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FORTIFICATION OF FLOUR WITH IRON IN COUNTRIES OF THE EASTERN MEDITERRANEAN ,MIDDLE EAST AND NORTH AFRICA

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5. Food fortification

5. 1 Introduction

Recognizing that food fortification is a cost-effective strategy for addressing micronutrient deficiencies, fortification of flour with iron is recommended as the primary strategy for most countries in the Region for reducing iron deficiency anaemia. Fortification is just one of four strategies, however, and must be used in conjunction with the others, supplementation, dietary diversification and public health measures such as promoting breast-feeding and controlling parasitic infestations.

In addition to the general fortification criteria, with iron fortification the following specific considerations must be taken into account:

- The vehicle should be a component of all meals because absorption varies inversely with the iron content of the meal.
- Food vehicles that are dark in colour or have a strong taste or odour permit the use of more reactive iron compounds.
- It should be ensured that iron does not separate out during mixing or storage.
- Ideally the vehicle should not require prolonged storage particularly under hot and humid climatic conditions since this could cause organoleptic problems.

5.2 Choosing the food vehicle(s): wheat flour as the vehicle of choice in the Region

Common food vehicles used around the world for iron fortification include processed cereals (such as wheat and corn), salt, sugar, condiments and other processed foods. Wheat flour represents perhaps the most appropriate vehicle for fortification in the Region because it meets the classical considerations for food vehicle choice. In this Region, wheat flour is:

- widely consumed in the form of bread and is affordable to groups vulnerable to iron deficiency anaemia;
- generally processed in a few large mills in most countries, with a few exceptions where there are numerous small flour producers;

? distributed through widespread networks that reach all regions of any given country;

? not subject to colour, taste or appearance change when fortified with the appropriate fortificant;

? not subject to nutrient loss on further processing into bread or cooking;

? consumed in fairly constant amounts so that fortification levels can be calculated accurately (250—280 g per day, 800/a white flour and 20% brown flour).

In its natural state, wheat is a good source of vitamin Bi (thiamin), vitamin B2 (riboflavin), niacin, vitamin B6 (pyridoxine), vitamin E, as well as iron and zinc. However, since most of these nutrients are concentrated in the outer layers of the wheat grain, a significant proportion is lost during the milling process. The lower the extraction rate of the flour (i.e. the more the refining), the greater the loss of vitamins and minerals.

In industrialized countries, wheat flour is generally fortified with vitamin Bi, vitamin B2, niacin and iron. In some countries, calcium and folate are also added. Vitamin A and vitamin D can also be added to flour.

The technology of flour fortification is simple. A premix of the micronutrients to be added is prepared or procured. The premix is then added to the flour at a uniform rate through a volumetric screw feeder located towards the end of the milling process. The premix can be fed directly on to the flour by gravity or by air convection using a pneumatic system.

5.3 Choosing the fortificant: ferrous sulfate/elemental iron as the fortificants of choice in the Region

Numerous fortificants are available for iron fortification. The biggest challenge is to identify a form of iron that is adequately absorbed, i.e. bioavailable, vet stable and does not alter the appearance or taste of the food vehicle. The two principal groups of iron fortificant compounds are the haem iron compounds and non-haem compounds. Haem iron is not affected by inhibitory compounds in vegetable foods and, thus, is bloavailable; however, it causes colour and taste changes. As a result, it is not a suitable fortificant for many products, including flour.

The non-haem sources that have had widespread use in fortification include iron-EDTA, ferrous sulfate, elemental iron (reduced iron), ferric orthophosphate, ferrous fumarate, sodium ferric pyrophosphate and other compounds. Each has various advantages and disadvantages. Ferric orthophosphate is the most stable iron form but it is largely unavailable. Ferrous fumarate is also very stable but it affects the colour of flour and as a result is suitable for use only in maize flour. Ferric phosphate enhances iron absorption but it is both costly and unstable. Thus, the most practical options for the Region are iron-EDTA, ferrous sulfate and elemental iron.

