Baking trials with fortified flour

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AkzoNobel

Helen Keller INTERNATIONAL

IFSBH

Ministerie van Buitenlandse Zaken

Problem statement

Factors that may limit the amount of fortificants that can be added to a single food vehicle

Nutrient	Technological/sensory	Safety	Cost
Vitamin A	X	XXX	XXX[a]
Vitamin D	–	X	X
Vitamin E	–	X	XXX
Vitamin C	XX	X	XXX[b]
Thiamine (vitamin B_1)	–	–	–
Riboflavin (vitamin B_2)	XX	–	–
Niacin (vitamin B_3)	–	XXX[c]	X
Vitamin B_6	–	X	–
Folic acid	–	XXX[d]	–
Vitamin B_{12}	–	–	X
Iron[e]	XXX	XX	X
Zinc	XX	XXX	X
Calcium	X	XX	XXX[f]
Selenium	–	X	X
Iodine	X	XXX	–

–, no constraint; X, a minor constraint; XX, moderate constraint; XXX, major constraint.

[a] If an oil-based form is used to fortify oils or fats, costs can be reduced.

[b] Cost constraints are mainly a consequence of losses during manufacturing, storage, distribution and cooking which mean that a considerable overage is required.

[c] Much less of a concern if niacinamide, as opposed to nicotinic acid, is used as the fortificant.

[d] The risk of adverse effects is minimized by the co-addition of vitamin B_{12}.

[e] Refers to the more bioavailable forms.

[f] Cost constraints are mainly a consequence of the need to add such large amounts.

Fortification of wheat flour and maize meal with different iron compounds: Results of a series of baking trials

Philip Randall, Quentin Johnson, and Anna Verster

Abstract

Background. *Wheat and maize flour fortification is a preventive food-based approach to improve the micronutrient status of populations. In 2009, the World Health Organization (WHO) released recommendations for such fortification, with guidelines on the addition levels for iron, folic acid, vitamin B_{12}, vitamin A, and zinc at various levels of average daily consumption. Iron is the micronutrient of greatest concern to the food industry, as some believe there may be some adverse interaction(s) in some or all of the finished products produced from wheat flour and maize meal.*

Objective. *To determine if there were any adverse interactions due to selection of iron compounds and, if differences were noted, to quantify those differences.*

Methods. *Wheat flour and maize meal were sourced in Kenya, South Africa, and Tanzania, and the iron compound (sodium iron ethylenediaminetetraacetate [NaFeEDTA], ferrous fumarate, or ferrous sulfate) was varied and dosed at rates according to the WHO guidelines for consumption of 75 to 149 g/day of wheat flour and > 300 g/day of maize meal and tested again for 150 to 300 g/day for both. Bread,* chapatti, ugali *(thick porridge), and* uji *(thin porridge) were prepared locally and assessed on whether the products were acceptable under industry-approved criteria and whether industry could discern any differences, knowing that differences existed, by academic sensory analysis using a combination of trained and untrained panelists and in direct side-by-side comparison.*

Results. *Industry (the wheat and maize milling sector) scored the samples as well above the minimal standard, and under academic scrutiny no differences were reported. Side-by-side comparison by the milling industry did indicate some slight differences, mainly with respect to color, although these differences did not correlate with any particular iron compound.*

Conclusions. *The levels of iron compounds used, in accordance with the WHO guidelines, do not lead to changes in the baking and cooking properties of the wheat flour and maize meal. Respondents trained to measure against a set benchmark and/or discern differences could not consistently replicate perceived difference observations.*

Key words: Ferrous fumarate, ferrous sulfate, maize meal, NaFeEDTA, wheat flour, WHO guidelines

Introduction

National fortification requires the support of a variety of stakeholders, including stakeholders from industries who use fortification premixes in their wheat flour and maize meal products.

Following the Second Technical Workshop on Wheat Flour Fortification: Practical Recommendations for National Application, the World Health Organization (WHO) [1] issued its "Recommendations on wheat and maize flour fortification meeting report: Interim Consensus Statement" in 2009, which was followed by the publication of the deliberations of the various working groups as a supplement to the *Food and Nutrition Bulletin* [2–9]. In this statement and the Supplement, guidelines were issued on the addition levels for iron, folic acid, vitamin B_{12}, vitamin A, and zinc at various levels of average daily consumption of wheat flour and maize meal (< 75, 75 to 149, 150 to 300, and > 300 g/day).

