COMBATING IRON DEFICIENCY

4. Product Evaluation Using Iron-Fortified Wheat Flour

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Summary

In order to determine the effects on the physical and sensory characteristics of wheat flour preparations after fortification with specific iron compounds, a study was carried out to ascertain which iron compound would be most appropriate in Sri Lanka. The iron compounds tested were ferrous sulphate and fumarate, elemental iron, hydrogen reduced iron and Na Fe EDTA. Iron was added to wheat flour to provide 44, 66 and 88 mg Fe/kg flour and mixed in a tumble laboratory blender. The flour was stored at ambient conditions (30 to 40°C, relative humidity above 80%) at the Ceylon Institute for Scientific and Industrial Research (CISIR), Colombo. At monthly intervals, four foods, viz., roti, string hoppers, bread and rusks, prepared from the flour were evaluated for their sensory characteristics, using 12 trained and experienced panelists. Bread and rusks were prepared at the National Bakery, Colombo, and roti and string hoppers were prepared at the CISIR.

The results show that the quality of all flours, including the unfortified, control flour, deteriorated during storage. By the third month none of the products made from any of the flours were edible. Flour storage at the ambient storage conditions in Sri Lanka requires that the flour be consumed within 3 months of milling. Flours fortified with Na Fe EDTA and ferrous fumarate became less acceptable sooner than the other flours. Flours fortified with reduced iron and with electrolytic iron showed fewer sensory changes. Most of the changes were related to flour storage time than to the level of the fortificant. Fortification at iron concentrations of 44 mg/kg and 66 mg/kg was viable.

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Introduction

Wheat flour is enriched i.e., the amount of iron lost in milling is added back to the flour after milling, in a number of countries, and fortified, i.e., the amount of iron added to flour is over and above that lost in milling, in a few. The USA, Great Britain, Kenya, Nigeria, Guyana, and Grenada are among the countries that regulate that wheat flour be fortified with iron. The practice of fortifying wheat flour with iron (and some members of the vitamin B complex) began in the 1940s when there was concern about the general health of populations following the depression, but it was during World War II that bread fortification was promoted. Since that time, there have been some adjustments in the level and forms of iron added to wheat flour but the principle of iron fortification has remained intact.

Unlike many other micronutrients, iron is not totally absorbed in the body, the amount absorbed being dependent on the form of the iron and the iron status of the individual. The efficiency of absorption in the intestine is known as bioavailability, and the bioavailability of different iron compounds is important in determining those compounds appropriate as fortificants in a particular food system. Ferrous sulphate is the reference iron against which the absorption of all other forms of iron are compared (Table 1). However, because it catalyses rancidity and other hydrolytic reactions in dry systems, thus causing adverse sensory characteristics, ferrous sulphate is not used as a fortificant in wheat flour. Nevertheless, because it is the 'gold standard' in absorption studies, it is important to include ferrous sulphate in an evaluation of iron fortificants for wheat flour.

Table 1

Content and bioavailability of iron fortificants

Iron source	% iron	% bioavailability[1]
Electrolytic	98	76
Reduced iron	98	2 – 76
Fe Sulphate	33	100
Fe Fumarate	33	95
NaFeEDTA	13	200
Ferric ortho-phosphate	28	46

[1]Bioavailability estimate derived from published animal studies.

Source: INACG, 1990.

The two most common forms of iron added to wheat flour and other processed cereal foods are electrolytically prepared elemental iron (less than 20 micron particle size) and hydrogen reduced elemental iron. The latter form of iron is most frequently used in wheat flour, while electrolytically prepared elemental iron is used at relatively high fortification levels in cereal-based dry complementary foods in North America. Ferrous fumarate is used in numerous prepared foods where colour is not a major defect and concentrations are not high. Ferrous sulphate is widely used in liquid foods and for pharmaceutical preparations. Because the compatibility of ferrous sulphate is not favourable with dry cereal products, it can be used as a positive standard.