Sodium iron EDTA (NaFeEDTA) is the only non-haem source that has good bioavailabilitv as it is relatively independent of meal composition and withstands the inhibitory effects of phytates. It has been given provisional approval as safe when used in supervised fortification programmes in iron deficient populations by the Joint FAG/WHO Expert Committee on Food Additives (JECFA). However, NaFeEDTA is not widely produced, is very expensive and thus has limited application.

Ferrous sulfate has excellent bioavailability, and relative biological value (RBV) is 1000/a, but it is unstable. Nonetheless, it is the fortificant of choice when used in baked goods because of the relatively short storage time associated with these products, eliminating the concern about

instability. However, the level of ferrous sulfate should be below 40 ppm and storage time should not exceed 3 months or be at a temperature above 30 CC. Ferrous sulfate is not recommended for flour intended for household use if this is stored for a long time.

Elemental iron is only half as bioavailable as ferrous sulfate and. On the other hand, it is more stable and half as expensive as ferrous sulfate. If elemental iron is used as the fortificant, higher levels (two or three times more) than those required for ferrous sulfate will be needed to compensate for the lower iron level and lower bioavailabilitv. This makes the cost of fortification with elemental iron, in the end, more expensive than with ferrous sulfate.

Although ferrous sulfate is probably the fortificant of choice in the Region providing proper usage, elemental iron is a viable alternative, especially where the flour will have a relatively long shelf-life. Table 5.1 shows a comparison of ferrous sulfate and elemental iron as fortificants.

Table 5.1 Comparison of ferrous sulfate and elemental iron as fortificants in flour

Ferrous sulfate	**Iron**
?? Light tan colour, no colour effect if ph <6	?? Unstable: use only in flour with < 1 month shelf-life
?? Non-magnetic	?? Elemental iron
?? Excellent bioavailability, RBV: 1 00%	?? Black colour, will darken flour slightly
?? 32% iron	?? Magnetic
?? Need desiccated form	?? Fair bioavailability, RBV: 40%-60%
?? Higher cost: two times that of elemental	?? 97% iron
	?? Need 325 mesh particle size
	?? Lower cost (but two to three times
	?? more needed than ferrous sulfate)
	?? Excellent stability in flour
??	

Notes

1. 30 ppm iron = 30 ppm elemental iron = 90 ppm ferrous sulfate (not accounting for bioavailability)
2. There is no difference chemically between the iron naturally occurring in bread and iron in the form of ferrous sulfate or elemental iron

5.4 Fortification of flour: biotechnical issues

Understanding technical and scientific issues will help with such decisions as choosing the appropriate food vehicle and fortificant, fortification levels and similar critical matters.

Bioavailability is affected by particle size where elemental iron is used as a fortificant.

Iron-absorption inhibitors include tanins (contained in tea and coffee), when taken within approximately 20 minutes of iron-rich food, phytates (contained in the fiber of high extraction flour itself) and soya. Infection in the individual or population and high iron stores in the individual or population (typically in men) can also depress iron absorption. While inhibitor issues need to be addressed, it is important to recognize the role the~ play on the other side of the equation: in populations with high iron stores, there is little danger of iron overload from consuming fortified flour since iron absorption in healthy populations with high stores will be only about —2%, depending on food composition.

Iron absorption enhancers include ascorbic acid (vitamin C), meat, yeast fermentation (which counterbalances the effects of the phytates)', EDTA and low iron stores. Although vitamin C doubles the amount of iron absorbed, and is usually added as an improver during the baking process, unfortunately, baking destroys it. However, people can be encouraged through LEC (information, education and communication) campaigns to eat fruit with their bread to enhance iron absorption. Consuming 70—100 mg of vitamin C can triple or quadruple iron absorption rates.