Of all of the micronutrients discussed, iron was the one of greatest concern to the food industry, as some industry delegates believed there may be some

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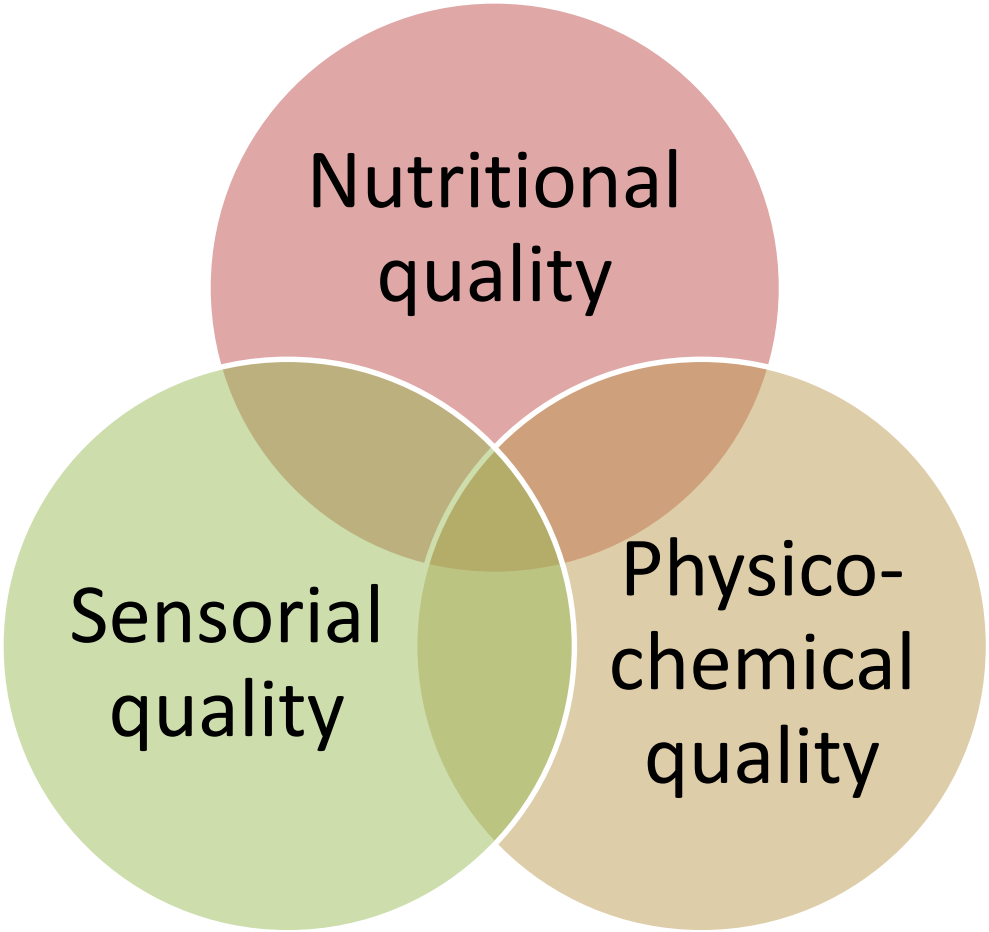
Fortification of **wheat flour** and **maize meal** with **different iron** compounds

Philip Randall, Quentin Johnson, Anna Verster

Food and Nutrition Bulletin, vol. 33, n°4

2012

Food Quality



Objective of the study

- Determine if there were any adverse interactions due to the selection of iron compounds in the finished products produced from wheat flour or maize meal, and if differences were noted, to quantify those differences.