More recently, other forms of iron including sodium-iron EDTA (NaFeEDTA) have been proposed as suitable fortificants but data on their appropriateness and compatibility are scarce. Ferric orthophosphate is not used in cereal fortification, despite its white colour, because of its low bioavailability.

Because so little is known about the total effects (physical and sensory characteristics) of specific iron compounds on wheat flour under specific conditions and at different levels, a study was conducted to determine which iron compound(s) would be viable as fortificants in Sri Lanka. This study took into account the ambient storage conditions and food preparation/processing procedures. The iron compounds selected were ferrous sulphate, elemental iron, hydrogen reduced iron, ferrous fumarate, and NaFeEDTA.

Methods

Samples of the different fortificants for the sensory trials were generously donated by three companies. Mallinckrodt Chemicals provided 0.5kg samples each of hydrogen reduced fine powder iron, ferrous sulphate, and ferrous fumarate, SCM Metal Products Inc. donated 1 kg A131 elemental iron, and Lohmann's donated 0.5 kg NaFeEDTA. All five iron compounds are recognised and approved as being safe for use in foods and food grade sources.

In order to determine the level of iron to be added to the wheat flour, the national per capita consumption of wheat flour in the estate (60.7 kg/year, 165 g/day) and rural sectors (25.3 kg/year, 70 g/day) were used to represent the range of consumption. Three levels of fortification were proposed. Technically, the lowest level (44 mg/kg) was derived from the fortification level mandated for flour fortification in the United States and represents the level found in wheat prior to milling, i.e., enrichment level. Long term usage has established that this fortification level is possible

Table 2

Average iron intake (g/day) based on average daily wheat consumption and proposed iron content of fortified wheat flour

	Daily wheat consumption (g/day)	
Fortificant level (mg/kg)	70 mg iron	165 mg iron
44	3.1	7.3
66	4.6	10.9
88	6.2	14.5

Table 3

WHO recommended daily iron intake for individuals on a low bioavailability diet

Iron intake mg/day	Group
14	4-12 months old
8	1-2 year old
9	2-6 year old
29	women

without significant changes in quality. Multiples of that level were selected to provide significant fortification levels.

Table 2 shows the amount of iron that would be consumed at given wheat consumption levels and proposed fortificant level and Table 3 shows the WHO recommended (2) daily iron intake for individuals on a diet where the bioavailability of iron is low. Thus, enriching flour might meet more than one-half of young children's recommended daily iron intake among the high wheat consumers, and less than one-quarter of young children's recommended daily intake among low wheat consumers, while the highest level would meet the recommended daily intake of infants but too much for children age 1 to 6 years. These levels probably overestimate the impact of fortification on young children because the wheat consumption data are for average per capita intakes, and young children most likely consume less wheat than the average.

A tumble laboratory blender with 8 kg capacity was used to prepare sufficient samples of the experimental flour at the Prima flour mill in Trincomalee. These flours were used to provide evaluations at baseline, and after one, two, and three months of storage. Wheat was prepared using electrolytic iron A 131, small particle hydrogen reduced iron, ferrous fumarate, disodium ferrous EDTA, and ferrous sulphate (as a positive control). Flour was prepared without processing aids, i.e., bromate, ascorbate, and enzyme treatments. Iron was added to provide 44, 66 and 88 mg/kg flour and quantities were verified by analysis following American Organization of Associated Chemist's procedures.

Duplicate fortified and control flour samples were sent to the CISIR, Colombo, for sensory evaluation, where the flour was stored at ambient condition in a grain warehouse. Temperatures ranged from 30-40°C and relative humidity above 80%. At monthly intervals, four commonly consumed wheat-based foods were prepared and their sensory characteristics evaluated. The four foods prepared from wheat flour were roti, string hoppers, bread, and rusks. Roti is a flat small round 'crumpet' prepared by mixing wheat flour and coconut and cooked/toasted on a pre-heated pan. String hoppers are thin noodles made from steamed wheat flour that are extruded and then steamed. Bread is similar to that baked in western countries. The formula used in this study contained less yeast as is commonly practised by rural Sri Lankan bakeries. Rusks, known locally as hulang viskiringna, are a dry toasted bread bun.

