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SHORT COMMUNICATION

BIOAVAILABILITY OF IRON FROM CEREAL-BASED WEANING FOODS

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ABSTRACT. Iron bioavailability from commercial weaning foods and wheat flour of varying extraction rate was measured using the *in vitro* method. Phytic acid content of the gruel and porridge meals decreased by 3 to 15%. Iron bioavailability values for each meal were lower in gruel than in porridge, but the relative inhibitory effect of phytate and the enhancing effect of cooking was similar. The availability of iron was related to the phytic acid content of the bread with the highest availability, 44%, from sour dough fermented bread containing no phytate and the lowest, 12%, from yeast-fermented bread. There was a strong inverse correlation between available iron and the phytate content of different weaning foods. The weaning foods tested may not be regarded as a useful source of bioavailable iron for rapidly growing infants if fed as gruel or porridge. However, substantial improvement in iron bioavailability due to fermentation may be of practical nutritional importance to the prevention of iron deficiency to vulnerable groups where cereal-based diets with a low animal protein content are the staples.

INTRODUCTION

Iron deficiency anaemia is still the major nutritional problem in the world, affecting primarily infants, children, and fertile women in the developing world but also in industrialised countries [1]. Breastfed infants generally have an adequate iron status during the first 4-6 months of life but after this time, human milk and the babies' iron stores are no longer sufficient to provide enough iron for the rapidly expanding blood volume [2,3]. This extra iron requirement must come from other food sources and is often obtained from industrially-prepared or home-prepared weaning or transitional foods until sometime during the second year of life when the infant adapts to the family diet. A number of convenient commercial weaning foods including *Faffa* and *Dubbie* are available in Ethiopia. *Faffa* is a dry blended product prepared form low extraction wheat flour, soy flour, dried skim milk, chick pea flour, sugar, salt and additives whereas, *Dubbie* is a dry blend of deffated soy flour and low extraction wheat flour [4]. In most Ethiopian cultures, traditional weaning foods are nonmilk family foods, based on the local staple-usually a cereal, such as tef flour, refined wheat flour, corn flour, sorghum flour or barley flour. When a staple is prepared as a weaning food, it is made either into a thick porridge, or into a watery gruel called *atmit*. Milk is seldom added to the gruel [5]. After the successful introduction of thin cereal gruel, other modified foods in the family menu are given to the child.

Although the iron content of the traditional Ethiopian diet may be very high, anaemia is present among pre-school and school-age children [6]. This may be hypothesised to be related to the probable poor availability of iron from such diets [7,8]. Few data have been reported on the bioavailability of iron from traditional weaning foods in Ethiopia, although it was shown elsewhere that high amounts of phytic acid in cereal-based weaning foods are inhibitory to the bioavailability of iron [9-11]. The present investigation was undertaken to evaluate bioavailability of iron contained in commercial weaning foods, *Faffa* and *Dubbie*. Wheat flour of different extraction rate, which is used as traditional weaning foods for infant feeding was also evaluated.

EXPERIMENTAL

Ingredients. Soy-fortified wheat flour (locally known as *Dubbie*) and *Faffa* obtained from Faffa Foods Factory, Addis Ababa, Ethiopia, was transported to India and stored at 4 °C until used. Commercial wholemeal wheat flour and white flour (62% extraction) were kindly supplied by the Department of Milling and Baking Technology, Central Food Technological Research Institute, Mysore, India.

Meal preparation. Porridge and gruel were produced as described earlier using wholemeal wheat flour, white flour, *Dubbie* and *Faffa* [5,10]. Sour dough fermented bread was prepared from *Dubbie*, wholemeal wheat flour or white flour as practised by housewives according to the method previously described [12]. Straight dough bread was baked using *Dubbie* flour as pup loaves according to the procedure of AACC [13]. The breads were dried at 60 °C for 24 h and milled on a 0.5 mm sieve. All the foods were produced using double distilled water.

Analytical methods. Phytic acid content of the flours and food samples were determined using the method developed by Haug and Lantzsch [14]. For total iron estimation, the samples were wet-acid digested using nitric acid and perchloric acid mixture (HNO_3:$HClO_4$, 5:1, v/v). The amount of iron in the digested samples were determined by atomic absorption spectrophotometry (model 3110, Perkin-Elmer, Norwalk, CT, USA). *In vitro* iron bioavailalbility was determined as described by Narasimha Rao and Prabhavathi [15]. Ionizable iron at pH 7.5 was used as an index of bioavailability. The free form of iron (ionizable iron) in the filtrate was determined by AOAC [16]. Soluble iron was estimated by the method of Tennat and Greenman and the 2,2'-bipyridyl method [16,17]. Results were given as means of three observations with the standard deviation of the mean. Differences in mean values of bioavailable iron and phytate content of food samples were tested statistically using analysis of variance.