Kenya

- UNGA Mills
- Kenyatta University

Tanzania

- Bakhresa Mills
- Tanzania Food and Nutrition Centre

South-Africa

- Southern African Grain laboratories

Flour Fortification

- Locally sourced wheat flour and maize meal: medium to high extraction
- Iron compounds:
  - Wheat flour: @75-149 g/day consumption (WHO guideline level)
    - NaFeEDTA
    - Ferrous fumarate ($FeC_4H_2O_4$)
    - Ferrous sulfate ($FeSO_4$)

  - Maize meal: @>300 g/day consumption (WHO guideline level)
    - NaFeEDTA
    - Ferrous fumarate ($FeC_4H_2O_4$)

Flour Fortification

TABLE 1. Wheat flour premix formulations: Premix for iron at World Health Organization recommendations for daily flour intakes of 75 to 149 g[a]

Variable	Micronutrient concentration (mg/kg)	Premix formulation by compound (mg/kg)		
Micronutrients				
Folic acid	2.6	2.87	2.87	2.87
Vitamin B_{12} (0.1%)	0.02	20.00	20.00	20.00
Zinc oxide	55	68.46	68.46	68.46
NaFeEDTA	40 (as iron)	320.00	—	—
Ferrous fumarate	60 (as iron)	—	190.36	—
Ferrous sulfate	60 (as iron)	—	—	189.87
Diluent		411.33	281.69	281.21
Addition rate (g/MT)		500	400	400

TABLE 2. Maize meal premix formulations: Premix for iron at World Health Organization recommendations for daily maize meal intakes of > 300 g[a]

Variable	Micronutrient concentration (mg/kg)	Premix formulation by compound (mg/kg)	
Micronutrients			
Vitamin A	1.0	13.33	13.33
Folic acid anhydrous	1.0	1.10	1.10
Vitamin B_{12} (0.1%)	0.008	8.00	8.00
Zinc	30	37.34	37.34
NaFeEDTA	15 (as iron)	120.00	—
Ferrous fumarate	20 (as iron)	—	63.45
Diluent		179.78	123.23
Addition rate (g/MT)		250	250

Additional samples: NaFeEDTA content of 20 ppm (as iron) –> corresponding to the WHO guidelines for a consumption of 150 to 300g /day of wheat flour and maize meal

Products

Kenya	Tanzania	South-Africa
Bread UNGA: sponge and dough Kenyatta: straight dough	Bread Bakhresa: straight dough Food centre: straight dough	Bread Chorleywood bread process
Chappati	Chappati	
Ugali	Ugali	
Uji	Uji	

- Preparation and evaluation under ‘local rules’
- Retention samples for re-evaluation after 3 or 6 months

Assessment

- Were the products acceptable under industry approved criteria?
- Were the products acceptable under academic sensory analysis using a combination of trained and untrained panelists?
- In direct side-by-side comparison, could milling industry assessment discern any differences, knowing that differences existed?