Sensory evaluations were done using 12 trained and experienced taste panelists. Not all 12 panelists were available to evaluate foods each time and the total number of panelists involved in the study was 15. Because 90 foods were being evaluated (four foods at three iron levels using five compounds and a control), the evaluations took three weeks to complete. The panel was convened once a day whereupon one food at one level of fortification (44 mg/kg, 66 mg/kg or 88 mg/kg) using all five fortificants and the control were tested. For the sensory evaluations, string hoppers and roti were prepared at CISIR using standard recipes. Bread and rusks were prepared at the National Bakery, Colombo, following normal procedures. Table 4 summarises the composition of the foods and their method of preparation.

Table 4

Main ingredients and method of preparing roti, string hoppers, bread, and rusks

Name of product	Main Ingredients (ratio)	Method of Preparation
Roti	Flour: coconut (3:1)	Toasted (200°C) 10min
String hoppers	Flour: water (approx 2:3)	Mixed with water (85°C) and steamed 8 min
Rusks	Flour: yeast (100:0.3)	Proof time (31°C) 120 min Baking time (230°C) 10 min Toasting time (175°C) 30 min
Bread	Flour: yeast (1000:1.5)	Proof time (31°C)120 min Baking time (230°C) 25 min

The sensory evaluation was based on testing for multiple sample difference in quality attributes following the procedures used in India (3). Panelists evaluated the five coded food samples based on taste, colour, odour, and acceptability, using a hedonic scale of -5 to +5, with 0 being the value assigned to the control food made with unfortified flour. Panelists were also invited to make comments on the evaluation forms. In addition to the above, the technicians responsible for preparing the foods kept records of their observations on the characteristics of the uncooked foods during their preparation.

The sensory evaluation data were entered using Lotus 1-2-3 and the files imported into SPSS PC+version 4.0 for analyses using ANOVA.

Results

Dough quality and final food characteristics

(a) Roti

Roti made with electrolytic iron and reduced iron flours showed similar characteristics to the control and white in colour, while dough made using ferrous fumarate and ferrous sulphate flour was yellowish white. Unlike the other fortified doughs, the NaFeEDTA dough was not pliable.

The external characteristics of cooked roti showed that all flours, except the NaFeEDTA flour, had similar properties to the control. The NaFeEDTA roti showed obvious signs of surface dehydration, resulting in a stiff-textured product. It was also hard to bite and did not have a sticky consistency.

After one month of flour storage, roti made from NaFeEDTA flour had a crust that was rubbery in texture. Internally, the roti was sticky and adhesive. After three months of storage, puffing of the dough was observed. No obvious changes were noted for rotis formulated from the other fortified flours or the control.

(b) String hoppers

Flours containing ferrous fumarate and ferrous sulphate produced creamy, rather than a white, dough. As observed for roti, the dough of flour containing NaFeEDTA was stiff compared with the other fortified

Table 5

Summary of significant changes in sensory attributes of wheat-based foods fortified with electrolytic iron

Product	Sensory attribute	Change	Response[1]	Mean sensory value Flour storage time 0mo	1mo	2mo	Mean sensory value Level (ppm) 44	66	88
Roti	Taste	Time	Inconsistent	1.63	2.13	0.42			
	Accept.	Time	Inconsistent	1.71	2.10	0.83			
S. Hoppers	Colour	Time	Deteriorates	1.67	0.04	0.08			
	Taste	Time	Deteriorates	1.83	1.54	-1.13			
	Odour	Time	Deteriorates	1.92	0.79	-0.08			
	Accept.	Time	Deteriorates	2.63	0.88	-1.21			
Bread	Colour	Time	Deteriorates	1.96	1.13	0.13			
	Colour	Time x Level	Interacts						
	Taste	Time	Deteriorates	1.54	0.83	0.17			
	Odour	Time	Deteriorates	1.54	1.25	0.38			
	Accept.	Time	Deteriorates	2.13	1.50	0.05			
Rusk	No differences								

[1] inconsistent – no pattern in direction of change over time/level of Fe
deterioration – the mean sensory value declines over time/level of Fe
interaction – time and level are interacting

flours and the control flour. Furthermore, surface dehydration of the dough caused difficulties in extrusion, resulting in a thicker string than the control.

