Asian Wheat Flour Products:

Impact of flour fortification on organoleptic properties

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Flour Fortification Initiative

A Public-Private-Civic Investment in Each Nation

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Executive Summary

In 2009 the World Health Organization (WHO) and partner organizations, including industry experts, published technical guidelines on the fortification of industrially milled wheat and maize flours with iron, zinc, folic acid, vitamin B12, and vitamin A.

The Flour Fortification Initiative (FFI) is a network of partners working together to make flour fortification standard milling practice so that people worldwide get the nutrition needed to be smarter, stronger and healthier. FFI builds alliances between governments and international agencies, wheat and flour industries, and consumer and civic organizations.

FFI has convened a series of meetings and workshops in Asia to review the content and implications of the 2009 WHO recommendations, and to consider how best to apply them in the national health, industrial, and political environments.

Between August and October 2009, at the request of FFI, researchers in China, India, Indonesia, Malaysia, the Philippines, and Sri Lanka conducted a series of studies to test whether flour fortified per the WHO recommendations could be successfully used to produce foods commonly consumed in Asian countries. Participating research institutions made fortified flour as per the WHO recommendations, and they used this flour to make a range of commonly eaten Asian wheat flour products, including fifteen different kinds of noodles and breads. All of the fortification premixes included iron, folic acid, and vitamin B12, and some premixes also included vitamin A, vitamin B1, vitamin B2, and zinc, depending on country norms. Tests were run to assess impact on processing factors, sensory and physical attributes and, where feasible, retention of the nutrients.

The results of the studies are summarized in this report by food product. For each food product, the available data is presented for color, texture, nutrient retention, sensory evaluation, and (for noodles) noodle crumb and sheet structure, water absorption and cook yield.

Generally speaking, the effect of fortification on various types of **noodles** was only with regard to color: grayish specks on the dough sheet, and slightly less bright or yellow noodles, were considered minor and acceptable differences in all cases. The texture, noodle crumb and sheet structure, water absorption and cook yield, and sensory evaluations (including taste, flavor, and mouthfeel) of fortified noodles were similar to control noodles and acceptable in all cases.

Also generally speaking, the effect of fortification on **bread products** was only with regard to color: grayish-brown spots were visible in some bread products or the bread was "less bright." Again, these differences were generally reported as "not significant" and acceptable. Other aspects of breads, including texture, taste, aroma, chewiness, etc., were considered similar between fortified and control breads, and the fortified breads ranked as acceptable or highly acceptable.

The most significant constraint of these studies was the lack of comparability of the nutrient retention data. Several factors contributed to this, including variation in study design, laboratory methods and equipment across the six countries, and the wide variation that is inherent in food testing.

Despite the constraints, and based on the information presented in this summary report, it is reasonable to conclude that:

1. The **processing and organoleptic** differences between fortified and non-fortified products were minimal, and were considered acceptable in all cases.

2. There are practically no significant differences reported between **various iron compounds** in these fortified products, with regard to processing and sensory characteristics. Researchers did not conclude any differences between electrolytic iron and NaFeEDTA, ferrous sulphate, or ferrous fumarate with regard to the major parameters, and all minor differences were considered acceptable.

3. The overall **acceptability** of fortified products is equal to that of unfortified products;

4. Micronutrients appear to be **retained** throughout the food preparation process; and

5. It appears possible to fortify common Asian wheat flour products as per the 2009 WHO recommendations.

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Background

In 2009 the World Health Organization (WHO) and partner organizations, including industry experts, published technical guidelines on the fortification of industrially milled wheat and maize flours with iron, zinc, folic acid, vitamin B12, and vitamin A[1] (**Appendix 1**).


World Health Organization

Recommendations on Wheat and Maize Flour Fortification
Meeting Report: Interim Consensus Statement

The guidelines were formulated based on global evidence on minimum levels of fortification needed to achieve a public health improvement, are presented for common ranges of flour consumption, and are intended for flours milled in industrial roller mills (i.e. >20 metric tons/day milling capacity.)[2] **Table 1** summarizes the average level of nutrients that WHO now recommends considering adding to fortified wheat flour.

Table 1. Average levels of nutrients to consider adding to fortified wheat flour based on extraction, fortificant compound, and estimated *per capita* flour availability.

Nutrient	Flour Extraction Rate	Compound	Level of nutrient to be added in parts per million (ppm) by estimated average per capita wheat flour availability (g/day)[1]			
			<75[2] g/day	75-149 g/day	150-300 g/day	>300 g/day
Iron	Low	NaFeEDTA	40	40	20	15
		Ferrous Sulfate	60	60	30	20
		Ferrous Fumarate	60	60	30	20
		Electrolytic Iron	NR[3]	NR[3]	60	40
	High	NaFeEDTA	40	40	20	15
Folic Acid	Low or High	Folic Acid	5.0	2.6	1.3	1.0
Vitamin B_{12}	Low or High	Cyanocobalamin	0.04	0.02	0.01	0.008
Vitamin A	Low or High	Vitamin A Palmitate	5.9	3	1.5	1
Zinc[4]	Low	Zinc Oxide	95	55	40	30
	High	Zinc Oxide	100	100	80	70

1 These estimated levels consider only wheat flour as main fortification vehicle in a public health program. If other mass-fortification programs with other food vehicles are implemented effectively, these suggested fortification levels may need to be adjusted downwards as needed.
2 Estimated per capita consumption of <75 g/day does not allow for addition of sufficient level of fortificant to cover micronutrients needs for women of childbearing age. Fortification of additional food vehicles and other interventions should be considered.
3 NR = Not Recommended because very high levels of electrolytic iron needed could negatively affect sensory properties of fortified flour.
4 These amounts of zinc fortification assume 5 mg zinc intake and no additional phytate intake from other dietary sources.

1 WHO, FAO, UNICEF, GAIN, MI, and FFI. *Recommendations on wheat and maize flour fortification. Meeting Report: Interim Consensus Statement.* Geneva, World Health Organization, 2009 (http://www.who.int/nutrition/publications/micronutrients/wheat_maize_fort.pdf).

2 http://www.foodandnutritionbulletin.org/downloads/FNB_v31n1_suppl_web.pdf

The Flour Fortification Initiative (FFI) is a network of partners working together to make flour fortification standard milling practice so that people worldwide get the nutrition needed to be smarter, stronger and healthier. FFI builds alliances between governments and international agencies, wheat and flour industries, and consumer and civic organizations. FFI's strategy is to stimulate interaction among the partners so that together we can achieve results that none of us could achieve independently. The goal of FFI is for 80% of the world's roller miller flour to be fortified with at least iron or folic acid by 2015.

As of June 2010, sixty countries worldwide have legislation or decrees that mandate fortification of one or more types of flour with either iron or folic acid. The fortified flour produced in these countries, plus the flour that is fortified voluntarily, represents 30% of the world's wheat flour that is produced in large roller mills. In South and East Asia, two countries (Indonesia and the Philippines) currently have legislation for mandatory wheat flour fortification. Others- including India, China, Nepal, Mongolia, Bangladesh, Thailand, Vietnam, and Cambodia- have legislation for voluntary fortification. Other countries in the region are considering mandatory or voluntary fortification.

FFI has convened a series of meetings and workshops in Asia to review the content and implications of the 2009 WHO recommendations, and to consider how best to apply them in the national health, industrial, and political environments.

Between August and October 2009, researchers in China, India, Indonesia, Malaysia, the Philippines, and Sri Lanka conducted a series of studies to test whether the 2009 WHO recommendations could be successfully used to produce foods commonly consumed in Asian countries. These studies were coordinated by FFI in collaboration with national teams. Participating research institutions made fortified flour as per the WHO recommendations, and they used this flour to make a range of commonly eaten Asian wheat flour products. Tests were run to assess impact on processing factors, sensory and physical attributes and, where feasible, retention of the nutrients.

This report summarizes the results of those research studies, and discusses the implications of the 2009 WHO recommendations for selected common flour-based Asian foods.

Objectives

While there is considerable global experience in making Western foods with fortified flour, there is less experience with foods that are particular to Asia.

The overall objective of the research studies was therefore to assess whether flour fortified as per the 2009 WHO recommendations could be used to make flour-based products commonly consumed in Asia. Specifically, researchers aimed to:

1. Examine the effects of fortified flour on processing and food technology, particularly with regard to local recipes and processes for production;
2. Evaluate the sensory and physical attributes of the fortified flours and food products;
3. Evaluate the retention of nutrients in the final (cooked, ready to eat) food products.

Methodology

The FFI Secretariat coordinated and facilitated tests of Asian food products in six countries, to assess whether flour fortified as per the 2009 WHO recommendations could be used to make flour-based products commonly consumed in those countries, with no negative effect on processing and food technology, nor on sensory or physical attributes. The six countries and respective research agencies are listed in **Table 2**.

Table 2. Principal Investigators for testing of fortified flours.

Country	Principal Investigator
China	Chinese Center for Disease Control and Prevention
India	Hexagon Nutrition (P) Ltd.
Indonesia	Indofood Sukses Makmur/Bogasari Flour Mills
Malaysia	Interflour UiTM R&D and Commercialisation Center
Sri Lanka	Industrial Technology Institute
Philippines	Pilmico Foods Corporation

Researchers were asked to compare food products made with flour fortified as per the 2009 WHO recommendations, and unfortified flour (or flour fortified to current national voluntary or mandatory standards) with regard to as many of the following parameters they were able to test: colour, texture, fortificant level (before and after preparation of the food), noodle crumb and sheet structure during processing (for noodles), water absorption, cook yield, sensory evaluation, and micronutrient content, especially folic acid and vitamin A, in the finished product. **Appendix 2** summarizes the various parameters tested and methods employed.

In China, Indonesia, Malaysia, Philippines, and Sri Lanka, the fortificant premixes were produced by Muhlenchemie GmBH & Co. KG. In India, the fortificant premixes were produced by Hexagon Nutrition (P) Ltd. Both premix companies kindly donated the premix for use in this study.

Table 3. Nutrients from the tested premixes, and estimated flour consumption.

Source ,ppm	Compound	Malaysia 1	Malaysia 2	Indonesia 1	Indonesia 2	Philippines 1	Philippines 2	India 1	India 2	India 3	China 1	China 2	China 3	Sri Lanka 1	Sri Lanka 2	Sri Lanka 3
Iron	NaFeEDTA	40		40		40		20			40			20		
	Ferrous fumarate		60		60		60						70		30	
	Ferrous sulphate								30			120				
	Electrolytic iron									60						60
Folic acid	Folic acid	2.6		2.6		5		1.3			2.6			1.3		
Vitamin B12	Cyanocobalamin	0.02		0.02		0.04		0.01			0.02			0.01		
Vitamin A	Vitamin A palmitate					5.9					3.0					
Zinc	Zinc oxide	55		55							55			40		
Thiamin B1		4.2		4.2							3.0			3.0		
Riboflavin B2		6.7		4.0							3.0			3.0		
Estimated consumption of flour (g/person/day)		75-150		75-150		<75		150-300			75-150			150-300		

Table 3 compares the nutrient content (ppm) of the fortified flours attributable to the premixes, and the estimated per capita flour consumption (grams/day) in the respective countries. The nutrient content of the various premixes took into consideration the estimated flour consumption in the participating countries, the 2009 WHO recommendations, existing standards in the countries, and potential standards. All premixes included iron, folic acid, and vitamin B12, and some premixes also included vitamin A, vitamin B1, vitamin B2, and zinc. Overall, the studies aimed to test the impact of the most comprehensive premix that the country might use if the WHO recommendations were adopted.