Stability of the iron added to flour is affected by both fortificant type and flour type. Instability in this case does not mean that iron levels will diminish; rather, oxidation of the iron causes fats contained in the flour to go rancid. Factors influencing rancidity include: 1) type of flour, 2) level of iron, *3)* temperature during storage, 4) fat content of the flour and 5) moisture level of the flour. The higher the iron level (e.g. above 30 ppm) and temperature (e.g. above 30 ZC), the sooner rancidity of the flour will occur. Also, since wheat germ has high levels of fat, flour with high levels of wheat germ (e.g. atta flour) will go rancid sooner when unstable iron compounds are used for fortification. In Bahrain, the turnover of flour is around 4 weeks, in Kuwait, about 2 weeks, in Lebanon, about 2 weeks. Therefore, turnover is not a problem for most countries in the Region.

'It is not realistic to think that bakers will be willing to increase fermentation time as this will reduce tum over and thus profits.

5.5 Determining iron fortification levels

5.5. 1 General principles

Numerous factors influence the recommended level of fortification. The amounts to be used should be decided by the appropriate nutrition authorities, based on sound nutritional surveys. In considering the level of fortification, the main determinants are:

? the recommended dietary intake (RDI) of the micronutrient

? prevalence of the deficiency

? per capita consumption of the food vehicle to be fortified

? extent of processing, transit, storage and food preparation losses of the micronutrient, if any

? current dietary habits of the population

? other dietary ingredients affecting absorption and bioavailability (including ingredients in the flour itself).

5.5.2 Extraction rates of flour

The rate of extraction will affect the level of iron that should be added during fortification. In milling wheat, the skin of the wheat is extracted (scratched off). The skin is the part of the grain that contains the vitamins and iron. Thus, the rate of extraction (the amount of flour recovered from the grain) will determine how much iron is left in the flour at the end of the milling process. The amount of iron left in the flour, in turn, will affect the amount of iron to add to flour during the fortification process.

The lower the rate of extraction, the lower the amount of iron (and vitamins) left. Extraction rates in the Region vary greatly, between 7005 and 98%. Low extraction (white) flour has an extraction rate in the range 70%—78%. Flours with extraction rates above 82% are termed high extraction flours. Whole wheat flour (or atta flour) has extraction rates as high as 95%—98%. Extraction removes zinc as well as iron. Thus, fortifying wheat flour with both iron and zinc could be of interest to many countries in the Region. Flour extraction rates in various countries are presented in Table 5.2. Table 5.3 gives further details on extraction rates and the impact on nutrient value.

Table **5.2 Flour extraction rates in various countries**

Country	Rate (%)	Country	Rate (%)
Australia	76	Italy	74
Belgium	74	Iran, Islamic Republic of	70,80 and 1 00
Canada	75	Netherlands	77
China	70 and 80	New Zealand	78
Egypt	74 and 82	Pakistan	74 and 97
France	74	Russia	80
Germany	79	Switzerland	72 and 80
Greece	83	Turkey	80
Hungary	77	UK	74
India	74 and 97	USA	75

Table 5.3 Micronutrient concentrations in whole wheat flour and in flours of different extraction rates (values per 100 g)

Percentage extraction	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Pyridoxine (mg)	total folate (iig)	Vitamin E (mg)	Iron (mg)	Zinc (mg)
100	**0.46**	**0.08**	**5.6**	**0.50**	**57**	**1.0**	**4.0**	**3.0**
85	**0.30***	**0.06**	**1 .7***	**0.30**	**51**	**trace**	**2.5**	**2.4**
72	0.100*.	0.03.	0.7*	0.15	31	trace	1.5	0.9
40	**0.100.***	**0.02**	**0.7***	**010**	**10**	**trace**	**1.5**	**0.7**

Source Paul AA., Southgate DAT *McCance & Widdowson's The Composition* of F*oods.* 4th edition and supplements. London, Her Majesty's Stationery Office. 1 980
* Before fortification

5.5.3 Levels of ferrous sulfate and elemental iron

It will be necessary to consider the type of flour being fortified and the characteristics of the fortificant used in setting fortificant levels.