Results wheat flour

- Bread score: Southern African grain laboratories

External properties

Volume
Symmetry
Top crust
Break
Shred
Bloom

Internal properties

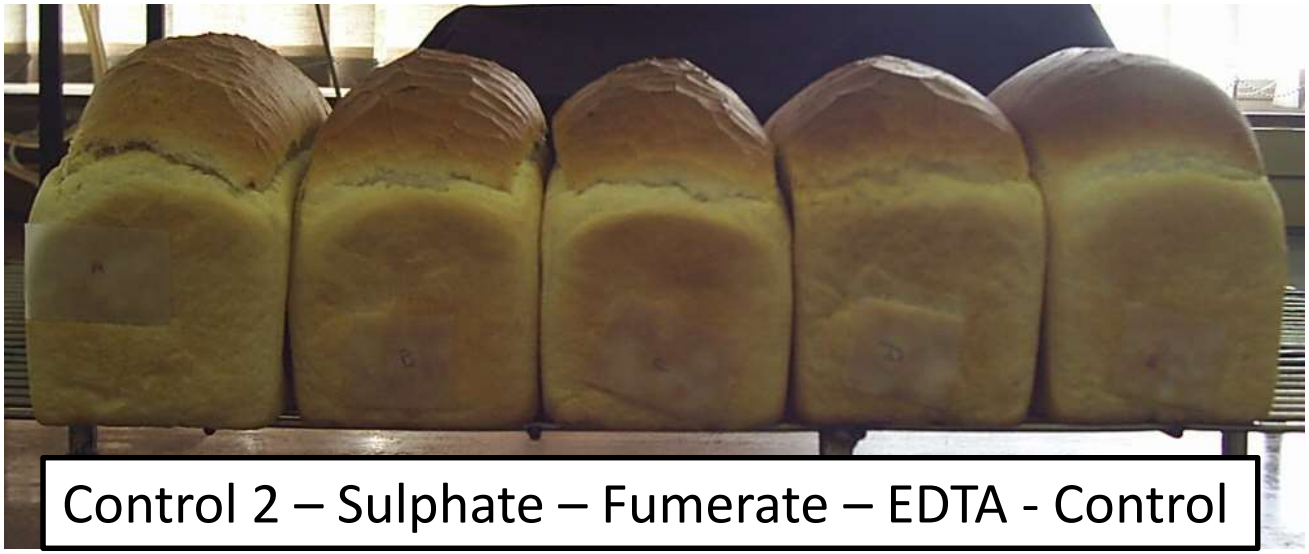
Grain
Texture
Colour

Results wheat flour

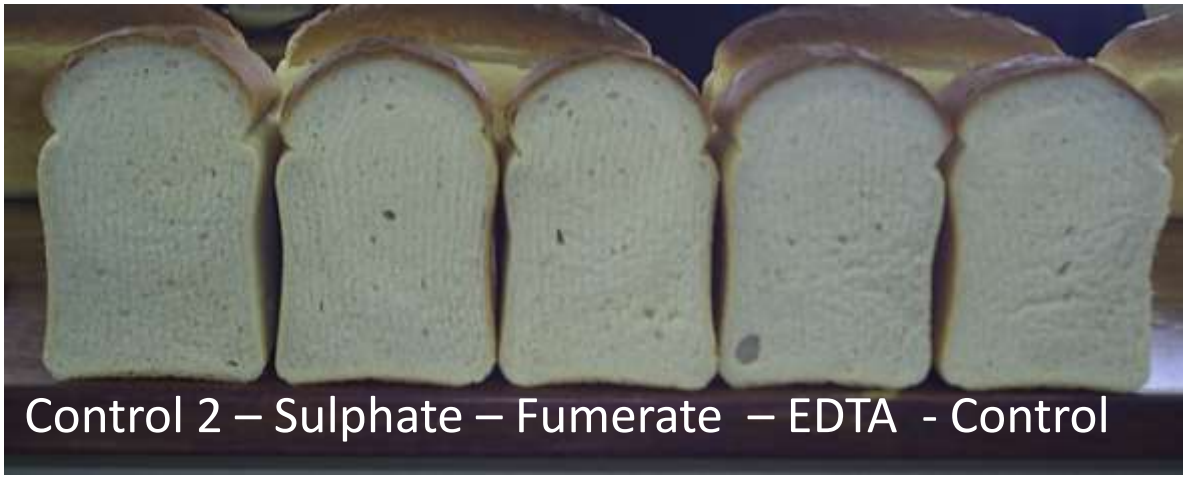
- Bread score: Southern African grain laboratories

TABLE 3. Southern African Grain Laboratories (SAGL): Results for bread — original samples

Characteristic	Perfect score	Control 1	Ferrous fumarate	Ferrous sulfate	NaFeEDTA	Control 2	SAGL internal control
External characteristics							
Subtotal	40	26	27	27	22	29	29
Internal characteristics							
Subtotal	60	49	49	51	47	50	51
Total	100	75	76	78	69	79	80
Loaf volume (cm^3)		2,990	2,975	3,065	3,065	3,075	2,990
Water absorption (%)		60	60	60	59	58	60



Control 2 – Sulphate – Fumerate – EDTA - Control



Control 2 – Sulphate – Fumerate – EDTA - Control

Results wheat flour

- Bread score: Southern African grain laboratories

TABLE 4. Southern African Grain Laboratories (SAGL): Results for bread — retention samples

Characteristic	Perfect score	Control 1	Ferrous fumarate	Ferrous sulfate	NaFeEDTA	Control 2	SAGL internal control
External characteristics							
Subtotal	40	20	22	19	20	28	29
Internal characteristics							
Subtotal	60	50	48	51	51	47	51
Total	100	70	70	70	71	75	80
Loaf volume (cm^3)		3,340	3,315	3,240	3,265	3,200	3,000
Water absorption (%)		59	58	59	58	58	59