For example, vitamin A was included in the premix tested in China and the Philippines. In China it was included because there is evidence of vitamin A deficiency in the population but no vitamin A supplementation policies. In the Philippines it was included because it is already part of the mandatory fortification standard. Ferrous fumarate and ferrous sulphate levels in the premix used in China are higher than the WHO recommendations but are in line with current voluntary standards. Zinc was not included in the premix for the Philippines and India as neither country is considering the inclusion of zinc. India and Sri Lanka tested a premix using NaFeEDTA as the source of iron, because both countries have high consumption of high extraction flour in some communities. Although the WHO recommendations do not include specifications for vitamins B1 and B2, existing standards in several of the countries include these vitamins. Hence B1 and B2 were included in the premix at levels currently used for Malaysia, India, China and Sri Lanka.

Table 4 shows which foods were tested in which countries.

Table 4. Foods tested.

Foods	Countries					
	China	India	Indonesia	Malaysia	Sri Lanka	Philippines
Wet noodles	X		X	X	X	X
Dry noodles						X
Instant noodles				X		X
Steamed bread	X		X			X
Pan/Sandwich bread			X	X	X	X
Soft rolls						X
Hard crust rolls/baguettes						X
Martabak			X			
Roti (canai)				X	X	
Chapatti		X				
Puri		X				
Pittu					X	
Godamba roti					X	
String hoppers					X	

All noodles were made with flour and water, and in some cases, salt and sodium carbonate were also added. Breads and other foods (e.g. chapatti, puri, pittu, godamba roti, and string hoppers) were made with flour, water, and other ingredients (yeast, sugar, salt, egg, oil, skim milk powder, shortening, shredded coconut, etc.) as per the local recipes.

Results

This section describes, for each food product, the impact of the fortified flour with regard to (as applicable and available): color, texture, fortificant level (before and after preparation, i.e. retention data), noodle crumb and sheet structure, water absorption, cook yield, and sensory evaluation. **Table 5** summarizes the impact of fortification on the processing and sensory characteristics of the foods. Following Table 5, each food product is discussed in detail, including the results of the retention studies.

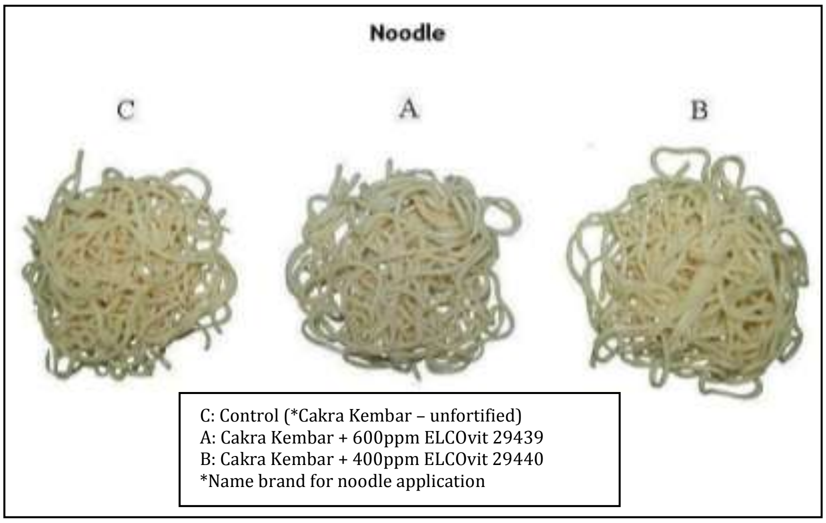
Table 5: Summary of Results.

	Foods	Impact of fortification of characteristics of foods
1	Wet Noodles	NaFeEDTA slightly darker (China, Indonesia, Philippines), but acceptable. NaFeEDTA slightly harder texture (China, Philippines), but acceptable. No other differences in processing, water absorption, cook yield, taste or aroma.
2	Instant Noodles	Fortified noodles slightly less bright, but acceptable in color (Malaysia). NaFeEDTA noodles slightly darker in color (Philippines), but acceptable. NaFeEDTA and ferrous fumarate dough sheet structure showed fine gray spots (Philippines). No unacceptable differences in texture or other sensory characteristics (overall noodle quality the same).
3	Steamed Bread	NaFeEDTA slightly darker, but acceptable, buns (China, Indonesia, and Philippines). No unacceptable differences in texture, taste, mouth feel, or aroma.
4	Pan/Sandwich Bread	Pan bread with NaFeEDTA in Indonesia, and all fortified flours in Malaysia and Sri Lanka, was slightly darker, but the change was acceptable. Dough had grayish brown spots visible (Philippines), but otherwise normal. No differences in texture, taste, and aroma; all were considered highly acceptable (Sri Lanka). No differences in moistness, softness, or grain evenness (Malaysia). Both fortified breads similar and acceptable in grain and texture (Philippines).
5	Soft Rolls	Dough normal but with grayish-brown spots (Philippines); acceptable finished product.
6	Hard Crust Baguette	Dough normal but with grayish-brown spots (Philippines); acceptable finished product.
7	Martabak	NaFeEDTA martabak was slightly darker; no differences in texture, taste, or aroma (Indonesia).
8	Roti (canai)	No differences in color, texture, taste, or overall acceptability (Malaysia and Sri Lanka).
9	Chapatti	NaFeEDTA fortified chapatti was the overall preferred (India).
10	Puri	Fortified puris were slightly darker, more dense, and absorbed less oil in cooking than control flour puri. Fortified puris were preferred in taste and chewability over the control (India).
11	Pittu	Minor differences in texture, taste, and flavor; all fortified pittu were considered acceptable (Sri Lanka).
12	Godamba roti	Fortified and non-fortified roti were well and equally accepted in terms of color, texture, flavor, taste, and overall acceptability (Sri Lanka).
13	String hoppers	Minor differences in color; all fortified string hoppers were considered acceptable (Sri Lanka).

1. *Wet noodles (China, Indonesia, Malaysia, Sri Lanka, Philippines)*

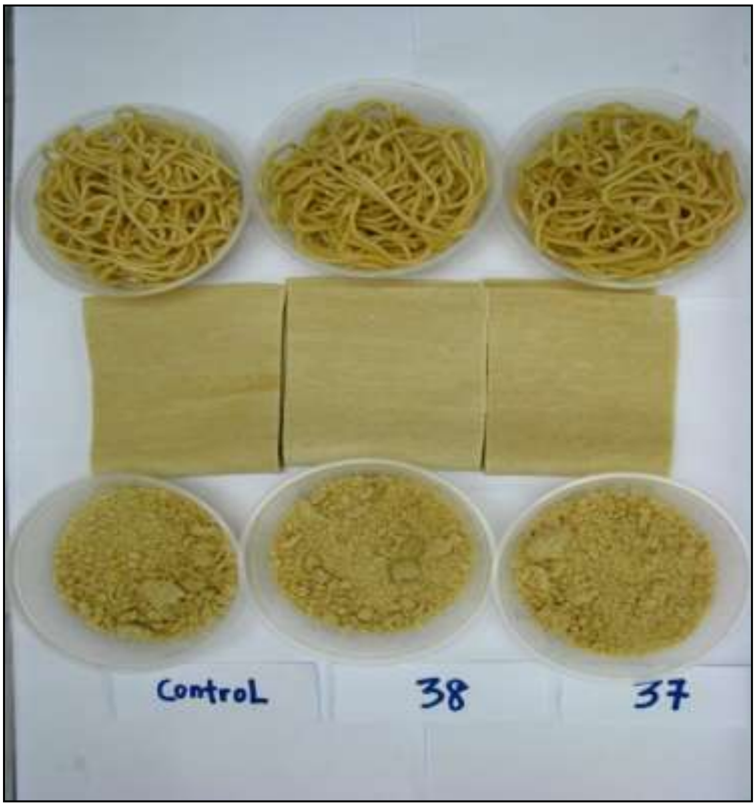
a. ***Color***. In China, flours 1 (NaFeEDTA) and 2 (ferrous sulphate) resulted in "less color compared to the control; the researchers concluded that these differences white" wet noodles whereas flour 3 (ferrous fumarate) caused a "slight yellow" were overall acceptable. In Indonesia, flour 1 (NaFeEDTA) resulted in a slightly darker color, but flour 2 (ferrous fumarate) gave a similar color to the control; both fortified flour noodles had a similar speckledness to the control; flour 2 was therefore recommended. In Sri Lanka, all three fortified flours (NaFeEDTA, ferrous fumarate, and electrolytic iron) produced noodles that had an equally good or better color than the control. In Malaysia, researchers measured the color of the dough sheets of all three flours- control, fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate)- at 0 hours (fresh), after 24 hours storage at room temperature, and after 1 minute par-boiling. No unacceptable color differences (black/white, red/green, or blue/yellow) were observed between the three dough sheets at any of the three times of measurement. In the Philippines, fine grayish-brown spots were observed on the dough sheet of noodles made with fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate); in comparing the two flours, the crumb color of flour 1 was "slightly darker in color", and flour 2 resulted in "brighter noodle strands", but both were acceptable.

Figure 1. Control and fortified wet noodles in Indonesia.



b. ***Texture***. In China, flours 1 (NaFeEDTA) and 2 (ferrous sulphate) resulted in noodles of a harder, but acceptable texture, while flour 3 (ferrous fumarate) and control noodles had a "normal" texture. In Indonesia, both fortified flours (NaFeEDTA and ferrous fumarate) resulted in a noodle texture (chewiness and hardness) which was similar to that of the noodles from control flour. In Malaysia, the texture of noodles made from the control, and fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) was similar and acceptable. Texture Analyzer scores were 1817.7, 1788.0, and 1776.5 respectively. In the Philippines, flour 1 (NaFeEDTA) resulted in a firmer noodle strand than flour 2 (ferrous fumarate). In Sri Lanka, all three fortified flours (NaFeEDTA, ferrous fumarate, and electrolytic iron) produced noodles that had an equally good or better texture than the control.

Figure 2. Control and Fortified Yellow Alkaline Noodles in Malaysia.



c. ***Retention of nutrients***. In China, researchers are currently verifying results of the initial retention studies, and this will soon be presented in **Table 6.** Indonesian researchers analyzed iron and folic acid (**Table 7**). The analysis of nutrients in the Malaysian noodles is shown in **Table 8.** In the Philippines, fresh noodles were analyzed for retention of folic acid, iron, and vitamin A, as shown in **Table 9.** Sri Lankan researchers estimated the iron content of three fortified noodles, and the losses during processing (**Table 10**).