A comparison of the cooked characteristics of string hoppers showed that hoppers made with ferrous fumarate and ferrous sulphate were pale yellow and dull in colour compared with the white shiny surface of those made from the other flours.

The elasticity of the strings of NaFeEDTA flour was less than for the other flours, which again indicated surface drying of the final product.

After two months of storage, string hoppers made from flour containing NaFeEDTA, ferrous fumarate, and ferrous sulphate could be used only within one hour of preparation. The product was dehydrated in all three cases, resulting in an inelastic dough. The strings became thicker on steaming. There was also a change in colour (yellowish brown) in ferrous fumarate and ferrous sulphate containing hoppers, which increased in intensity with storage compared with the control.

(c) Bread

The behaviour of all the doughs was similar except for that made using NaFeEDTA. In this case, the surface of bread dough ruptured during proofing with NaFeEDTA flour at levels of 66 ppm and 88 ppm, but not 44 ppm. The water absorption of the flours, determined by a Farinograph, also showed that water absorption in the dough made with NaFeEDTA flour (57.8%) was higher than for the other flours (57%-57.3%).

The crust of bread made from ferrous sulphate flour darkened rapidly in the oven. A comparison of the baked breads showed that shell tops formed with the NaFeEDTA flour, which ruptured in bread made with 66 ppm and 88 ppm NaFeEDTA. However, the texture of the crumb was finer and more silky white than in the other breads.

The properties of bread changed with increasing time of flour storage. This was most evident with the NaFeEDTA, ferrous fumarate, and ferrous sulphate flours. The colour of bread was yellowish compared with the control, while the crumb texture was hard and lumpy. The loaf volume of breads decreased with storage time for all flours except that made using NaFeEDTA flour, which produced a fuller loaf compared with all the other breads.

Irrespective of the iron concentration and storage time, bread made from flour fortified with ferrous sulphate was unacceptable because it was discoloured and/or was rancid. The same observations have been found for infant cereals, under similar storage conditions, even though the iron content was considerably higher at 475 mg/kg. 'Off flavours' have also been reported for processed maize cereals containing 88 to 440 mg ferrous sulphate/kg when stored at elevated temperatures (4).

(d) Rusks

There was an uneven colouring of the crust with white specks after baking using NaFeEDTA flour. The white, blister-like, spots on the surface of the rusk crumb made with NaFeEDTA flour resulted in a lighter colour product compared with the rusks made from the control flour. The symmetry of the NaFeEDTA rusk was larger than others.

The crust rusks made from flour containing ferrous sulphate darkened rapidly in the oven resulting in a cooked product that had a dark, golden brown colour compared with the control.

A change in product characteristics of rusks was most evident in those made from NaFeEDTA flour, in which white specks were found in the crust, causing an uneven colour that increased with flour stored over time. The texture of all rusks, including the control, became harder with flour stored over time and increasing levels of NaFeEDTA, ferrous fumarate, and ferrous sulphate.

Sensory evaluation

The ANOVA results for the sensory evaluation trials that are statistically significant are presented in Tables 5 through 9. A mean sensory score of zero indicates that there is no difference in the characteristic of the sample made with fortified flour compared with the fortified control. A positive score indicates that the characteristic of the food made with fortified flour was more favourable compared with that in the unfortified control food. None of the foods prepared with 88 ppm of any of the iron compounds were acceptable. They were therefore excluded from the analyses.

(a) Electrolytic iron fortified flour

The taste and acceptability of roti made with electrolytic iron flour remained positive over the time that the flour was stored (Table 5). Nevertheless, compared with the control roti, both of these characteristics declined over storage time although there was no consistency in the direction of change.