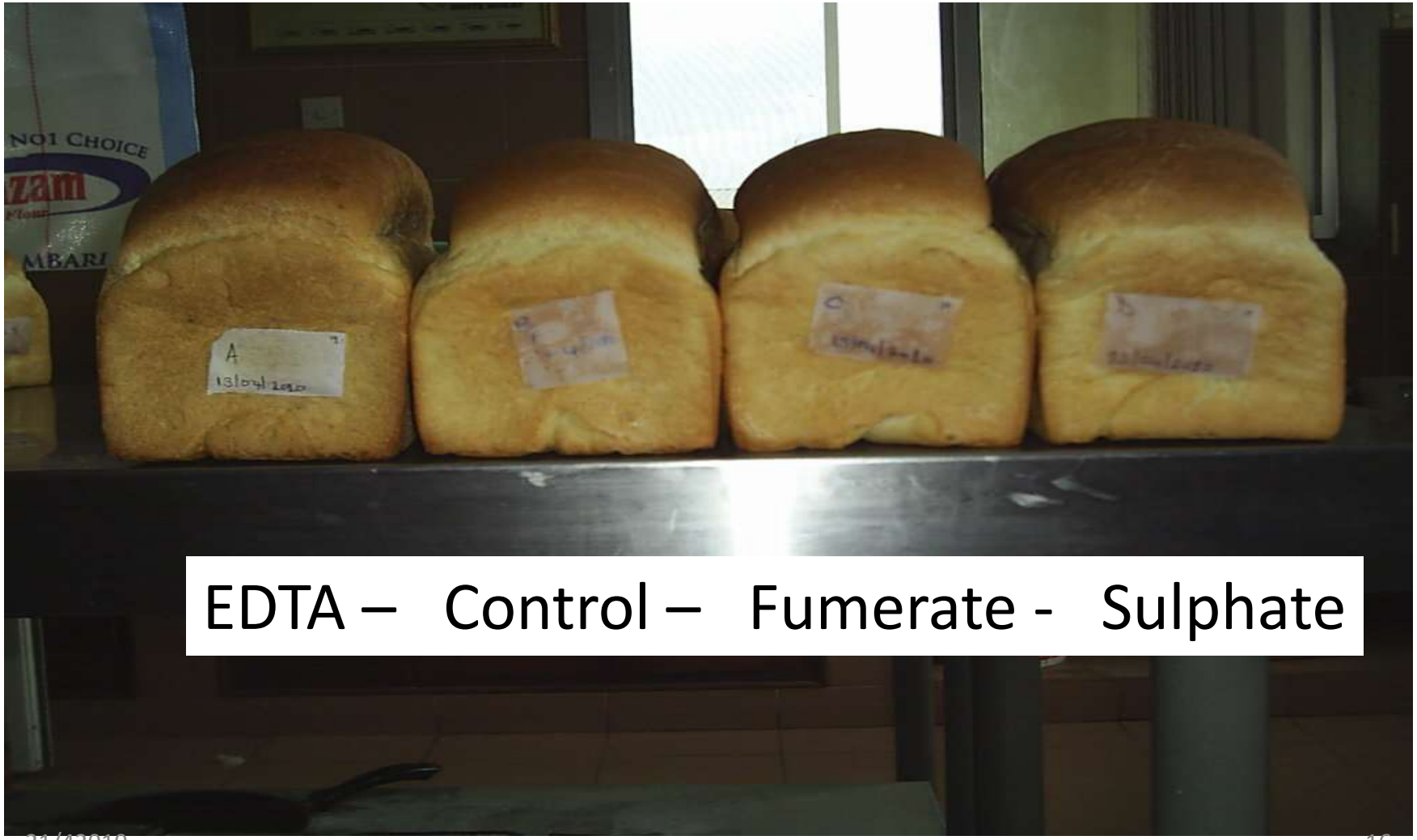
Results wheat flour

- Bread score: Bakhresa Mills, Tanzania

Characteristic	Perfect score	Control 1	Ferrous fumarate	Ferrous sulfate	NaFeEDTA
Original sample					
Bread volume	30	27	27	28	28
Appearance	20	18	18	18	18
Texture	25	24	24	24	24
Crumb color	14	14	14	14	14
Crumb grain	7	5	5	5	5
Oven spring	4	3	3	2	3
Total	100	91	91	91	92
Retention samples					
Bread volume	30	27	27	27	23
Appearance	20	18	16	12	17
Texture	25	24	24	24	23
Crumb color	14	13	12	12	12
Crumb grain	7	6	5	5	5
Oven spring	4	3	3	3	2
Total	100	91	87	83	82