Table 6. Nutrient content of noodles in China, Loss Rates (LR) in %.

	Expected dosage from fortificant (ppm)	Flour				Noodles (per 100g flour equivalent)							
		Control	Flour 1 NaFeEDTA 40ppm	Flour 2 ferrous sulphate 120ppm	Flour 3 ferrous fumarate 70ppm	Control	LR%	Flour 1	LR%	Flour 2	LR%	Flour 3	LR%
Vit A	**3.0 ppm**	--	2.92	2.91	2.91	--	--	1.63	44.1	1.18	59.3	1.60	45
Vit B1	**3.0 ppm**	1.15	4.54	4.58	3.86	.256	77.7	1.71	57.1	1.70	58.0	1.73	45.7
Vit B2	**3.0 ppm**	.30	2.87	3.08	2.77	.464	-54.7*	1.26	68.9	1.36	67.8	1.54	56.6
Vit B12	**0.02 ppm**	.0007	.0282	.0232	.0350	.0006	14.3	.0134	53.5	.0163	30.3	.0144	59.9
Iron	**See column headings**	18.0	51.0	99.0	68.0	9.6	46.7	40.0	7.88	80.0	13.1	56.0	7.2
Zinc	**55 ppm**	8.0	52.0	52.0	52.0	4.8	40.0	43.2	12.7	46.4	5.45	41.6	16.4

Note: *Losses are to be expected; therefore some errors in sampling, analysis and calculations may have occurred.

Table 7. Iron and folic acid content of Indonesian noodles.

	Expected dosage from fortification (ppm)	Noodles from unfortified flour (Control)	Noodles from fortified flour A (NaFeEDTA, 40ppm)	Noodles from fortified flour B (ferrous fumarate, 60ppm)
Iron (mg/kg)	See column headings	3.82	23.99	35.35
Folic Acid (mg/kg)	2.6ppm	Not detected*	0.88	Not detected

** Limit of detection was 0.06mg/kg.*

Table 8. Nutrient content of wheat flour, noodles from unfortified flour, and noodles from fortified flours 1 and 2 in Malaysia.

	Expected dosage from fortification ppm	Unfortified wheat flour	Noodles from unfortified flour (Control)	Noodles from fortified flour 1 (NaFeEDTA, 40ppm)	Noodles from fortified flour 2 (ferrous fumarate, 60ppm)
Iron (mg/kg)	See column headings	6	5	23	51
Zinc (mg/kg)	55	3	3	26	**35**
Vitamin B1 (mg/kg)	4.2	<2.5	<2.5	<2.5	<2.5
Vitamin B2 (mg/kg)	6.7	<2.5	<2.5	<2.5	<2.5
Vitamin B12 (µg/g)	0.02	0.002	0.02	0.0105	0.0130
Folic acid (µg/g)	2.6	0.185	0.134	0.279	0.287

Table 9. Nutrient content of fresh noodles in the Philippines.

	Expected dosage from fortification (ppm)	Noodles from fortified flour 1 (NaFeEDTA 40ppm)	Noodles from fortified flour 2 (ferrous fumarate 60ppm)
Folic Acid (ppm)	5.0	2.7	2.6
Iron (ppm)	See column headings	30.7	43.4
Vitamin A (ppm)	5.9	2.3	2.3

Table 10. Iron content of fortified cooked noodles in Sri Lanka.

Cooked Noodles	Expected dosage from fortification (ppm)	Iron in flour-(on dry basis) (ppm)	±SD	Iron in product (after processing) - (on dry basis) (ppm)	±SD	%Loss in added Fe[3] (on dry basis)
Control (correction factor)	n/a	7.86	0.27	8.33	0.27	n/a
Flour 1 (NaFeEDTA)	20ppm	27.37	0.30	19.39	0.33	29.15
Flour 2 (Ferrous fumarate)	30ppm	34.73	0.95	27.16	0.22	21.80
Flour 3 (Electrolytic iron)	60ppm	64.87	4.21	65.3	1.05	5.73

d. ***Noodle crumb and sheet structure***. In Indonesia, flour 1 (NaFeEDTA) and flour 2 (ferrous fumarate) had a uniform crumb that was not significantly different from that of the control. The noodle sheet color after 24 hours storage in room temperature was not significantly different between the fortified flours and the control in terms of brightness and yellowness, and noodle elasticity was also similar in all three flours. In Malaysia, the unfortified control flour and both fortified flours (NaFeEDTA and ferrous fumarate) resulted in noodles of a similar crumb, which the researchers described as slightly yellow, moderately bright, and crumbly for all three samples. The dough sheet for all three samples was described as moderately tough texture and streaky appearance. In the Philippines, fortified flour 1 (NaFeEDTA) resulted in a fine and uniform crumb structure, whereas flour 2 (ferrous fumarate) gave a slightly bigger crumb structure; both fortified flours resulted in fine grayish-brown spots on the dough sheet structure.

e. ***Water absorption***. In China, there were no significant differences between the fortified flours and the controls with respect to moisture and water absorption. Moisture was 13.8%, 13.5%, 13.6%, and 13.8% and water absorption was 60.8%. 61.7%, 61.9%, and 61.3% for the control, and flours 1 (NaFeEDTA), 2 (ferrous sulphate), and 3 (ferrous fumarate) respectively. In Indonesia, the water absorption of wet noodles per 100g for 1 minute boiling in 100ml water was 54.2% for flour 1 (NaFEDTA), and 52.4% for flour 2 (ferrous fumarate); these values were slightly (but not significantly) higher than that of the control flour (49.0%). In Malaysia, there were no significant differences in terms of water absorption (%) of noodles produced using fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) compared to the control. In the Philippines, water uptake of the noodles made with fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) was similar to that of unfortified noodles.

f. ***Cook yield***. In Indonesia, the cook yield of flour 1 (NaFeEDTA) was 154.2%, flour 2 (ferrous fumarate) was 152.4% and the control flour was 149.0% (no

[3] Sri Lankan researchers calculated % Loss during processing with the formula:%Loss in added Fe = [((Total Fe in fortified flour – Fe in control flour)- (Total Fe in fortified product – total Fe in control product)) x 100] / (Total Fe in fortified flour – Fe in control flour)

significant differences). The measurement compared the weight of 100g uncooked noodles to the weight of the same noodles after 1 minute boiling. In Malaysia, there were no significant differences in terms of cook yield of noodles produced using fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) compared to the control. In the Philippines, the cooked yield of fresh noodles was 498.55 grams and 500.5 grams for fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) respectively, a yield that is comparable to unfortified noodles.

g. ***Sensory evaluation***. In China, flours 1 (NaFeEDTA) and 2 (ferrous sulphate) resulted noodles with a more bitter, but acceptable taste, while no taste differences were detected between noodles made from flour 3 (ferrous fumarate) and the control flour. In Indonesia, noodles from flour 1 (NaFeEDTA) and flour 2 (ferrous fumarate) had the same mouthfeel compared to noodles from the control flour. In Malaysia, the sensory characteristics of noodles- including yellowness, overall surface appearance, firmness, elasticity, smoothness, overall texture, alkaline flavour, and overall quality- were judged by a 10-member trained panel to be of similar quality for the control and both fortified flours (NaFeEDTA and ferrous fumarate). In Sri Lanka, all three fortified flours (NaFeEDTA, ferrous fumarate, and electrolytic iron) produced noodles that had an equally good or better flavour and taste than the control.

2. Instant ***noodles (Malaysia, Philippines)***

a. ***Color***. In Malaysia, researchers measured the color of the dough sheets of all three flours- control, fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) - at 0 hours (fresh), and after 24 hours storage at room temperature. The color of the three (dry) instant noodle blocks was also measured. No unacceptable color differences (black/white, red/green, or blue/yellow) were observed between the three dough sheets at any of the three times of measurement. The color of the final products from all flours was acceptable, even though the fortified noodles were slightly less bright than the control noodles. In the Philippines, fine grayish-brown spots were noticed on the dough sheets made from fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate). Comparing the two fortified flours, the crumb color of flour 1 was slightly darker in color, and the final product (the cooked instant noodle from flour 1) was also darker in color.

Figure 3. Instant noodles (Control and Fortified) in Malaysia.

b. ***Texture***. In Malaysia, the texture of instant noodles made from the control, and fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) was similar and acceptable, as evaluated by both the Texture Analyzer and the sensory panel. In the Philippines, there was no significant difference in the firmness of the noodle strands from flours 1 (NaFeEDTA) and 2 (ferrous fumarate).

c. ***Retention of nutrients***. The analysis of nutrients in the instant noodles from Malaysia is shown in **Table 11**, and the nutrient analysis of instant noodles in the Philippines is shown in **Table 12**.

Table 11. Nutrient content of wheat flour, instant noodles from unfortified flour, and instant noodles from fortified flours 1 and 2 in Malaysia.

	Expected dosage from fortification ppm	**Unfortified wheat flour**	**Instant noodles from unfortified flour (Control)**	**Instant noodles from fortified flour 1 (NaFeEDTA, 40ppm)**	**Instant noodles from fortified flour 2 (ferrous fumarate, 60ppm)**
Iron (mg/kg)	See column headings	6	11	47	61
Zinc (mg/kg)	55	3	6	44	47
Vitamin B1 (mg/kg)	4.2	<2.5	<2.5	<2.5	<2.5
Vitamin B2 (mg/kg)	6.7	<2.5	<2.5	4.3	4.7
Vitamin B12 (µg/g)	0.02	0.002	0.33	0.016	0.0299
Folic acid (µg/g)	2.6	0.185	0.109	0.438	0.283

Table 12. **Nutrient content of instant noodles in the Philippines.**

	Expected dosage from fortification (ppm)	Instant noodles from fortified flour 1 (NaFeEDTA 40ppm)	Instant noodles from fortified flour 2 (ferrous fumarate 60ppm)
Folic Acid (ppm)	5.0	3.6	3.4
Iron (ppm)	See column headings	67.4*	82.7*
Vitamin A (ppm)	5.9	4.1	4.1

d. ***Noodle crumb and sheet structure***. In Malaysia, the unfortified control flour and both fortified flours (NaFeEDTA and ferrous fumarate) resulted in instant noodles of a similar crumb, which the researchers described as slightly yellow, moderately bright, and crumbly for all three samples. The dough sheet for all three samples (control, flours 1 and 2) was described as moderately tough texture and streaky appearance. In the Philippines, fortified flour 1 (NaFeEDTA) resulted in a fine and uniform crumb structure, whereas flour 2 (ferrous fumarate) gave a slightly bigger crumb structure; both fortified flours resulted in fine grayish-brown spots on the dough sheet structure.

e. ***Sensory evaluation***. In Malaysia, the sensory characteristics of the instant noodles from all three flours- including brightness, yellowness, overall surface appearance, firmness, elasticity, smoothness, overall texture, and overall quality- were judged to be of similar quality by a 10-member trained panel. In the Philippines, both fortified noodles were a similar firmness; the color of flour 1 (NaFeEDTA) noodles was slightly darker, and flour 2 (ferrous fumarate) noodle strands were brighter.

f. ***Rancidity***. Malaysian researchers conducted a separate experiment on the peroxide value (PV) of instant noodles made with 5 flours (4 fortified, 1 control, **Table 13**), stored for one year at ambient temperature. The objective was to determine the effect of fortification on shelf life as measured by PV. As a point of reference, Japanese standards call for PV ≤30 milliequivalent O_2/kg to indicate food safety and quality[4]. The results of the Malaysian experiment are **Table 14**. It should be noted that the noodles used in the rancidity experiment were not the same as the noodles used in the retention studies.