Absorption of iron from bread is l%—2%. At the beginning of the milling process, flour contains 30—40 ppm iron. As the flour is extracted at higher degrees to make white flour, approximately two-thirds of the iron is lost. Even at high extraction rates with atta flour, approximately 500/o of the iron is lost. In fortifying the flour, the goal is to restore the levels lost through milling and to compensate where there is low bioavailability.

The typical levels of ferrous sulfate (as iron) used for fortification are 25 ppm to 35 ppm in flour', 1000 mg/kg in salt, 1.3% in sugar, and 1—2 mg/ 100 Cal edible portion in infant cereal.

5.6 Iron fortification costs

In calculating the cost of iron fortification, it is necessary to consider the costs not only of production, marketing and distribution of the fortified product, but also costs related to programme management.

With regard to production of fortified flour, mills in the Region are very modern and equipment tends to be "state of the art". The only additional piece of equipment likely to be needed for fortification during milling is a mixer (feeder), which is relatively inexpensive (about USS 5000), including shipping and delivery costs. Some companies that sell fortificants will even provide free mixers to mills that purchase their prernixes. Since typical packaging currently used by millers and bakers is adequate for fortified flour, no additional packaging costs should be incurred, other than labeling to provide additional information (such as the manufacture/expiry date, fortificant type and level, and manufacturer's name). Producers must engage in routine quality assurance to be sure that the flour produced meets the standards set by the government. Additional laboratory equipment for quality assurance of fortified flour is relatively inexpensive. Materials for semi-quantitative rapid spot tests consist of three different reagents and a simple plastic or metal spatula and strip for analysis. For precise quantitative analysis, a spectrophotometer is required. Progressively, the incremental costs of fortification borne by producers could be passed on to the consumer, as is the case with iodized salt.

Programme costs include the cost of developing an information and communications strategy to inform the public and create a demand for fortified flour, regulation and enforcement, monitoring and evaluation. Regulation and enforcement costs include additional expenses for sample taking and analysis, as well as additional costs associated with inspection and enforcement. Since these mechanisms should already have been set up during the country's salt iodization programme, the incremental costs for iron fortified flour should be minimal. In any event, a country's food control system should have these mechanisms in place in order to assure

food safety and other measures of consumer and industry protection, regardless of whether the foods are fortified are not. The dosages and costs of iron fortification with and without addition of folic acid are presented in Table 5.4.

A level of 30 ppm when using ferrous sulfate and 60 ppm when using elemental iron was agreed by the participants of the workshop to be the most appropriate for the Region.

Table 5.4 Application, dosages and costs of iron fortification of flour

Property	**Reduced iron**		**Ferrous sulfate**	
Colour	Black		Light tan	
Magnetic	Yes		No	
Relative bioavailability (%)	50		1 00	
Iron content (%)	97		32	
Type of flour in which iron source can be used at this level without problems of flour shelf-life (see note 1)	All flours		Bakery flour Pasta flour/semolina White flour used within 6 weeks	
	+ folic acid		+ folic acid	
Nutrient addition levels				
Iron (ppm)	30	30	30	30
Folic acid (ppm)	0	1.5	0	1.5
Addition rate (g/t)	30	1 00	1 00	1 00
Dilution required	Yes	No	No	No
Cost (US FOB, US$/kg)	4.25	2.88	2.25	3.78’
Cost (USS/t flour)	0.1 5	0.36	0.30	0.45

Notes

1. The shelf-life figures given for flour fortified with ferrous sulfate are very conservative and could be considerably~ longer **with lower extraction rates and** lo~ storage temperatures

2. Equipment (feeder and associated equipment) will be around USS 5000 per mill unit. Costs based on firm price quotation of a feeder are US$3000 per mill unit)

3. Base iron source cost for adding iron corrected for bioavailability:
   20 ppm iron as ferrous sulfate or 40 ppm iron as reduced iron **USS** 0.20/t flour
   30 ppm iron as ferrous sulfate or 60 ppm iron as reduced iron: **USS** 030/t flour

4. ?f' indicates, ?e indicates estimated cost, t = tonne or 1 000 kg