All the sensory characteristics of string hoppers declined with storage time and, by the second month, all were slightly unacceptable compared with the control.

Compared with the control bread, the sensory characteristics of bread also deteriorated with increasing flour storage time. Despite this decline, the mean sensory values of electrolytic iron bread remained positive at two months, indicating that it still compared favourably with the control bread. However, there was a significant interaction between the colour of bread, time, and level of fortification.

There were no significant differences in the sensory qualities of rusk using electrolytic iron flour.

These results suggests that flour fortified with electrolytic iron should be used within two months.

(b) Reduced iron fortified flour

The colour of roti deteriorated with the increasing level of fortificant, although it still remained positive compared with the unfortified roti (Table 6).

All four sensory qualities of string hoppers deteriorated with increasing time of flour storage and by month two, the qualities were similar or slightly worse than those in the control roti.

The pattern of sensory quality change for bread was more complicated. Colour, taste, and acceptability deteriorated with increasing flour storage time. There was, however, interaction between colour, flour storage time, and level of fortification. The pattern for odour was inconsistent. Despite the decline in the sensory characteristics, the mean sensory values after two months of storage were only slightly lower than that for control bread.

There were no significant differences in the sensory qualities of rusk using reduced iron flour.

These results suggest that flour fortified with reduced iron should be used within two months.

(c) NaFeEDTA fortified flour

The taste of roti deteriorated with flour storage time, although it still remained positive compared with the unfortified roti (Table 7).

String hoppers made with NaFeEDTA did retain their sensory qualities, compared with those made from unfortified flour. All four characteristics declined with increasing flour storage time and colour, taste, and acceptability were affected by the level of fortification with 66 ppm, being less favourable than string hoppers made from unfortified flour. Furthermore, there was an interaction between acceptability, flour storage time, and level of fortification.

The change in the sensory characteristics of bread made using NaFeEDTA flour were complex. Colour and taste deteriorated with increasing flour storage time, but there was an inconsistent pattern for odour and acceptability of bread. Colour, taste, and acceptability interacted with both flour storage time and level of fortification.

The acceptability of rusks deteriorated with increasing level of fortificant, although the 66 ppm rusk compared favourably with the unfortified rusk.

These results suggest that flour fortified with NaFeEDTA does not store very well and should probably be used within one month of production. Clearly, the concentration of NaFeEDTA was important in determining the sensory qualities of the foods.

(d) Ferrous fumarate fortified flour

The taste of roti deteriorated with increasing concentration of fortificant, although it was still comparable with unfortified roti (Table 8).

String hoppers made with ferrous fumarate developed an unpalatable taste and odour with increasing flour storage time. The acceptability of hoppers made with 66 ppm ferrous fumarate was less than that for those made from unfortified flour.

All the sensory qualities of bread made with ferrous fumarate declined with

Table 6

Summary of significant changes in sensory attributes of wheat-based foods fortified with reduced iron

Product	Sensory attribute	Change	Response[1]	Mean sensory value Flour storage time 0mo	1mo	2mo	Mean sensory value Level (ppm) 44	66	88
Roti	Colour	Level	Deteriorates				1.92	0.97	NT
S. Hoppers	Colour	Time	Deteriorates	1.92	1.33	0.04			
	Taste	Time	Deteriorates	1.96	1.58	-0.17			
	Odour	Time	Deteriorates	2.13	1.50	-0.42			
	Accept.	Time	Deteriorates	2.67	2.21	-0.08			
Bread	Colour	Time	Deteriorates	1.88	1.42	0.00			
	Colour	Time x Level	Interacts						
	Taste	Time	Deteriorates	2.08	1.54	-0.17			
	Odour	Time	Deteriorates	1.79	2.04	-0.13			
	Accept.	Time	Deteriorates	3.00	2.79	-0.43			
Rusk	No differences								

[1] inconsistent – no pattern in direction of change over time/level of Fe
deterioration – the mean sensory value declines over time/level of Fe
interaction – time and level are interacting
NT – flour at 88 ppm exlcuded in sensory analyses as product was totally unacceptable

increasing flour storage time. Both taste and acceptability interacted with flour storage time and level of fortification.