Table 13. Amount of fortificants added to achieve target.

Type of fortificant	Targeted amount	Amount added to flour (based on instructions provided by the supplier)
Electrolytic iron	4.2 mg/100g	4.33 mg/100g
Folic acid	150 ug/100g	170 ug/100g
Ferrous fumarate	4.2 mg/100g	12.78 mg/100g
Ferrous sulphate	4.2 mg/100g	13.13 mg/100g
Vitamin B1	0.42 mg/100g	0.53 mg/100g
Vitamin B2	0.67 mg/100g	0.71 mg/100g

Table 14. Peroxide values of fortified instant noodles after 1 year storage.

Sample	Peroxide value, mequiv O_2/kg
Control (unfortified)	28.3
Electrolytic iron + folic acid	42.1
Ferrous fumarate + folic acid	31.7
Ferrous sulphate + folic acid	35.3
Ferrous fumarate + folic acid + vitamin B1 + Vitamin B2	35.4

All samples, except for the unfortified control, exceeded the standard PV limit set for noodles in Japan (PV ≤30 mequiv O_2/kg), indicating that fortification seems to cause some rancidity after

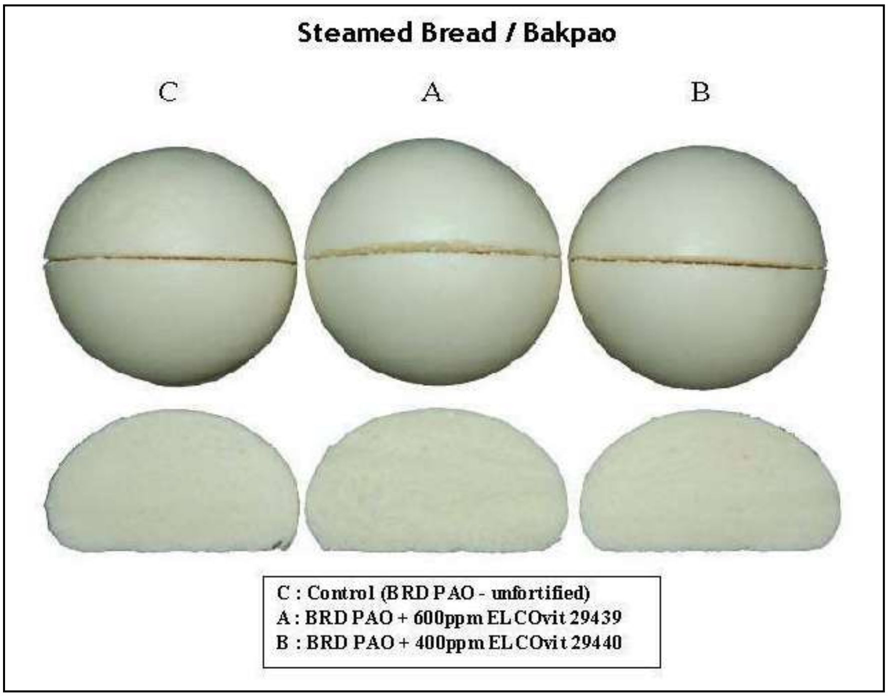
[4] Gatoh N and S Wada (2006). The importance of peroxide value in assessing food quality and food safety. J American Oil Chemists' Society. 83:473-474.

one year of storage. The PV of the noodles fortified with ferrous fumarate and folic acid was the lowest compared to other fortified samples. The PV was highest in the sample fortified with electrolytic iron plus folic acid. These results suggest that wheat flour products with a long shelf life are better fortified with ferrous fumarate, followed by ferrous sulphate and then electrolytic iron. These results are considered indicative, with no replicates

3. Steamed bread ***(China, Indonesia, Philippines)***

a. ***Color***. In China, the color of the steamed bread was "lightly affected" by fortification, but the changes were within the acceptable range. In Indonesia, the color of buns from flour 1 (NaFeEDTA) was slightly darker than the control, while buns from flour 2 (ferrous fumarate) were slightly brighter than the control buns. In the Philippines, the dough from fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) appeared normal, but grayish brown spots were visible. When the buns were steamed, flour 1 buns had a darker crust color and flour 2 buns had a brighter crust color.

Figure 4. Control and Fortified Steamed Bread in Indonesia.



b. ***Texture***. In China, steamed buns from all four flours - fortified flours 1 (NaFeEDTA), 2 (ferrous sulphate), and 3 (ferrous fumarate), and the control flour- were equally smooth in appearance. In Indonesia, the texture of steamed buns from fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) was similar to that of the buns from the control flour. In the Philippines, steamed buns from fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) scored "4" (on a 5 point scale) with regard to grain and texture.

c. ***Retention of nutrients***. In China, researchers are currently verifying results of the initial retention studies, and this will soon be presented in **Table 15**. The analysis from Indonesia is **Table 16**, and the analysis from the Philippines is shown in **Table 17.**

Table 15. Nutrient content of steamed bread in China, Loss Rates (LR) in %.

	Expected dosage from fortificant (ppm)	Flour				Steamed bread (per 100g flour equivalent)							
		Control	Flour 1 NaFeEDTA 40ppm	Flour 2 ferrous sulphate 120ppm	Flour 3 ferrous fumarate 70ppm	Control	LR%	Flour 1	LR%	Flour 2	LR%	Flour 3	LR%
Vit A	**3.0 ppm**	--	2.92	2.91	2.91	--	--	2.69	7.95	2.52	13.4	2.27	22.1
Vit B1	**3.0 ppm**	1.15	4.54	4.58	3.86	.912	20.7	3.43	25.7	3.66	19.9	3.40	8.34
Vit B2	**3.0 ppm**	.300	2.87	3.08	2.77	.660	-120.0*	2.98	9.88	3.07	13.2	2.46	27.1
Vit B12	**0.02 ppm**	.0007	.0282	.0232	.0350	.0007	0	.0283	-0.4*	.0228	1.87	.0230	34.9
Iron	**See column headings**	18.0	51.0	99.0	68.0	15.6	13.3	46.8	5.45	96.0	0.74	64.8	1.60
Zinc	**55 ppm**	8.0	52.0	52.0	52.0	7.2	10.0	55.2	-6.2*	52.8	-1.5*	49.2	4.55

Note: *Losses are to be expected; therefore some errors in sampling, analysis and calculations may have occurred.

Table 16. Iron and folic acid content of Indonesian steamed bread.

	Expected dosage from fortification (ppm)	**Steamed bread from unfortified flour (Control)**	**Steamed bread from fortified flour A (NaFeEDTA, 40ppm)**	**Steamed bread from fortified flour B (ferrous fumarate, 60ppm**
Iron (mg/kg)	See column headings	1.11	22.91	24.64
Folic acid (mg/kg)	2.6ppm	Not detected*	0.75	Not detected

** Limit of detection was 0.06mg/kg.*

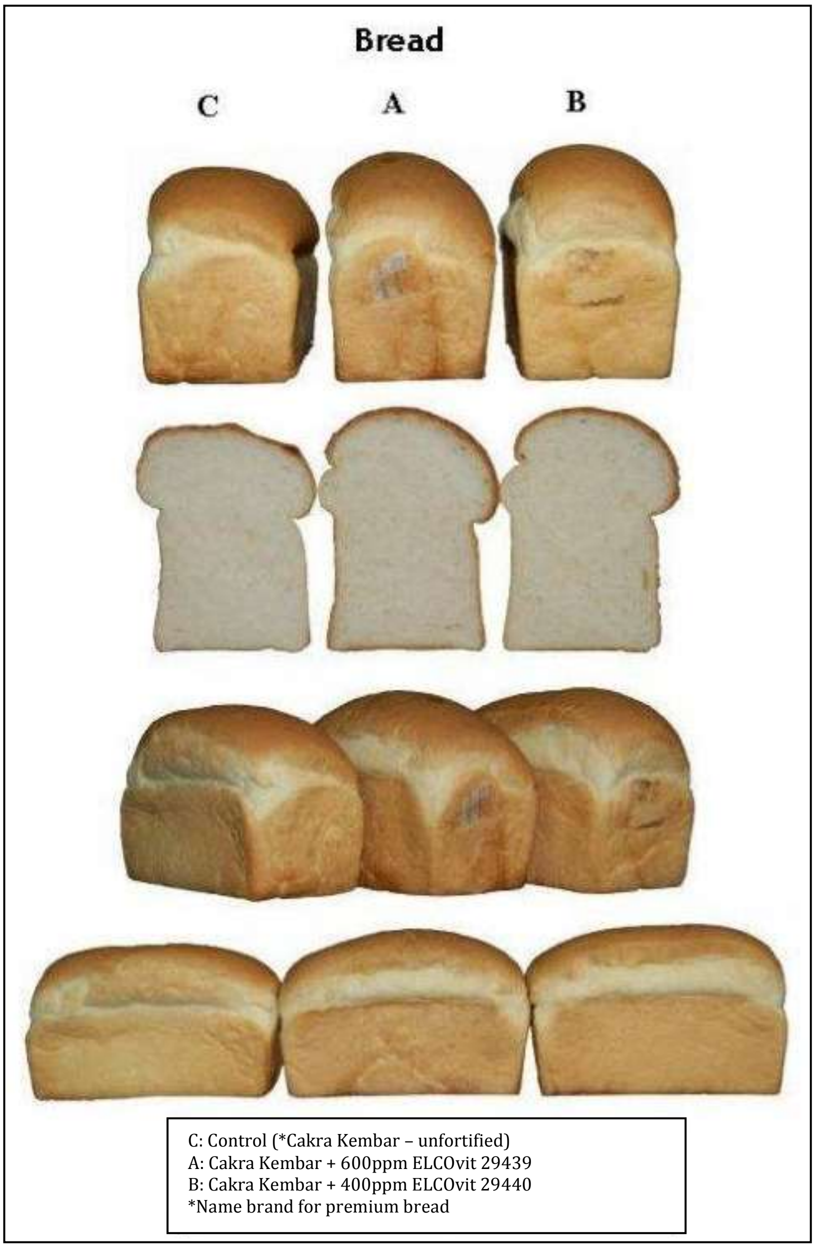
Table 17. Nutrient content of steamed bread in the Philippines.