Minimum acceptable score = 75

Tanzanian Wheat Flour - Mill



Tanzanian Wheat Flour - Mill

EDTA - Control

Fumerate - Sulphate

Results wheat flour

- Bread score: Kenyatta University, Kenya

Characteristic	Control	Ferrous fumarate	Ferrous sulfate	NaFeEDTA
Original samples				
Appearance	7.3 (1.2)	6.9 (1.5)	7.4 (0.9)	6.9 (1.4)
Color	7.2 (1.4)	6.9 (1.3)	7.3 (0.9)	7.1 (1.4)
Odor	6.3 (1.6)	6.9 (1.7)	6.9 (1.6)	6.9 (1.2)
Texture	6.8 (1.8)	6.9 (1.5)	6.8 (1.3)	7.0 (1.4)
Taste	6.6 (1.6)	7.0 (1.5)	6.6 (1.7)	6.9 (1.5)
Overall	7.0 (0.7)	7.1 (1.3)	6.8 (1.4)	6.9 (1.4)
Retention samples				
Appearance	7.1 (1.7)	6.9 (1.3)	6.4 (1.7)	6.1 (1.6)
Color	6.8 (1.4)	7.2 (1.6)	6.4 (1.7)	6.2 (1.6)
Odor	6.6 (1.6)	6.7 (1.6)	6.3 (1.7)	6.2 (1.8)
Texture	6.7 (1.5)	6.6 (1.6)	6.1 (2.1)	5.6 (1.9)
Taste	6.7 (1.6)	6.3 (2.1)	6.3 (2.0)	5.8 (1.7)
Overall	7.0 (1.3)	6.5 (1.6)	6.2 (1.7)	5.8 (1.6)

Results wheat flour

- Bread acceptability: Kenyatta University, Kenya

Question	Control	Ferrous fumarate	Ferrous sulfate	NaFeEDTA
Original samples (n=20)				
Is this product generally ACCEPTABLE ?	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)
Would you BUY this product if it was commercially available ?	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)	1.1 (0.4)
Would you BUY the product knowing it contained health benefits?	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)	1.0 (0.0)
Retention samples (n=19)				
Is this product generally ACCEPTABLE?	1.1 (0.3)	1.2 (0.4)	1.2 (0.4)	1.3 (0.5)
Would you BUY this product if it was commercially available?	1.1 (0.2)	1.2 (0.4)	1.3 (0.5)	1.4 (0.5)
Would you BUY this product knowing it contained health benefits?	1.0 (0.0)	1.1 (0.3)	1.1 (0.3)	1.1 (0.2)

Results: wheat flour

- Breakfast bread rolls

TABLE 8. Nairobi workshop delegate assessment (percentage of respondents)

Assessment	Control 1	Ferrous fumarate	Ferrous sulfate	NaFeEDTA	Control 2
Group positive	16	8	26	11	0
Group negative	11	11	11	34	30
Group undecided	63	71	63	56	70