There was an interaction between acceptability, flour storage time, and level of fortification for rusks.

The above results suggest the concentration of ferrous fumarate and time that flour was stored are important factors determining the sensory characteristics of flour.

(e) Ferrous sulphate fortified flour

The colour of roti made with ferrous sulphate changed with increasing flour storage time although there were inconsistent results (Table 9).

Both the level of fortificant and time that flour was stored caused a deterioration in the colour, taste, odour, and acceptability of string hoppers. Taste and acceptability both interacted with storage time of flour and concentration of ferrous sulphate.

The acceptability of both bread and rusks changed with flour storage time, but the direction of change was not consistent.

The results suggest that ferrous sulphate affects the sensory characteristics of flour in many ways.

Summary and Conclusions

The sensory evaluation results showed that string hoppers followed by bread present the greatest challenge in identifying an appropriate iron fortificant. Clearly, the steaming of wheat flour prior to making the dough and the subsequent steaming of the hoppers is fairly stressful to the flour and results in a number of chemical reactions. Because roti is made with coconut, it is quite likely that the strong taste and odour of coconut masks any small changes in these sensory properties in fortified flour. Rusks are dry toasted buns, thus any changes in colour and texture are less likely to be noted.

It was quite clear during the sensory evaluation trial that the quality of all flours, including the control, deteriorated with time. Indeed, by the third month, none of the products made from any of the flours were edible, and thus no data are available. The ambient flour storage conditions in Sri Lanka are harsh, with high temperatures and humidity. Flour storage under such conditions requires that consumption be relatively rapid. Indeed, the normal distribution system is such that flour reaches shops within six weeks and is consumed within three months of being milled. The sensory evaluation data suggest that flours fortified with NaFeEDTA and ferrous fumarate became less acceptable sooner than the other flours. Unsatisfactory results from the ferrous sulphate flour were anticipated. This compound was included as a positive control.

Flours fortified with electrolytic iron and reduced iron showed fewer sensory changes than the other flours. Most of the changes were related to flour storage time rather than the level of fortification. The sensory properties of foods

Table 7

Summary of significant changes in sensory attributes of wheat-based foods fortified with NaFeEDTA

Product	Sensory attribute	Change	Response[1]	Mean sensory value Flour storage time 0mo	1mo	2mo	Mean sensory value Level (ppm) 44	66	88
Roti	Taste	Time	Deteriorates	1.08	-0.54	-0.42			
S. Hoppers	Colour	Time	Deteriorates	1.17	0.50	-0.33			
	Colour	Level	Deteriorates				1.31	-0.42	NT
	Taste	Time	Deteriorates	1.33	0.92	0.63			
	Taste	Level	Deteriorates				1.14	-0.06	NT
	Odour	Time	Deteriorates	1.04	0.83	-0.17			
	Accept.	Time	Deteriorates	0.88	0.00	-0.50			
	Accept.	Level	Deteriorates				0.75	-0.50	NT
	Accept.	Time x Level	Interacts						
Bread	Colour	Time	Deteriorates	1.83	0.88	-0.17			
	Colour	Time x Level	Interacts						
	Taste	Time	Deteriorates	1.13	1.00	-0.29			
	Taste	Time x Level	Interacts						
	Odour	Time	Inconsistent	-0.04	1.21	-0.42			
	Accept.	Time	Deteriorates	0.42	0.83	-0.52			
	Accept.	Time x Level	Interacts						
Rusk	Accept.	Level	Deteriorates				1.36	0.25	NT

[1] inconsistent – no pattern in direction of change over time/level of Fe
deterioration – the mean sensory value declines over time/level of Fe
interaction – time and level are interacting
NT – flour at 88 ppm excluded in sensory analyses as product totally unacceptable