	Expected dosage from fortification (ppm)	Steamed bread from fortified flour 1 (NaFeEDTA 40ppm)	Steamed bread from fortified flour 2 (ferrous fumarate 60ppm)
Folic Acid (ppm)	5.0	3.3	3.0
Iron (ppm)	See column headings	39.1	50.4
Vitamin A (ppm)	5.9	3.3	3.1

d. ***Sensory evaluation***. In China, researchers report that steamed buns from fortified flours had a better structure than buns from the control flour. The buns from all four flours- fortified flours 1 (NaFeEDTA), 2 (ferrous sulphate), and 3 (ferrous fumarate), and the control flour- had a mildly slimy feel in the mouth. The buns from flours 2 (ferrous sulphate) and 3 (ferrous fumarate) had an odd taste, but this difference was considered to be within the acceptable range. In Indonesia, the taste and aroma of buns from fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) was similar to that of the control buns. In the Philippines, buns from flours 1 (NaFeEDTA) and 2 (ferrous fumarate) had no unusual odor or taste; the chewiness of the flour 1 bun was "just right", and the flour 1 bun was "a little doughy".

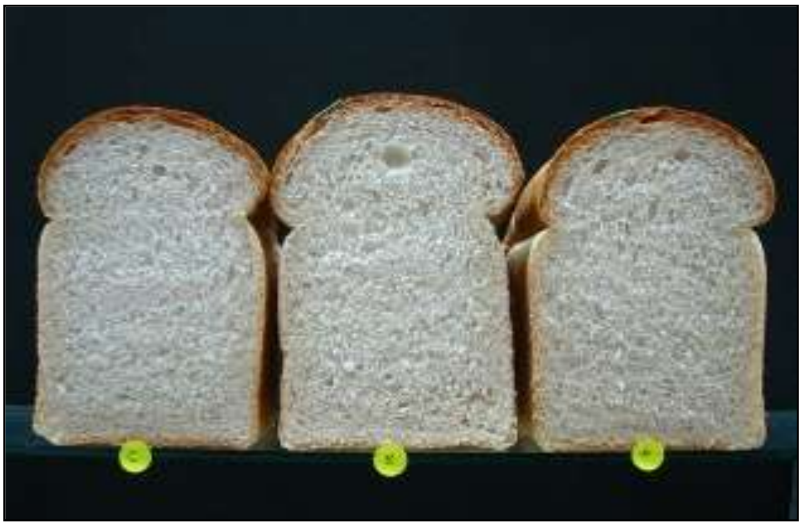
4. Pan/Sandwich bread ***(Indonesia, Malaysia, Philippines, Sri Lanka)***

Figure 5. Control and Fortified Pan Bread from Indonesia.



a. ***Color***. In Indonesia, the color of pan bread made with fortified flour 1 (NaFeEDTA) was darker than the control, while bread made with flour 2 (ferrous fumarate) was similar to the control; the differences were not significant. In Malaysia, the color of sandwich breads made from fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) were different from the control flour bread, as measured by chromameter (black/white, red/green, and yellow/blue spectra). A trained descriptive sensory panel judged the two fortified breads to be slightly "less bright" than the control bread. In the Philippines, sandwich bread dough made from fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) were normal but with grayish-brown spots visible. The bread baked with flour 1 had a slightly darker crust, but the crust color of the bread from flour 2 was just right. In Sri Lanka, the crust and crumb color of breads made from fortified flours 1 (NaFeEDTA), 2 (ferrous fumarate), and 3 (electrolytic iron) were all significantly different from the crust and crumb color of the control bread, as measured by a chromameter. However, the 12 trained panelists found all four breads to be similar and highly acceptable (rated as "like very much").

Figure 6. Control and Fortified Sandwich Bread from Malaysia.



b. Texture. In Indonesia, the texture of breads made with fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) was similar to the control. In Malaysia, sandwich breads baked with control flour and fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) measured 213.84g, 204.51g, and 237.02g (to achieve 25% compression), respectively. All three breads were judged by the sensory panel to have similar moistness, softness, and grain evenness. In Philippines, breads from both fortified flours (NaFeEDTA and ferrous fumarate) scored "4" (on a 5 point scale) with regard to grain and texture. In Sri Lanka, the texture of breads from fortified flours 1 (NaFeEDTA), 2 (ferrous fumarate), 3 (electrolytic iron), and the control flour were found to be similar and highly acceptable.

c. Retention of nutrients. **Table 18** shows the iron content of pan bread in Indonesia. **Table 19** shows the analysis of nutrients in the sandwich breads from Malaysia. The nutrient content of sandwich bread in the Philippines is shown in **Table 20**. In Sri Lanka, researchers estimated the losses of iron due to baking (**Table 21**).

Table 18. Iron and folic acid content of Indonesian pan bread.

	Expected dosage from fortification (ppm)	Pan bread from unfortified flour (Control)	Pan bread from fortified flour A (NaFeEDTA, 40ppm)	Pan bread from fortified flour B (ferrous fumarate, 60ppm)
Iron (mg/kg)	See column headings	7.03	35.87	44.98
Folic acid (mg/kg)	2.6ppm	Not detected*	Not detected	Not detected

** Limit of detection was 0.06mg/kg.*

Table 19. Nutrient content of wheat flour, unfortified sandwich bread, and fortified sandwich bread from flours 1 and 2 in Malaysia.

	Expected dosage from fortification ppm	Unfortified wheat flour	Sandwich bread from unfortified flour (Control)	Sandwich bread from fortified flour 1 (NaFeEDTA, 40ppm)	Sandwich bread from fortified flour 2 (ferrous fumarate, 60ppm)
Iron (mg/kg)	See column headings	6	9	35	44
Zinc (mg/kg)	55	3	6	36	37
Vitamin B1 (mg/kg)	4.2	<2.5	<2.5	6.5	5.0
Vitamin B2 (mg/kg)	6.7	<2.5	<2.5	5.0	5.0
Vitamin B12 (µg/g)	0.02	0.002	0.0015	0.018	0.015
Folic acid (µg/g)	2.6	0.185	0.117	0.305	0.325

Table 20. Nutrient content of sandwich bread in the Philippines.

	Expected dosage from fortification (ppm)	Sandwich bread from fortified flour 1 (NaFeEDTA 40ppm)	Sandwich bread from fortified flour 2 (ferrous fumarate 60ppm)
Folic Acid (ppm)	5.0	4.5	4.3
Iron (ppm)	See column headings	50.5	73.0
Vitamin A (ppm)	5.9	3.6	3.6

Table 21. Iron content of fortified pan bread in Sri Lanka.

Pan bread	Expected dosage from fortification (ppm)	Iron in flour-(on dry basis) (ppm)	±SD	Iron in product (after processing) - (on dry basis) (ppm)	±SD	%Loss in added Fe (on dry basis)
Control (correction factor)	n/a	14.8		3.77	0.13	n/a
Flour 1 (NaFeEDTA)	20ppm	22.52	2.44	18.70	0.30	17.00
Flour 2 (Ferrous fumarate)	30ppm	34.44	1.88	30.85	3.64	10.43
Flour 3 (Electrolytic iron)	60ppm	60.43	1.27	46.27	0.30	23.44

a. ***Sensory evaluation***. In Indonesia, the taste and aroma of breads made with fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) were similar to the taste and aroma of the control bread. In Malaysia, breads baked with control flour and fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) were judged by the sensory panel to have similar flavor and overall acceptability. In the Philippines, sandwich breads baked from both fortified flours (NaFeEDTA and ferrous fumarate) had no unusual odor or taste, and were considered acceptable overall. In Sri Lanka, the flavor and taste of breads from fortified flours 1 (NaFeEDTA), 2 (ferrous fumarate), 3 (electrolytic iron), and the control flour were found to be similar and highly acceptable.

5. Soft rolls ***(Philippines)***

a. ***Color***. The color of the dough from both fortified flours (NaFeEDTA and ferrous fumarate) was normal but with grayish-brown spots visible, and the crumb color score from both flours was ranked as "4" (on a scale of 1 to 5).

b. ***Texture***. The grain and texture of rolls from both fortified flours was ranked as "4" (on a scale of 1 to 5).

c. ***Retention of nutrients***. The analysis of nutrient content of soft rolls is shown in **Table 22**.

d. ***Sensory evaluation***. The rolls from both fortified flours had no unusual odor or taste, the chewiness was "just right", and the rolls were considered acceptable overall.

Table 22. Nutrient content of soft rolls in the Philippines.

	Expected dosage from fortification (ppm)	Soft rolls from fortified flour 1 (NaFeEDTA 40ppm)	Soft rolls from fortified flour 2 (ferrous fumarate 60ppm)
Folic Acid (ppm)	5.0	3.6	3.6
Iron (ppm)	See column headings	38.7	55.7
Vitamin A (ppm)	5.9	3.5	3.4

6. Hard crust rolls/baguette *(Philippines)*

a. ***Color***. The color of the dough from both fortified flours (NaFeEDTA and ferrous fumarate) was normal but with grayish-brown spots visible.

b. ***Retention of nutrients***. The analysis of nutrient content of hard crust rolls/baguette is shown in **Table 23**.

c. ***Sensory evaluation***. There were no significant differences in the character of the crusts of baguettes made from fortified flours 1 and 2.

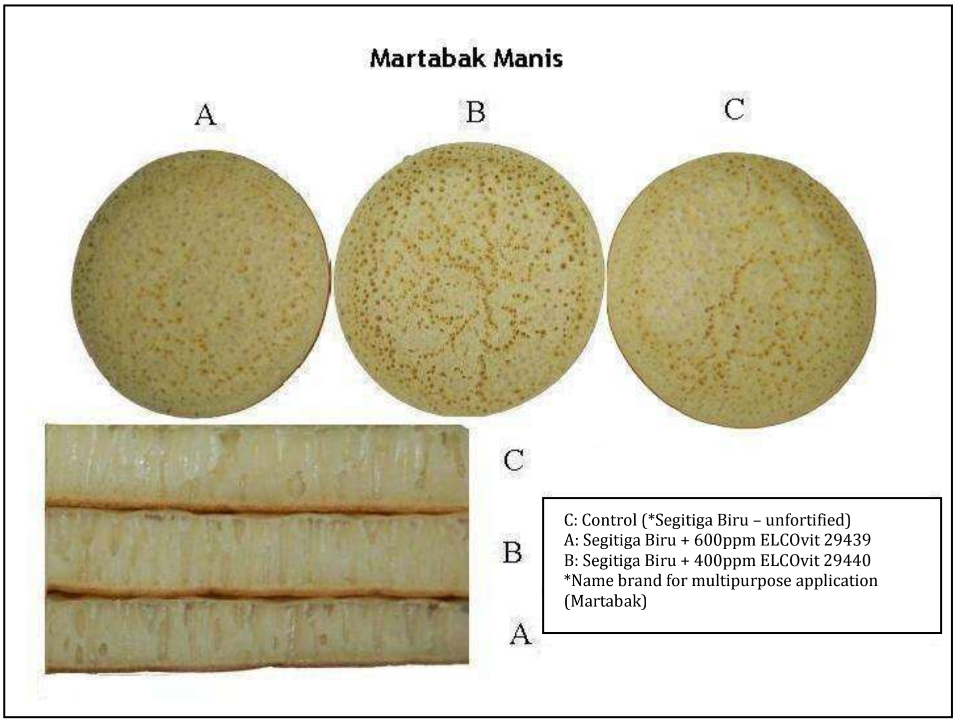
Table 23. Nutrient content of hard crust rolls/baguette in the Philippines.

