aimed to test the nutritional quality of white haricot bean-maize porridge, a potential complementary food made using household food processing. Focus group discussions were conducted with mothers and revealed that traditional processing practices were soaking, germination and roasting. Although few used pulses in complementary foods (only maize), they expressed preference for white haricot bean to incorporate as a pulse in food for infants and young children. Germination (for 48 or 72 h) and roasting methods of household processing and preparation methods were used during preparation of white haricot bean flour, and soaking and roasting were selected in preparation of maize flour. Proximate nutrient analysis was done on processed and unprocessed flours using standard methods. There were no significant differences in iron (p=0.114), and zinc (p= 0.326) between 48 and 72 h germinated white haricot bean. However, processed products showed significant reduction of phytate (p= 0.001). Community acceptability test was undertaken with 36 mother-child pairs. There were no significant mean differences among porridge samples for sensory attributes. This study shows that processing such as germination of pulse is necessary for improved bioavailability of iron and zinc, and that pulse-cereal porridge is suitable as a complementary food.

Key words: Phytate, iron, zinc, porridge, maize flour, haricot bean flour, germination, roasting, soaking.

INTRODUCTION

Appropriate infant and child feeding, including complementary feeding, is critical for child growth, development and survival (WHO and UNICEF, 2008). Poor households subsist on monotonous staple-based diets and intakes of animal-source foods are low (Gibson et al., 2008). Lack of diversity in the diet is strongly associated with inadequate intake and risks of deficiencies of essential micronutrients such as vitamin A, iron and zinc in young children (Hawkes and Ruel, 2011). In Ethiopia, the most recent national survey indicates that 21.4% of under 5 children are mildly anemic, 20.4% are moderately anemic and 2.5% are severely anemic. Cite Reference (Central Statistics Agency (CSA) CSA, 2012) Previous studies conducted in southern Ethiopia indicated the presence

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of zinc and iron deficiency (Hambidge et al., 2006; Stoecker et al., 2009; Gibson et al., 2008). The main source of zinc is animal source foods such as meat which is lacking in many rural poor households. Young children are in the rapid growth phase where requirements for nutrients are increased, yet in Ethiopia, it is common to find their diet is mainly cereal based which is low in iron and zinc, and high in phytate content (Kebebu et al., 2013).

Locally available foods such as pulses are rich source of protein, vitamins and minerals. In resource-limited households, malnutrition is attributable not solely to insufficient amounts of food but also to the poor nutritional quality of the available food supply, especially among plant-based diets (WHO and UNICEF, 2008; Gibson et al., 2008). Low bioavailability of nutrients, arising from the presence of antinutrients such as phytate is another factor that limits the quality of predominantly plant-based diets (Hawkes and Ruel, 2011; Central Statistics Agency (CSA), 2012). Given the heavy reliance of low-income populations on cereals as a food source, the negative effects of low mineral bioavailability on mineral status and subsequent health are potentially quite substantial. Combining pulses with other plant-based protein sources such as cereal grains can generate a more complete protein than either alone and can also provide vitamins and minerals not found in either by itself, especially in complementary foods (Egounlety, 2002).

Household food-processing and preparation methods such as soaking, fermentation, roasting and germination can enhance the bioavailability of micronutrients in plant-based diets by decreasing phytate content and improving overall digestibility and absorption of nutrients (Hotz and Gibson, 2007). Using home based recipes with easily available pulse products and traditional ways of food processing methods should encourage greater acceptance of products with improved nutrient availability in areas where the usual diet is of poor nutritional quality (De Onis et al., 2012). Therefore, this study aimed to test the nutritional quality of a pulse-cereal complementary food after simulating household food processing procedures to decrease phytate content. A white haricot bean and maize complementary food was formulated, and various household processing methods were tested, after which acceptance was determined by community women and their children.

METHODOLOGY

This study was conducted at Hawassa Zuria woreda, in Sidama zone, Southern Nations and Nationalities People Region, Ethiopia. Hawassa Zuria woreda is situated 22 km south east of the regional capital of Hawassa. Main crops are maize, red paper, enset (also called false banana, *Enset ventricosum*), potato, and red and white haricot (kidney) beans, according to the Hawassa Zuria woreda health report of 2010. This study area was selected because previous studies conducted in the region indicated the presence of zinc and iron deficiency in children and adults (Hambidge et al., 2006; Stoecker et al., 2009; Gibson et al., 2008; Aubuchon-Endsley et al., 2011). Ethical approval was obtained from Hawassa University's Ethical approval committee.