Table 8

Summary of significant changes in sensory attributes of wheat-based foods fortified with ferrous fumarate

Product	Sensory attribute	Change	Response[1]	Mean sensory value Flour storage time 0mo	1mo	2mo	Mean sensory value Level (ppm) 44	66	88
Roti	Taste	Level	Deteriorates				1.47	0.14	NT
S. Hoppers	Taste	Time	Deteriorates	1.67	0.50	-0.21			
	Odour	Time	Deteriorates	1.67	0.63	-0.25			
	Accept.	Level	Deteriorates				0.83	-0.36	NT
Bread	Colour	Time	Deteriorates	1.33	0.79	0.04			
	Taste	Time	Deteriorates	1.21	0.83	-0.42			
	Taste	Time x Level	Deteriorates						
	Odour	Time	Inconsistent	0.21	1.58	-0.42			
	Accept.	Time	Deteriorates	-0.38	1.08	-0.78			
	Acept.	Time x Level	Interacts						
Rusk	Accept.	Time x Level	Interaction						

[1] inconsistent – no pattern in direction of change over time/level of Fe
deterioration – the mean sensory value declines over time/level of Fe
interaction – time and level are interacting
NT – flour at 88 ppm exlcuded in sensory analyses as product totally unacceptable

Table 9

Summary of significant changes in sensory attributes of wheat-based foods fortified with ferrous sulphate

Product	Sensory attribute	Change	Response[1]	Mean sensory value Flour storage time 0mo	1mo	2mo	Mean sensory value Level (ppm) 44	66	88
Roti	Colour	Time	Inconsistent	1.04	2.13	0.75			
S. Hoppers	Colour	Time	Deteriorates	1.13	1.13	0.04			
	Colour	Level	Deteriorates				1.31	0.22	NT
	Taste	Time	Deteriorates	1.63	0.75	-0.54			
	Taste	Time x Level	Interacts						
	Odour	Time	Deteriorates	1.13	0.17	0.00			
	Odour	Level	Deteriorates				0.89	-0.13	NT
	Accept.	Level	Deteriorates				0.86	-0.25	NT
	Accept.	Level x Time	Interacts						
Bread	Accept.	Time	Inconsistent	-0.25	1.00	0.86			
Rusk	Accept.	Time	Inconsistent	0.13	-0.13	1.38			

[1] inconsistent – no pattern in direction of change over time/level of Fe
deterioration – the mean sensory value declines over time/level of Fe
interaction – time and level are interacting
NT – flour at 88 ppm excluded in sensory analyses as product totally unacceptable

Table 10

Summary of acceptability of fortified with iron

	Bread	Roti	S. Hoppers	Rusks
Electrolytic iron	+	+	?	+
Reduced iron	+	+	?	+
NaFeEDTA	–	?	–	–
Ferrous fumarate	–	?	–	?
Ferrous sulphate	–	–	–	–

\+ acceptable
– unacceptable
? between acceptable and unacceptable

made from flour fortified with NaFeEDTA, ferrous fumarate, and ferrous sulphate were affected by both flour storage time and level of fortification. Furthermore, there were more interactions between flour storage time and level of fortification when using the latter three iron compounds.

Table 10 summarises the results of the sensory evaluation trials (odour, colour, flavour, and acceptability) of the foods made from flour immediately after fortification and after one and two months of storage using the different iron compounds at 44 mg/kg and 66 mg/kg. The conclusions of the product evaluation trails are that both electrolytic iron and reduced iron are acceptable and that fortification with an iron concentration of 44 mg/kg and 66 mg/kg is viable. It is recommended that both iron compounds be tested at 66 mg/kg in the efficacy trial. The purpose of testing more than one compound is that there is only one source of electrolytic iron and the government should not be beholden to one company. The rationale for testing at only one level is that a planned bioavailability study in a small number of human subjects will discern the relative effectiveness of iron bioavailability at different concentrations.

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