	Expected dosage from fortification (ppm)	Hard rolls/baguette from fortified flour 1 (NaFeEDTA 40ppm)	Hard rolls/baguette from fortified flour 2 (ferrous fumarate 60ppm)
Folic Acid (ppm)	5.0	4.6	4.4
Iron (ppm)	See column headings	77.3	73.1
Vitamin A (ppm)	5.9	3.7	3.8

7. Martabak (Indonesia)

a. ***Color***. The color of martabak made from fortified flour 1 (NaFeEDTA) was slightly darker than the control, whereas the martabak from fortified flour 2 (ferrous fumarate) was slightly brighter than the control; the differences were not significant.

Figure 7. Martabak from fortified flours and control flour in Indonesia.



b. ***Texture***. The texture of martabak made from fortified flour 1 was similar to that of the control flour martabak; the texture of martabak from fortified flour 2 was less compact, compared to the control, but the differences were not significant.

c. ***Retention of nutrients***. The iron content of martabak is shown in **Table 24**.

d. ***Sensory evaluation***. The taste and aroma of martabak made from fortified flours 1 and 2 were similar to the control.

Table 24. Iron and folic acid content of Indonesian martabak.

	Expected dosage from fortification (ppm)	Martabak from unfortified flour (Control)	Martabak from fortified flour A (NaFeEDTA, 40ppm)	Martabak from fortified flour B (ferrous fumarate, 60ppm)
Iron (mg/kg)	See column headings	5.36	22.51	31.21
Folic acid (mg/kg)	2.6ppm	1.87	1.38	0.89

8. Roti canai ***(Malaysia, Sri Lanka)***

a. ***Color***. In Malaysia, the color and appearance of roti canai made from the control flour and fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) were similar. In Sri Lanka, all three fortified roti samples (NaFeEDTA, ferrous fumarate, and electrolytic iron) and the control roti were similarly accepted ("like very much") with regard to color.

b. ***Texture***. In Malaysia, the surface crispness and firmness of roti canai made from the control flour and fortified flours 1 and 2 were similar. In Sri Lanka, all three fortified roti samples and the control roti were similarly accepted ("like very much") with regard to texture.

c. ***Retention of nutrients***. The analysis of nutrients in the roti canai from Malaysia is shown in **Table 25**. Based on these results, there appears to be sufficient retention of nutrients. In Sri Lanka, researchers

Figure 8. Roti canai from fortified flours and control flour in Malaysia.

estimated the iron content of roti from three fortified flours, and the respective losses during processing (**Table 26**).

d. ***Sensory evaluation***. In Malaysia, the chewiness, floury taste, and overall quality of roti canai made from the control flour and fortified flours 1 (NaFeEDTA) and 2 (ferrous fumarate) were similar. In Sri Lanka, all three fortified roti samples (NaFeEDTA, ferrous fumarate, and electrolytic iron) and the control roti were similarly accepted ("like very much") with regard to flavour, taste, and overall acceptability.

Table 25. Nutrient content of wheat flour, roti canai from unfortified wheat flour, and roti canai from fortified flours 1 and 2 in Malaysia.

	Expected dosage from fortification ppm	Unfortified wheat flour	Roti canai from unfortified flour (Control)	Roti canai from fortified flour 1 (NaFeEDTA, 40ppm)	Roti canai from fortified flour 2 (ferrous fumarate, 60ppm)
Iron (mg/kg)	See column headings	6	10	29	37
Zinc (mg/kg)	55	3	4	32	30
Vitamin B1 (mg/kg)	4.2	<2.5	<2.5	5.0	5.0
Vitamin B2 (mg/kg)	6.7	<2.5	<2.5	4.0	3.0
Vitamin B12 (μg/g)	0.02	0.002	0.004	0.015	0.016
Folic acid (μg/g)	2.6	0.185	0.098	0.259	0.266

Table 26. Iron content of fortified roti in Sri Lanka.

Roti	Expected dosage from fortification (ppm)	Iron in flour-(on dry basis) (ppm)	±SD	Iron in product (after processing) - (on dry basis) (ppm)	±SD	%Loss in added Fe (on dry basis)
Control (correction factor)	n/a	0		24.34	1.51	n/a
Flour 1 (NaFeEDTA)	20ppm	22.52	2.44	15.36	11.18	31.81
Flour 2 (Ferrous fumarate)	30ppm	34.44	1.88	30.02	0.50	12.84
Flour 3 (Electrolytic iron)	60ppm	60.43	1.27	31.07	0.23	48.59

9. Chapatti ***(India)***

a. ***Color***. The color of chapattis from fortified atta flours 1 (NaFeEDTA), 2 (ferrous sulphate), and 3 (electrolytic iron) was slightly darker than the control, but no spots were observed particular to the fortified flour.

b. ***Texture***. Chapatti made from fortified flour 2 (ferrous sulphate) was more dense than chapatti from fortified flours 1 (NaFeEDTA) and 3 (electrolytic iron), or the control. No holes or cracking were observed upon roasting the chapattis made from the 3 fortified flours or the control.

Figure 9. Control and Fortified Chapatti in India.

c. ***Retention of nutrients***. The analysis of nutrients in fortified chapattis yielded the expected levels of nutrients, with comparison to the specifications of the fortified flours (**Table 27**).

d. ***Water absorption***. Moisture was most retained by the chapatti from fortified flour 2 (ferrous sulphate), followed by the control, followed by fortified flours 1 (NaFeEDTA) and 3 (electrolytic iron).

e. ***Cook yield***. The sizes and weights of chapattis made from fortified flours 1 (NaFeEDTA), 2 (ferrous sulphate), and 3 (electrolytic iron) and the control, were similar.

f. ***Sensory evaluation***. Chapatti from flour 1 (NaFeEDTA) was the most preferred in overall rank. Chapatti from flour 2 (ferrous sulphate) was least preferred in taste and chewability and overall rank. Chapatti from flour 3 (electrolytic iron) was the most preferred in taste and chewability. Chapattis from flours 1 (NaFeEDTA) and 3 (electrolytic iron) were preferred over the control in taste, chewability, and overall rank.

Table 27. Nutrient Analysis of Fortified Chapattis and Puris in India.

Sample: Flour 1 (NaFeEDTA, 20ppm)			
Nutrient	**Flour Specs***	**Chapattis**	**Puris**
Vitamin B12	0.01 – 0.015 g	Detected	Detected
Folic Acid	1.30 – 1.69 g	1.30 ppm	1.25 ppm
Iron	20.00 – 22.00 g	23.00 ppm	21.00 ppm

Sample: Flour 2 (Ferrous Sulphate, 30ppm)			
Nutrient	**Flour Specs***	**Chapattis**	**Puris**
Vitamin B12	0.01 – 0.015 g	Detected	Detected
Folic Acid	1.30 – 1.69 g	1.39 ppm	1.21 ppm
Iron	30.00 – 33.00 g	31.00 ppm	28.00 ppm

Sample: Flour 3 (Electrolytic Iron, 60ppm)			
Nutrient	**Flour Specs***	**Chapattis**	**Puris**
Vitamin B12	0.01 – 0.015 g	Detected	Detected
Folic Acid	1.30 – 1.69 g	1.32 ppm	1.27 ppm
Iron	60.00 – 66.00 g	63.00 ppm	60.00 ppm

*Label claim of expected nutrients (g) per 1,000kg of fortified flour (equivalent of ppm).

10. Puri (India)

a. ***Color***. The color of puris from fortified atta flours 1 (NaFeEDTA), 2 (ferrous sulphate), and 3 (electrolytic iron) was slightly darker than the control, but no spots were observed particular to the fortified flour.

b. ***Texture***. Puris made from the three fortified flours were more dense than puri from the control flour. No holes or cracks were observed in any of the puris upon frying.

Figure 10. Control and Fortified Puris in India.

c. ***Retention of nutrients***. The analysis of nutrients in fortified puris yielded the expected levels of nutrients, with comparison to the specifications of the fortified flours (**Table 27**).

d. ***Water absorption***. Puri made from fortified flour 2 (ferrous sulphate) absorbed significantly less oil than the other fortified flours or the control, but the lesser oil content did not affect the taste and chewability of flour 2 puri compared to puris from other fortified and control flours.

e. ***Cook yield***. The sizes and weights of puris made from fortified flours 1, 2, and 3 and the control, were similar.

f. ***Sensory evaluation***. Puri made with fortified flours 2 (ferrous sulphate) and 3 (electrolytic iron) was comparable in taste and chewability, and preferred over the control, and marginally preferred over puri made with fortified flour 1 (FeEDTA). Puri from fortified flour 2 was the most preferred in overall rank and the control was the least preferred.

11. Pittu ***(Sri Lanka)***

a. ***Color***. There were no significant differences in the color of pittu made from fortified flours 1 (NaFeEDTA), 2 (ferrous fumarate), and 3 (electrolytic iron) and pittu made from the control flour; all were considered acceptable with regard to color.

b. ***Texture***. There were minor differences in the texture of the pittu samples: the texture of pittu from flour 2 (ferrous fumarate) was least preferred and the texture from flour 3 (electrolytic iron) was most preferred. All four pittu (from fortified flours 1, 2, and 3 and the control flour) were considered acceptable with regard to texture.

Figure 11. Pittu in Sri Lanka.

c. ***Retention***. Researchers estimated the iron content of pittu samples and the respective losses during processing (**Table 28**).

d. ***Sensory evaluation***. There were minor differences in the taste and flavor of the four pittu samples: pittu from flour 2 (ferrous fumarate) was least preferred and pittu from flour 3 (electrolytic iron) was most preferred. All four pittu (from fortified flours 1, 2, and 3 and the control flour) were considered acceptable with regard to taste and flavour.

Table 28. Iron content of fortified pittu in Sri Lanka.

Pittu	Expected dosage from fortification (ppm)	Iron in flour - (on dry basis) (ppm)	±SD	Iron in product (after processing) - (on dry basis) (ppm)	±SD	%Loss in added Fe (on dry basis)
Control (correction factor)	n/a	0		10.32	0.30	n/a
Flour 1 (NaFeEDTA)	20ppm	22.52	2.44	21.20	0.22	5.99
Flour 2 (Ferrous fumarate)	30ppm	34.44	1.88	29.96	0.12	12.91
Flour 3 (Electrolytic iron)	60ppm	60.43	1.27	57.06	0.84	5.52

12. Godamba roti *(Sri Lanka)*

Figure 12. Godamba roti from Sri Lanka.

a. ***Color, Texture, and Sensory evaluation***. All four godamba roti samples- from fortified flours 1 (NaFeEDTA), 2 (ferrous fumarate), 3 (electrolytic iron), and the control flour- were well and equally accepted ("like very much" ranking) in terms of color, texture, flavour, taste, and overall acceptability.

b. ***Retention***. Researchers estimated the iron content and losses during processing of all godamba roti samples (**Table 29**).