Study design

Laboratory-based experimental study design was used for this study. For the community consultation, three Focus Group Discussions (FGD) took place with mothers who were living in the study area, to find out (1) the traditional ways of pulse based foods processing practices; (2) whether pulses were used in preparation of complementary foods in the community; (3) overall feeding practices of infants and young children; (4) the most common pulses available in the area; and (5) their knowledge, attitudes and beliefs regarding incorporating pulses in preparation of complementary foods. Discussion in a private area was facilitated by principal investigators, and tape recorded. The answers to the five questions were grouped, and emerging themes regarding potential for pulse-cereal complementary foods of high nutritional quality were summarized to inform the research on complementary food preparation and acceptability.

The community consultation indicated that the complementary foods normally made were maize-based gruels, and that the preferred pulse was white haricot bean. The food processing methods in use in the community were germination and roasting. A series of laboratory-based studies then tested these household processing methods applied to preparation of a pulse-cereal porridge as complementary food. The ingredients were purchased in the local market, and the flours and complementary food that were formulated in the food laboratory at Hawassa University, were analyzed. Once formulation was completed, the resulting porridges were tested for acceptance in the community.

Preparation of white haricot bean flour

The white haricot beans were first cleaned of defective grains, stones and other debris, then washed and soaked in clean tap water for 12 h. After draining, the beans were left to germinate at room temperature for 48 or 72 h, respectively. These two batches of germinated seeds were rinsed, and then dried in the sun to facilitate removal of the hulls and aid in removing moisture. The sun dried beans were roasted using a hot plate which is a commonly available household appliance. After 5 min of roasting, the beans were milled using the community's milling machine, to obtain smooth and consistent particle sizes. The resulting flours were stored in airtight polyethylene plastic containers until further use.

Preparation of maize flour

Defective grains, stones, and other debris were removed from the locally obtained maize. After washing in clean tap water, the maize was soaked overnight at room temperature. The soaked maize grains were thoroughly washed and sun dried. The dried maize was roasted for five minutes. After milling to a smooth and consistent particle size, maize flour was stored in an airtight polyethylene plastic bag.

Preparation of porridge

Three types of porridge were prepared from maize and haricot bean mix. Porridge was chosen because it has smooth consistency and is palatable for young children. FAO/WHO/UNICEF (1985) guidelines are to add up to 40% pulses into cereal-based products. The unprocessed (control) porridge was prepared from 70 g unprocessed maize flour and 30 g unprocessed haricot bean flour and same amount of oil and salt as that of treatment porridges. Two treatment foods were prepared, one was by using white haricot bean flour that had undergone 48 h of germination, and the other from beans germinated for 72 h. Both treatment porridges were prepared from 70 g of processed maize flour blended with 30 g white haricot bean flour, and cooked in boiling water with oil, salt and a measured amount of water.

Laboratory analysis of prepared flours

All chemicals and reagents used in the laboratory analysis were analytical grade. Each laboratory determination was carried out on separate fresh samples using standard methods. Iron and zinc levels were analyzed at the Saskatchewan Food Industry Development Center (Saskatoon SK, Canada) and phytate analyzed at University of Saskatchewan (Saskatoon SK, Canada). Other proximate analyses were done at Ethiopian Health and Nutrition Research Institute (Addis Ababa, Ethiopia) (AOAC) 2000). Determinations included moisture content (AACC international method 44-15.02), protein (Kjeldahl method), calcium, iron and zinc (inductive coupled plasma mass spectrometry, ICP-MS), crude fat and ash (AOAC 4.5.01, 2000; AOAC 923.03, 2000), crude fiber (AOAC 962.09) and phytate [(modified Wade Reagent Method of Gao et al., (2007).

Acceptability testing

Thirty six (36) mothers and their young children aged 7-20 months performed field sensory evaluation using a modified five-point grade scale whereby five and one represented the highest and the lowest orders of preference, respectively. Terminologies for sensory evaluation were appearance, flavor, taste, texture (mouth feel) and overall acceptability. Each mother-child pair was given a sample of each of the three porridges in random order, and in duplicate. Mothers were told to taste the food and feed their children with it. Prior to conducting the sensory tests mothers were asked not to feed their children for an hour prior to conducting the sensory tests. The objectives of the study were explained to mothers and they were instructed to give their honest opinions. Mothers assigned a score to the preference of their children based on the facial expression and their general reaction after tasting the food mixtures. Samples were served with similar utensils.

Statistical analysis

Analysis of recorded, transcribed and translated consultation discussions were performed using thematic analysis technique. Themes developed by comparing findings from each theme across study sites (by kebele/district) to look for similarities and differences in response within and between communities. Initial conclusions were triangulated by comparing responses between target populations to examine the relationships between their demand, experiences and perceptions. The findings presented are consistent within subgroups and across study sites.