RESULTS AND DISCUSSION

Faffa and wholemeal wheat flour contained more iron as compared with *Dubbie* and white flour (Table 1). The amount of iron in the weaning foods used in the present study ranged from 0.025 mg/g to 0.053 mg/g, significantly lower than the 0.075 mg/g normally used to fortify weaning foods in Europe [11]. Phytic acid ranged from 1050 μmol to 310 μmol per 100 g flour (Table 1). Although *Dubbie* and *Faffa*, are produced from low extraction flour with a relatively low content of phytate, the high phytic acid content observed in these products may have originated from soy flour and chickpea flour which are added as complementary protein sources of these products.

When the weaning foods were prepared as meals, phytic acid content was reduced by 3% in *Dubbie* gruel, 9% in *Faffa* gruel, 10% in white flour gruel and 5.% in wholemeal wheat flour gruel while further reduction amounting to 7, 13, 15, and 8 %, respectively, were observed in porridges prepared from all four sorts of flours (Table 1). Iron availability (ionizable iron) after *in vitro* digestion was 9.4% in *Faffa* flour with its native phytic acid content of 1016 mmol/100 g dry matter (Table 1). The ionizable iron increased significantly to 10.6 and 11.2.%, respectively, after the product had been cooked as gruel or porridge. The relatively higher available iron from

Faffa gruel or porridge as compared to same meals prepared from wholemeal wheat flour with identical values of phytic acid content may be due to the enhancing influence of milk on iron availability as previously reported [18]. Cooking of the wheat flours into porridge and gruel increased ionizable iron by more than 2-fold in white flour compared to wholemeal wheat flour (Table 1). The available iron was strongly associated with the respective changes in the phytic acid content of the meals. Similar trends were also observed for soluble iron in porridges and gruels prepared from the weaning foods. Such close correlation between ionizable iron and the phytic acid content of the meals observed in the present study, regardless of the type of flour is further evidence that the flour used for infant feeding is important mainly in regard to its phytic acid content. These observations are in agreement with other findings previously reported for polished rice and unpolished rice [19].

Table 1. Food Fe content, available Fe and phytic acid in cereal-based weaning foods.[a]

Flour type	Fe content ppm	Available Fe[b] %	Soluble Fe %	Predicted Fe, %	Phytic acid µmol
Dubbie flour	28.29±1.4	7.47±1.11	9.41±0.47	4.00±0.34	795.8±7.3
Gruel	28.19±1.7	8.12±1.50	10.24±0.23	4.78±0.59	774.2±4.1
Porridge	28.29±1.8	9.27±0.91	11.03±0.51	5.32±0.91	742.0±9.2
Faffa flour	53.21±1.97	9.39±0.51	9.93±0.73	4.90±0.72	1016.2±9.3
Gruel	53.24±2.03	10.59±0.25	12.03±0.61	5.49±0.60	924.8±8.7
Porridge	53.41±1.80	11.19±0.81	12.93±0.31	5.75±0.86	887.2±3.9
White flour	25.40±0.75	12.98±0.43	13.67±0.13	5.65±0.69	310.4±3.8
Gruel	25.48±0.25	14.27±0.14	13.17±0.18	7.20 ±0.55	279.6±5.2
Porridge	25.43±0.17	15.49±0.32	14.07±0.64	7.77±0.63	263.5±1.9
Wholemeal wheat flour	40.20±0.9	5.85±0.25	5.89±0.58	3.24±0.60	1050.3±7.9
Gruel	40.36±0.5	6.05±0.14	6.09±0.61	3.33±0.55	994.7±8.3
Porridge	40.33±0.8	6.80±0.55	6.69±0.74	3.63±0.83	962.4±5.8
Dubbie yeast-fermented dough	32.53±0.87	-	-	-	-

[a]Mean ± SD of triplicates. [b]Measured as *in vitro* ionizable Fe.

Sour dough fermentation reduced the phytic acid content by 75% in both *Dubbie* and wholemeal wheat flour, and by 89% in white flour (Table 2). The ionizable iron and soluble iron values were increased to 18 and 19%, respectively, whereas values for predicted available iron increased by more than 2-fold. Similar but significantly higher values were also observed when wholemeal wheat flour or white flour were used as raw materials (Table 2).