Table 29. Iron content of fortified godamba roti in Sri Lanka.

Godamba roti	Expected dosage from fortification (ppm)	Iron in flour-(on dry basis) (ppm)	±SD	Iron in product (after processing) - (on dry basis) (ppm)	±SD	%Loss in added Fe (on dry basis)
Control (correction factor)	n/a	0		10.67	0.19	n/a
Flour 1 (NaFeEDTA)	20ppm	22.52	2.44	22.33	1.05	No loss
Flour 2 (Ferrous fumarate)	30ppm	34.44	1.88	34.61	0.12	No loss
Flour 3 (Electrolytic iron)	60ppm	60.43	1.27	46.38	3.99	23.26

13. String hoppers ***(Sri Lanka)***

a. ***Color***. The color of string hoppers made from fortified flours 1 (NaFeEDTA), 2 (ferrous fumarate), and 3 (electrolytic iron) and the control flour were all accepted in the category of "moderately liked". When compared, the color of the string hoppers from flour 3 was liked the best, and that from flour 1 was liked the least.

Figure 13. String hoppers from Sri Lanka.

b. ***Texture***. There were no significant differences in the texture of string hoppers from fortified flours 1, 2, and 3, and the control flour.

c. ***Retention***. Researchers estimated the iron content and losses due to processing in all string hopper samples (**Table 30**).

d. ***Sensory evaluation***. There were no significant differences in the taste and flavour of string hoppers from fortified flours 1,2, and 3 and the control flour.

Table 30. Iron content of fortified string hoppers in Sri Lanka.

String hoppers	**Expected dosage from fortification (ppm)**	**Iron in flour - (on dry basis) (ppm)**	**±SD**	**Iron in product (after processing) - (on dry basis) (ppm)**	**±SD**	**%Loss in added Fe (on dry basis)**
Control (correction factor)	n/a	0.10		4.83	0.43	n/a
Flour 1 (NaFeEDTA)	20ppm	21.18	0.19	15.30	0.13	30.27
Flour 2 (Ferrous fumarate)	30ppm	32.51	0.13	28.38	1.36	12.70
Flour 3 (Electrolytic iron)	60ppm	59.03	1.11	59.0	0.85	2.37

Discussion and Conclusions

The wide (and growing) variety of commonly consumed food products made with wheat flour in Asia has warranted the studies summarized in this report. Flour fortification is already ongoing in some of the largest flourmills in Asia. The 2009 recommendations from WHO aim to ensure that past, current, and future investments in flour fortification will be optimized in terms of their positive impacts on the health of consumers. The types and levels of nutrients added should not impart negative consequences on the processing or organoleptic/sensory characteristics of the flour nor the products made from it.

A remarkably wide variety of noodles and breads exist across Asia. While it is common in the West for fortified flours to be used in the production of pasta and breads, the recipes (and modes of preparation) that are particular to Asia warrant independent investigation as to the effects of fortification. The research represented in this report is for the most commonly consumed wheat flour products in the six countries.

Generally speaking, the effect of fortification on various types of **noodles** was only with regard to color: grayish specks on the dough sheet, and slightly less bright or yellow noodles, were considered minor and acceptable differences in all cases. The texture, noodle crumb and sheet structure, water absorption and cook yield, and sensory evaluations (including taste, flavor, and mouthfeel) of fortified noodles were similar to control noodles and acceptable in all cases.

The rancidity experiment by Malaysian researchers indicates that fortification may impact the shelf life of instant noodles. Because the experiment only looked at the peroxide value (PV) of noodles after one year, and because the shelf life of instant noodles is typically 4 to 6 months, a remaining research question is to find out how many months after storage did the PVs rise above the safe level (PV ≤30mequiv/kg is considered safe, following the Japanese standard). Furthermore, the Malaysian experiment tested various forms of iron, but didn't include NaFeEDTA. Therefore another remaining research question would be to evaluate the impact of NaFeEDTA on oxidation and shelf life.

The effect of fortification on **bread products** was also primarily with regard to color: grayish-brown spots were visible in some bread products, or the bread was "less bright". Again, these differences were generally reported as "not significant" and acceptable. Other aspects of breads, including texture, taste, aroma, chewiness, etc., were considered similar between fortified and control breads, and the fortified breads ranked as acceptable or highly acceptable.

Grayish specks in the dough (for noodles and bread) or bread products themselves were generally considered acceptable by the researchers and panelists. It's important to note that the cause of these specks is unknown, and not necessarily related to the iron in the fortification premix, as the specks are not always observed, even when iron is present. If specks are a cause for concern for producers or consumers, further investigation may be warranted.

Generally speaking, we can say that the fortified foods in all country studies did retain a notable proportion of nutrients throughout processing. Studies in China and

Sri Lanka were designed to calculate loss rates of nutrients (the loss of added iron due to cooking or baking, etc). Studies in India, Indonesia, Malaysia, and the Philippines were not designed to calculate loss rates, as they didn't analyze nutrients in the flours (or doughs), only the foods. Philippines and India did not analyze control (unfortified) flour. It should also be noted that for the analysis of iron content, atomic absorption spectrophotometry (AAS) will detect not only the iron added by fortification, but also the intrinsic iron in the flour and any other ingredients. This may explain why, in some cases, the iron content of the foods is higher than the expected dosage of added iron in the fortified flours.

While these six research studies examined the retention of nutrients in the foods prepared with various fortified flours, it should also be noted that the bioavailability (or the body's ability to absorb the nutrient) is not the same for all iron fortificants. The researchers didn't examine bioavailability; many studies have done so in the past. Generally speaking, NaFeEDTA is the most bioavailable of all the iron forms, and electrolytic iron is the least bioavailable. This is a key issue with regard to effectiveness and achieving the intended benefits for public health, so much so that the WHO 2009 recommendations propose only NaFeEDTA, but no other iron fortificant, for high extraction flour.

As with any research, there were constraints. Researchers were given limited time in which to conduct their studies. The comparative nature of this summary report is limited by the fact that researchers in each of the six countries employed different study designs and methods of analysis. Furthermore, not all parameters could be tested in all countries, which also limited the comparability of findings. In some cases, there were difficulties with measuring retention of nutrients in the final food products, and therefore suspected errors in the reported findings are not presented in this document, but warrant further investigation.

The retention data in this report demonstrates the wide variations that can occur in food testing, and that making standards for fortified foods rather than flours can be problematic and complicated. The analyses presented are only a snapshot of one set of data, whereas several samples would have to be run to make it statistically relevant. The fact that multiple laboratories and different equipment and procedures were used adds to this variability.

Despite the constraints, and based on the information presented in this summary report, it is reasonable to conclude that:

1. The **processing and organoleptic** differences between fortified and non-fortified products were minimal, and were considered acceptable in all cases.

2. There are practically no significant differences reported between **various iron compounds** in these fortified products, with regard to processing and sensory characteristics. Researchers did not conclude any differences between electrolytic iron and NaFeEDTA, ferrous sulphate, or ferrous fumarate with regard to the major parameters, and all minor differences were considered acceptable.

3. The overall **acceptability** of fortified products is equal to that of unfortified products;

4. Micronutrients appear to be **retained** throughout the food preparation process; and

5. It appears possible to fortify common Asian wheat flour products as per the 2009 WHO recommendations.

Appendix 1: WHO 2009 Recommendations

Recommendations on Wheat and Maize Flour Fortification Meeting Report: Interim Consensus Statement

PURPOSE

This statement is based on scientific reviews prepared for a Flour Fortification Initiative (FFI) technical workshop held in Stone Mountain, GA, USA in 2008 where various organizations actively engaged in the prevention and control of vitamin and mineral deficiencies and various other relevant stakeholders met and discussed specific practical recommendations to guide flour fortification efforts being implemented in various countries by the public, private and civic sector. This joint statement reflects the position of the World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), The United Nations Children's Fund (UNICEF), Global Alliance for Improved Nutrition (GAIN), The Micronutrient Initiative (MI) and FFI. It is intended for a wide audience including food industry, scientists and governments involved in the design and implementation of flour fortification programs as public health interventions.

BACKGROUND

WHO and FAO published in 2006 the *Guidelines on Food Fortification with Micronutrients* (WHO/FAO, 2006). These general guidelines, written from a nutrition and public health perspective are a resource for governments and agencies implementing or considering food fortification and a source of information for scientists, technologists and the food industry. Some basic principles for effective fortification programs along with fortificants' physical characteristics, selection and use with specific food vehicles are described. Fortification of widely distributed and consumed foods has the potential to improve the nutritional status of a large proportion of the population, and neither requires changes in dietary patterns nor individual decision for compliance. Technological issues to food fortification need to be fully resolved especially with regards to appropriate levels of nutrients, stability of fortificant, nutrient interactions, physical properties and acceptability by consumers (WHO/FAO, 2006). Worldwide, more than 600 million metric tons of wheat and maize flours are milled annually by commercial roller mills and consumed as noodles, breads, pasta, and other flour products by people in many countries. Fortification of industrially processed wheat and maize flour, when appropriately implemented, is an effective, simple, and inexpensive strategy for supplying vitamins and minerals to the diets of large segments of the world's population. It is estimated that the proportion of industrial-scale wheat flour being fortified is 97% in the Americas, 31% in Africa, 44% in Eastern Mediterranean , 21% in South-East Asia , 6% in Europe, and 4% in the Western Pacific regions in 2007 (FFI, 2008).

THE FFI SECOND TECHNICAL WORKSHOP ON WHEAT FLOUR FORTIFICATION

Nearly 100 leading nutrition, pharmaceutical and cereal scientists and milling experts from the public and private sectors from around the world met on March 30 to April 3, 2008 in Stone Mountain, GA, USA to provide advice for countries considering national wheat and/or maize flour fortification. This *Second Technical Workshop on Wheat Flour Fortification: Practical Recommendations for National Application* was a follow up to a FFI, the US Centers for Disease Control and Prevention (CDC) and the Mexican Institute of Public Health, first technical workshop entitled "Wheat Flour Fortification: Current Knowledge and Practical Applications," held in Cuernavaca, Mexico in December 2004 (FFI, 2004). The purpose of this second workshop was to provide guidance on national fortification of wheat and maize flours, milled in industrial roller mills (i.e. >20 metric tons/day milling capacity), with iron, zinc, folic acid, vitamin B_{12} and vitamin A and to develop guidelines on formulations of premix based on common ranges of flour consumption. A secondary aim was to agree on the best practices guidelines for premix manufactures and millers. Expert work groups prepared technical documents reviewing published efficacy and effectiveness studies as well as the form and levels of fortificants currently being added to flour in different countries. The full reviews will be published in a supplement of *Food and Nutrition Bulletin* in 2009 and the summary recommendations of this meeting can be found in http://www.sph.emory.edu/wheatflour/atlanta08/ (FFI, 2008).