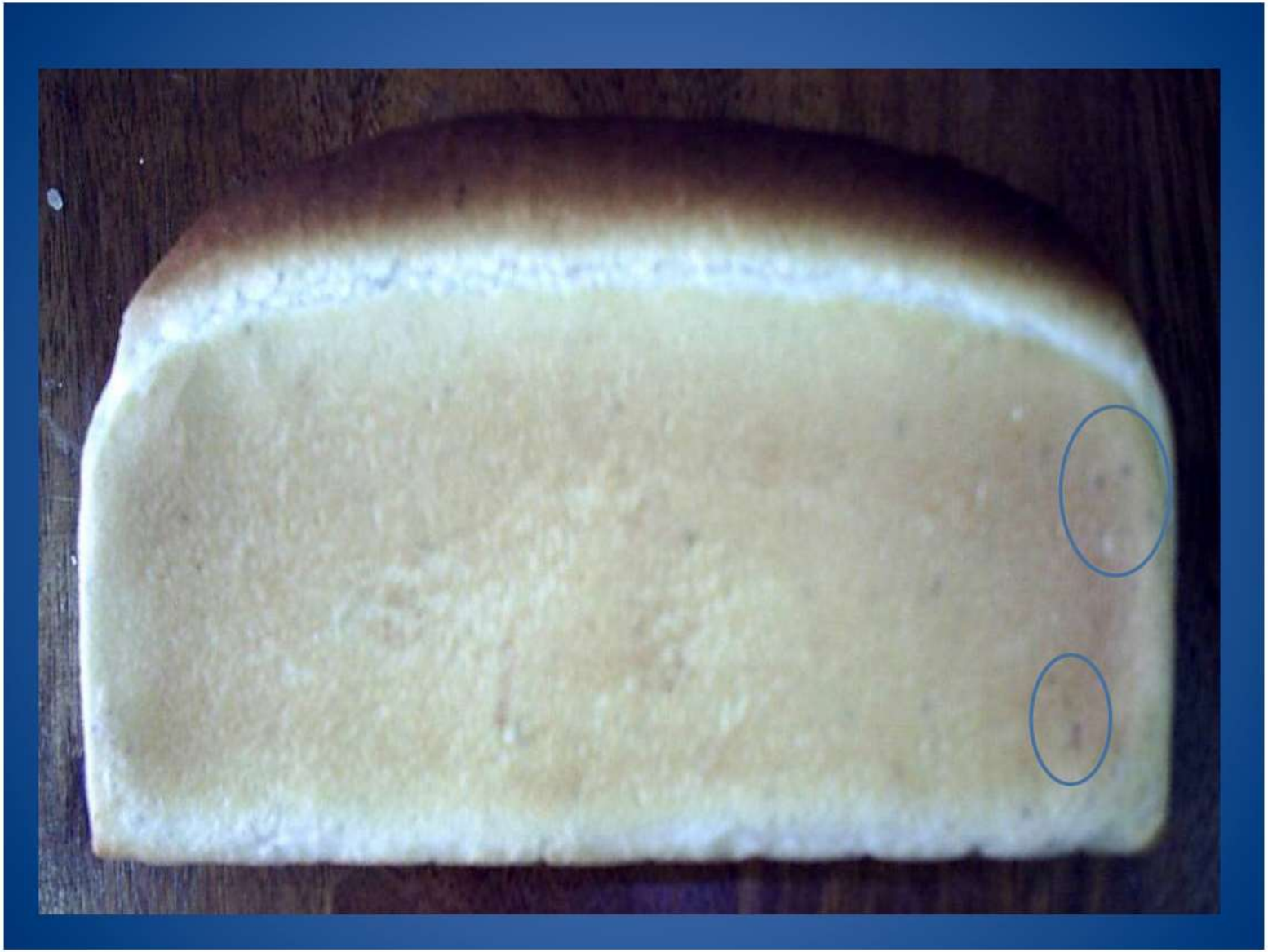
- > 50 delegates failed to reach any consensus on any sample. Two adverse comments related to either of the two control samples and one to EDTA. Two positive comments related to EDTA