Analysis of experimental data was conducted using SPSS version 16.0. Means and standard deviations were calculated for proximate laboratory results and acceptability (sensory attributes) of the complementary foods. Factorial analysis of variance (ANOVA) and Duncan's multiple significant tests were conducted to determine significantly different means. Independent sample t-test was conducted to see the significance difference in processed and unprocessed maize samples. Differences were considered significant at $p < 0.05$.

RESULTS

In the community group consultation, the common pulses in the area were red and white haricot beans. The former was grown only during time of plentiful rain. While most participants agreed they ate red haricot bean during the coffee ceremony, at which time it was boiled and roasted after soaking; they also mentioned that red haricot bean is considered a "poor person's diet". The white haricot bean was preferred, especially when mixed in the national dish "Kocho", so that the resulting food remained white.

Respondents knew the health benefits of pulses including their benefits to infants. However, they did not incorporate pulses in an infant's diet, raising two major problems: pulse was not available in the dry season, and they did not know how to prepare complementary foods using pulses. Their usual complementary food was prepared from maize as a form of a thick porridge or a thin gruel, to which they might add oil/fat, powdered milk, potato and/or egg. Thus they had no experience with any traditional food processing method specifically for adding pulses in infant food. However, they roasted or boiled pulses after a short period of soaking.

Composition of haricot bean flour after soaking

The analysis of the three haricot bean flours is shown in Table 1. There were no significant differences in iron and zinc content among groups, thus germination had no detrimental effect on these minerals. Phytate concentrations, however, were lower in both geminated flours, which would lead to improvement in mineral bioavailability.

While there were significant differences between the ungerminated and germinated flours in protein, fat and carbohydrate, other differences showed no pattern to germination. Significant differences between 48 and 72 h germination included fat, energy and ash content.

Maize flour that was processed by soaking and roasting showed no differences to unprocessed flour except in iron content, where levels appeared to improve with processing (Table 2).

Acceptability

There were no significant mean differences among porridge samples except for overall acceptability. Here, the bean porridge made with 72 h germinated bean flour was liked less well than that made with the 48 h germinated bean flour porridge and the bean porridge made with ungerminated beans. As the mean acceptability score was 4.0 for all samples, it appeared that all of the porridges were moderately well liked and not very different (Table 3).

Table 1. Proximate analysis of mineral, phytate and macronutrients of ungerminated and germinated haricot bean flour, Mean (SD) of triplicate analysis.

Component per 100 g	Content of samples		
	No germination	48 h germination	72 h germination
Zinc (mg)	3.21 (0.28) [a]	3.45 (0.05)[a]	3.34 (0.01)[a]
Iron (mg)	6.03 (0.08)[a]	6.09 (0.01)[a]	5.90 (0.09)[a]
Phytate (µg)	206.7 (58.7)[a]	166.1 (10.0)[b]	163.4 (75.0)[b]
Protein (%)	25.00 (0.16)[a]	27.5 (0.25)[b]	28.17 (0.59)[a]
Fat (%)	1.35 (0.50)[a]	2.54 (0.90)[b]	4.22 (0.98)[c]
CHO (g%)	60.24 (0.15)[a]	55.36 (0.77)[ab]	53.79 (1.21)[b]
Energy (kcal)	353.1 (0.3)[b]	354.3 (1.5)[b]	365.9 (5.0)[a]
Fiber (g)	6.72 (0.13)[a]	6.20 (1.13)[a]	5.29 (0.98)[a]
Ash (g%)	4.03 (0.04)[a]	4.25 (0.08)[b]	4.02 (0.12)[a]
Moisture (g%)	9.37 (0.03)[a]	10.34 (0.45)[b]	9.79 (0.15)[a]

Values in the same row with different superscript letters are significantly different from each other at p<0.05.

Table 2. Proximate analysis of mineral, phytate and macronutrients of unprocessed and processed maize, Mean (SD) of triplicate analysis.

Component per 100 g	Content of sample	
	Unprocessed	Processed#
Zinc (mg)	1.86 (0.10)[a]	2.02 (0.07)[b]
Iron (mg)	1.65 (0.05)[a]	1.80 (0.01)[a]
Phytate (µg)	143.5 (6.9)[a]	134.0 (7.0)[a]
Protein (%)	7.88 (0.05)[a]	8.68 (0.42)[b]
Fat (%)	6.65 (1.24)[a]	8.21 (0.53)[a]
CHO (g%)	73.84 (1.22)[b]	71.45 (0.53)[a]
Energy (kcal)	386.7 (6.5)[a]	394.5 (1.6)[a]
Fiber (g)	1.74 (0.34)[a]	2.71 (0.09)[b]
Ash (g%)	1.92 (0.24)[a]	2.14 (0.26)[a]
Moisture (g%)	9.70 (0.31)[a]	9.50 (0.47)[a]

Values in the same row with different superscript letters are significantly different from the other value at p<0.05. # Maize was processed by soaking and boiling

Table 3. Children's acceptability based on mothers' perception at Hawassa Zuria woreda (n=36) June 2013.