Addition of flour to the fermented dough restituted the concentration of phytic acid which led to a marked reduction in the concentrations of ionizable iron and soluble iron at the beginning of the second phase of fermentation. This observation is consistent with the results reported by Hallberg *et al.* [20]. The content of phytic acid in *Dubbie* and wholemeal wheat flour sour dough fermented bread was reduced to about 93 µmol and 160 µmol, respectively, whereas it was completely degraded in white flour sour dough fermented bread (Table 2). This subsequently increased bioavailability of iron by more than 4-fold in the breads, despite the differences in the raw materials utilised is in agreement with previous studies on iron availability which showed that even a small amount of phytate causes marked inhibition [20,21]. The increase in available iron was strongly correlated to the degradation of phytate in *Dubbie*, wholemeal wheat flour and white flour ($p = 0.05$, $r = -0.8138$, $r = -0.6179$, $r = -0.7828$, $r = -0.8459$, respectively). In the present study, the phytate content increased in the order of white flour sour dough bread < *Dubbie* sour dough bread < wholemeal wheat flour sour dough bread < yeast leavened bread, whereas the bioavalability of iron decreased in the same order in agreement with the findings of Brune *et al.*[22]. The predicted available iron values in sour dough breads of all three sorts of flours constituted about 50% of the ionizable iron where Sunita *et al.* [23] observed similar values for selected cereal-based preparations such as *dosa*, *idli* and *chapatti*.

Table 2. Available Fe and phytic acid in sour dough yeasted and bread.[a]

Flour Type	Time h	Available Fe[b] %	Soluble Fe %	Predicted Fe %	Phytate μmol
Dubbie	0	8.21±0.17	9.30±0.24	4.34±0.56	788.6±6.7
	18	18.49±0.34	19.39±0.43	9.19±0.62	198.6±10.1
	0SF	13.19±0.39	15.77±0.16	6.69±0.67	963.6±11.6
	6SF	37.70±0.58	38.92±0.18	18.23±0.76	189.3±3.8
	Bread	39.14±0.58	41.25±0.50	18.91±0.76	93.2±2.4
Wholemeal wheat					
flour	0	5.85±0.25	5.89±0.58	3.24±0.60	1029.3±1.2
	18	12.41±0.46	16.55±0.93	11.03±0.70	254.9±9.8
	0SF	15.90±0.42	18.84±0.29	7.97±0.68	1281.1±11.6
	6SF	25.56±0.42	32.97±0.26	12.51±0.68	227.2±27.6
	Bread	27.63±0.39	37.46±0.33	13.49±0.62	159.5±27.4
White flour	0	12.98±0.43	13.67±0.15	6.59±0.69	304.7±1.5
	18	40.89±0.32	46.16±0.16	19.73±0.63	35.3±4.4
	0SF	32.4±0.43	37.76±0.45	15.61±0.69	353.9±7.6
	6SF	41.8±0.49	50.19±0.86	20.15±0.71	22.8±6.3
	6SF	41.8±0.49	50.19±0.86	20.15±0.71	22.8±6.3
	Bread	43.76±0.87	54.43±0.97	21.08±0.89	-
Dubbie yeast-fermented					
	0	7.14±0.63	7.75±0.12	3.84±0.78	831.0±9.2
	90	7.93±0.14	9.03±0.24	4.22±0.55	630.9±7.9
	145	9.16±0.11	10.77±0.16	4.79±0.53	538.5±6.8
	170	10.44±0.45	11.51±0.20	5.39±0.69	517.7±8.2
	225	11.62±0.17	12.35±0.93	5.95±0.56	509.7±4.4
	Bread	11.93±0.13	12.40±0.30	6.10±0.54	507.4±8.8

[a]Mean ± SD of triplicates. SF-second phase fermentation. [b]Measured as *in vitro* ionizable Fe.

The effect of fermentation on iron availability in yeast-fermented bread was different from that obtained by the sour dough fermentation process (Table 1). In this process the iron originated from dough additives increased the iron level by 15%. In the straight-dough bread low values for ionizable and soluble iron, and higher values for phytic acid content were observed as compared with *Dubbie* sour dough fermented bread (Table 2). Such differences appear to be due to the high phytase activity developed during sour dough fermentation which led to increased phytate hydrolysis as compared with yeast-fermented bread.

In terms of energy density, about 30 g flour of the individual weaning foods used in this study would only provide about 10% of the infants daily energy requirement [24]. At bioavilability values shown in Table 1, the gruels and porridge would provide from 7 to 15% of the daily requirement for absorbed iron for boys aged 6-12 months [25]. These weaning foods thus appear not be regarded as useful sources of bioavailable iron for rapidly growing infants if fed as gruel or porridge. With sour dough fermentation of the flours, the weaning foods may contribute more than 33% of the daily requirement for iron for the infants as compared to porridge or gruel meals of same raw materials.

In conclusion, owing to the high phytate content of commercial weaning foods and high extraction flour (wholemeal wheat flour) which inhibits the availability of iron, traditional indigenous food preparation such as fermentation can significantly improve the absorption of iron. However, further studies are required to extend these findings to other commercial weaning foods and home-prepared traditional weaning diets.

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