RECOMMENDATIONS FOR WHEAT AND MAIZE FLOUR FORTIFICATION

Wheat and maize flour fortification is a preventive food-based approach to improve micronutrient status of populations over time that can be integrated with other interventions in the efforts to reduce vitamin and mineral deficiencies when identified as public health problems. However, fortification of other appropriate food vehicles with the same and/or other nutrients should also be considered when feasible. Wheat and maize flour fortification should be considered when industrially produced flour is regularly consumed by large population groups in a country. Wheat and maize flour fortification programmes could be expected to be most effective in achieving a public health impact if mandated at the national level and can help achieve international public health goals. Decisions about which nutrients to add and the appropriate amounts to add to fortify flour should be based on a series of factors including the nutritional needs and deficiencies of the population; the usual consumption profile of "fortifiable" flour (i.e. the total estimated amount of flour milled by industrial roller mills, produced domestically or imported, which could in principle be fortified); sensory and physical effects of the fortificant nutrients on flour and flour products; fortification of other food vehicles; population consumption of vitamin and mineral supplements; and costs. Flour fortification programs should include appropriate Quality Assurance and Quality Control (QA/QC) programs at mills as well as regulatory and public health monitoring of the nutrient content of fortified foods and assessment of the nutritional/health impacts of the fortification strategies. Though the wheat and maize flours can be fortified with several micronutrients, the technical workshop focused on iron, folic acid, vitamin B_{12}, vitamin A and zinc, which are five micronutrients recognized to be of public health significance in developing countries.

1. IRON

The suggested levels for fortification of wheat flour with iron were reviewed by experts from published efficacy and effectiveness studies with various iron-fortified foods (Hurrell R *et al,* 2009). The authors estimated the daily amounts of selected iron compounds, including NaFeEDTA, ferrous sulphate, ferrous fumarate and electrolytic iron that have been shown to improve iron status in populations. The selection of the type and quantity of vitamins and minerals to add to flour, either as a voluntary standard or a mandatory requirement, lies with national decision makers in each country and therefore the choice of compounds as well as quantities should be viewed in the context of each country's situation. Based on available data from the Food Balance Sheets of FAO and World Bank-supported Household Income and Expenditure Surveys (HIES), it was proposed that four wheat flour average consumption ranges be considered in designing flour fortification programs: >300 g/day, 150-300 g/day, 75-150 g/day and <75 g/day.

2. FOLIC ACID

Well conducted studies from the United States (Williams LJ *et al,* 2002), Canada (De Wals P *et al,* 2007), and Chile (Hertrampf E & Cortes F, 2004) have documented decreases of 26%, 42%, and 40%, respectively, in the rate of neural tube defects (NTD) affected births after implementation of national regulations mandating wheat flour fortification with folic acid. Wheat and maize flour fortification with folic acid increases the intake of folate by women and can reduce the risk of neural tube and other birth defects.

3. VITAMIN B_{12}

An unpublished pilot study testing the feasibility of adding B-complex vitamins and iron to flour in Israel showed that vitamin B_{12} added to flour was stable during baking, did not affect the quality of the bread, and increased plasma B_{12} concentrations slightly within six months (Allen L *et al,* 2008). However, evidence is still lacking about the population impact of fortification of wheat flour with vitamin B_{12} to improve vitamin B_{12} status. Nevertheless, fortifying flours with vitamin B_{12} could be a feasible approach to improve vitamin B_{12} intake and the status of populations as there are no known adverse consequences of vitamin B_{12} fortification, and there are no known adverse effects of high intakes of the vitamin.

4. VITAMIN A

Wheat and maize flour can technically be fortified with vitamin A as vitamin A is stable in flour without producing organoleptic changes. As is the case for some other vitamins, high humidity and high temperatures can adversely affect vitamin A content during the preparation of wheat and maize flour products. Experience with vitamin A fortification of wheat and maize flour in developing

Table 1. Average levels of nutrients to consider adding to fortified wheat flour based on extraction, fortificant compound, and estimated *per capita* flour availability

Nutrient	Flour Extraction Rate	Compound	Level of nutrient to be added in parts per million (ppm) by estimated average per capita wheat flour availability (g/day)[1]			
			<75[2] g/day	75-149 g/day	150-300 g/day	>300 g/day
Iron	Low	NaFeEDTA	40	40	20	15
		Ferrous Sulfate	60	60	30	20
		Ferrous Fumarate	60	60	30	20
		Electrolytic Iron	NR[3]	NR[3]	60	40
	High	NaFeEDTA	40	40	20	15
Folic Acid	Low or High	Folic Acid	5.0	2.6	1.3	1.0
Vitamin B_{12}	Low or High	Cyanocobalamin	0.04	0.02	0.01	0.008
Vitamin A	Low or High	Vitamin A Palmitate	5.9	3	1.5	1
Zinc[4]	Low	Zinc Oxide	95	55	40	30
	High	Zinc Oxide	100	100	80	70

1. These estimated levels consider only wheat flour as main fortification vehicle in a public health program. If other mass-fortification programs with other food vehicles are implemented effectively, these suggested fortification levels may need to be adjusted downwards as needed.
2. Estimated per capita consumption of <75 g/day does not allow for addition of sufficient level of fortificant to cover micronutrients needs for women of childbearing age. Fortification of additional food vehicles and other interventions should be considered.
3. NR = Not Recommended because very high levels of electrolytic iron needed could negatively affect sensory properties of fortified flour.
4. These amounts of zinc fortification assume 5 mg zinc intake and no additional phytate intake from other dietary sources.

countries is increasing. Although vitamin A is most often used in the fortification of oils and fats, currently 11 countries are fortifying or propose to fortify wheat and/or maize flour with this vitamin. Two published efficacy trials have reported the impact of vitamin A fortified wheat flour on vitamin A nutritional status but there are no published studies that have evaluated the effectiveness of this intervention on a national scale (West KP *et al*, 2009). Wheat and, more broadly, other cereal grain flour (e.g. maize) can be considered as a vehicle for delivery of vitamin A to populations at risk of vitamin A deficiency.

5. ZINC

Unpublished results from a trial of wheat flour fortification in China suggests that zinc fortified flour could improve zinc status in women of childbearing age (Brown K *et al,* 2009). Fortification of other foods with zinc has shown that zinc intake and absorption increase when some zinc fortified foods are consumed but the impact as a public health intervention remains unknown. More research on efficacy and effectiveness of large scale zinc fortification programs is needed. The levels of nutrients to consider adding to fortified wheat flour based on extraction, fortificant compound, and estimated per capita flour availability are presented in Table 1. These levels and compounds could theoretically improve the nutritional status of the populations consuming the fortified wheat flour regularly in different preparations.

SUMMARY OF STATEMENT DEVELOPMENT

This statement was prepared by the core group from WHO's Department of Nutrition for Health and Development in close collaboration with FAO, the nutrition section of UNICEF, GAIN, MI and FFI. The core group members were: Dr Francesco Branca (WHO), Dr Juan Pablo Pena-Rosas (WHO), Mr Brian Thompson (FAO), Mr Arnold Timmer, (UNICEF), Dr Regina Moench-Pfanner (GAIN), Dr Annie Wesley (MI) and Dr Glen Maberly (FFI). The core group evaluated the commissioned scientific reviews prepared by international nutrition, pharmaceutical and cereal scientists and milling experts from the public and private sector working in the area of micronutrients, milling and food fortification, as well as the summary of discussions and conclusions from the consultation. This position statement is based on these documents and was initiated at WHO headquarters and further discussed and reviewed by members of the core group who provided technical and editorial advice. This statement contains all the consensus recommendations of the core group.

CONFLICTS OF INTEREST

All members of the core group were asked to submit and sign Declaration of Interest statements which are on file. There were no known conflicts of interest disclosed among the core group members developing this statement.

PLANS FOR UPDATE

It is anticipated that the recommendations in this statement will remain valid until December 2010. The Department of Nutrition for Health and Development at WHO headquarters in Geneva will be responsible for initiating a review following formal *WHO Handbook for Guideline Development* procedures at that time.

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Appendix 2: Test Parameters and Methodology

Parameters	China	India	Indonesia	Malaysia	Philippines	Sri Lanka
Colour	Subjective visual examination	Subjective visual examination by 7-member untrained panel	Konica Minolta CR-300 chromameter	Konica Minolta CR-410 chromameter	Konica Minolta CR-310 chromameter	Minolta chromameter
Texture	Perten/2200 brabender farinograph was used to detect ductility and tensile strength; subjective examination of "mouth feel", "structure" (for steamed bread), and "elasticity" (for noodles)	Subjective visual examination by 7-member untrained panel	Trained panelists and TA-XT2i Texture Analyzer	Trained panelists and TA-XT2i Texture Analyzer	Subjective evaluation by researchers	Subjective evaluation by trained panelists
Noodle Crumb and Sheet Structure (noodles only)	Sheet structure evaluated by physical measurement of noodle before and after drying (% of dilapidation)	N/A	Trained panelists	Subjective evaluation by researchers	Subjective evaluation by researchers	Not tested
Water absorption (noodles only)	Farinograph method	N/A	Mathematically calculated using weight of noodles before and after cooking	Mathematically calculated using weight of noodles before and after cooking	Mathematically calculated using weight of noodles before and after cooking	Not tested

Cook yield	Weights of foods measured with electronic scale	Weights of food measured	Weight of noodles after boiling	Weight of noodles after boiling	Weight of noodles after boiling	Not tested
Sensory Evaluation	Subjective examination by researchers	7-member untrained panel used 5-point Hedonic scale	Subjective evaluation by trained panelists	Subjective evaluation by trained panelists	Subjective evaluation by researchers	Subjective evaluation by trained panelists
Micronutrient content:	China	India	Indonesia	Malaysia	Philippines	Sri Lanka
Iron	AAS	Atomic Absorption / Colorimetric Methods	AAS	ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry) methods were used. To determine the heavy metals level, AOAC methods were used (AOAC, 1984).	AAS	AOAC Offical Method of Analysis (2000), Method 944.02, Iron in Flour, spectrophoto-metric method (Chapter 32.1.09)
Folic Acid	Microbiologic al assay	HPLC	HPLC	AOAC 960 46/ Microassay Turbimetric Method	HPLC	Not tested
Vitamin B12	HPLC	HPLC	Not tested	AOAC 960 46/ Microassay Turbimetric Method	Not tested	Not tested
Vitamin A	HPLC	N/A	N/A	N/A	HPLC	N/A
Zinc	AAS	N/A	Not tested	ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry) methods were used.	N/A	Not tested

Thiamin (B1)	Colorimetry	N/A	Not tested	In-house method based on AOAC 942 23, 970.65 and HPLC	N/A	Not tested
Riboflavin (B2)	Flourimetric method	N/A	Not tested	In-house method based on AOAC 942 23, 970.65 and HPLC	N/A	Not tested