Sample	Appearance	Flavor	Taste	Texture	Overall
Unprocessed 70% maize and 30% haricot bean	4.46 (.05)[a]	4.26 (.15)[a]	4.21 (.01)[a]	4.33 (.04)[a]	4.33 (.01)[b]
Processed 70% maize and 30% 48 h germinated haricot bean	4.25 (.04)[a]	4.14 (.11)[a]	4.02 (.12)[a]	4.09 (.02)[a]	4.14 (.01)[b]
Processed 70% maize and 30% 72 h germinated haricot bean	4.36 (.39)[a]	4.04 (.21)[a]	3.48 (.68)[a]	3.97 (.19) [a]	4.01(.09)[a]
Significance (p value)	0.696	0.478	0.313	0.110	0.026*

*indicates significance at p < 0.05.

DISCUSSION

Traditional food processing methods for pulses include soaking, germination, frying, fermentation, boiling, roasting, and blanching (Walingo, 2009). These processing procedures of plant-based food components are known to improve digestibility and to remove or reduce anti-nutritional factors such as phytate (Gebrelibanos et al., 2013). Further, these methods may enhance organoleptic properties of food, thus increasing acceptability. While considered “traditional”, these methods are being quickly forgotten (Walingo, 2009). Our results show that by germinating white haricot beans, the resulting flour had significantly lower level of phytate, which is known to reduce iron and zinc absorption (Sandburg et al., 1999; Hawkes and Ruel, 2011). This is in agreement with studies on germination of pulses wherein germination increased protein content and dietary fiber, and also reduced phytate content and increased mineral bioavailability (Ghavidel and Prakash, 2006). Some researchers have shown improved zinc content (El-Adawy, 2002), which we did not observe. Ibnouf (2007) found that roasting reduced phytate content of beans, and this might have influenced the phytate contact of the bean flours. However, roasted maize did not show a decline in phytate.

Red and white haricot beans are common in the Hawassa Zuria woreda, of Ethiopia, yet most people there consider red haricot bean as a “poor” person’s food. When consumed, it was common to boil or roast beans, and there was a positive attitude towards the benefit of red or white haricot beans in the study community. Beans were known to “replace meat” (as a protein source) by the community members we interviewed. However it was not common to incorporate pulses into complementary foods, thus mothers/caregivers did not know how to prepare complementary food using haricot bean. This attitude was observed previously in a different area of southern Ethiopia (Kebebu et al., 2013). Also of note was the finding that few community members used any processing methods, except soaking and roasting.

Finding that processing of the beans reduced levels of phytate in the bean flours has importance to the promotion of complementary foods made from pulses. Phytates have a high binding capacity to minerals such as iron and zinc and reduce their bioavailability (Sandberg et al., 1999). Germination induces hydrolysis of phytate (which is more accurately called inositol-hexaphosphate), and this prevents binding of divalent cations. While the fall in phytate cannot be attributed to germination alone, we did not see a drop in phytate level in processed maize, which was processed by roasting. Overall, there was no difference in phytate levels between germinating for 48 h and for 72 h. Therefore, the shorter time would be preferred.

Sensory attributes of formulated and control porridges showed that there was no significant difference in terms of aroma, color, and taste between foods made with treated or untreated samples. However, the difference in overall acceptability showed that one of the treated porridges was as acceptable as the commonly used complementary food in that community. Concerns that infants and young children would not like the pulse-cereal porridge were unfounded. Further study is needed to test whether adding 30% of 48 h germinated haricot bean to maize flour would improve nutritional status of infants and young children.

Conclusion

This study formulated a complemnary food product using household processing and preparation methods to reduce the phytate content and thus enhance the bioavialbility of iron and zinc. A white haricot bean-maize blend was selected based on community consultation with mothers. These ingredients were inexpensive, locally available and commonly consumed in the study area, however, mothers did not incorporate pulses into complementary foods. Germination and roasting methods of household processing and preparation methods were selected and used to process the beans. Laboratory analyses showed a decrease in phytate with germination of haricot bean. Household formulated complementary food using locally available pulses and cereals should be encouraged.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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