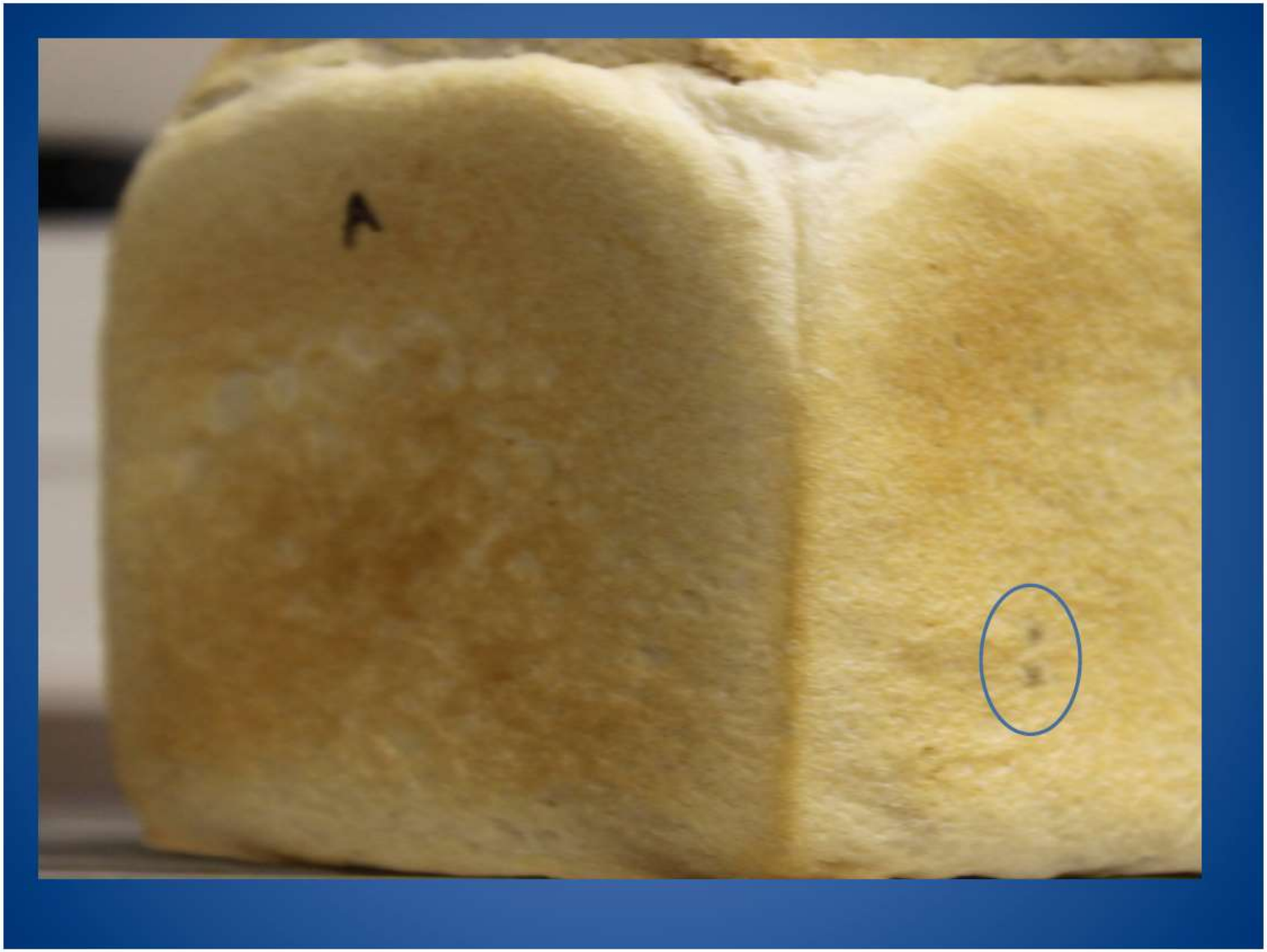
Conclusion BREAD

- All breads passed minimum requirements for overall bread quality
- 20 ppm NaFeEDTA no problem (extra trials)
- 40 ppm NaFeEDTA may be problematic in bread (caution note WHO?) => Nigeria UPDATE
- Spotting was observed

  -> but would you really notice?

  -> caused by iron source?

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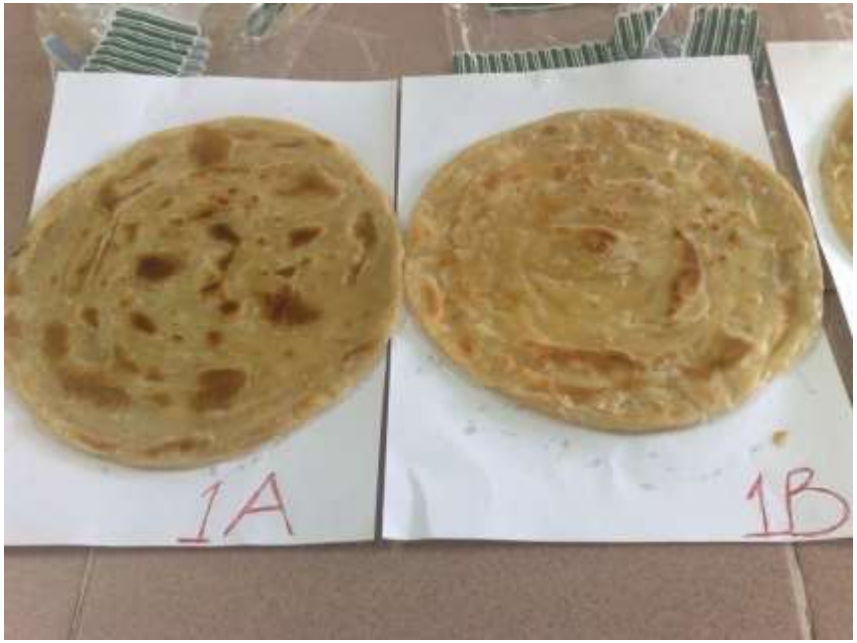
Results: wheat flour

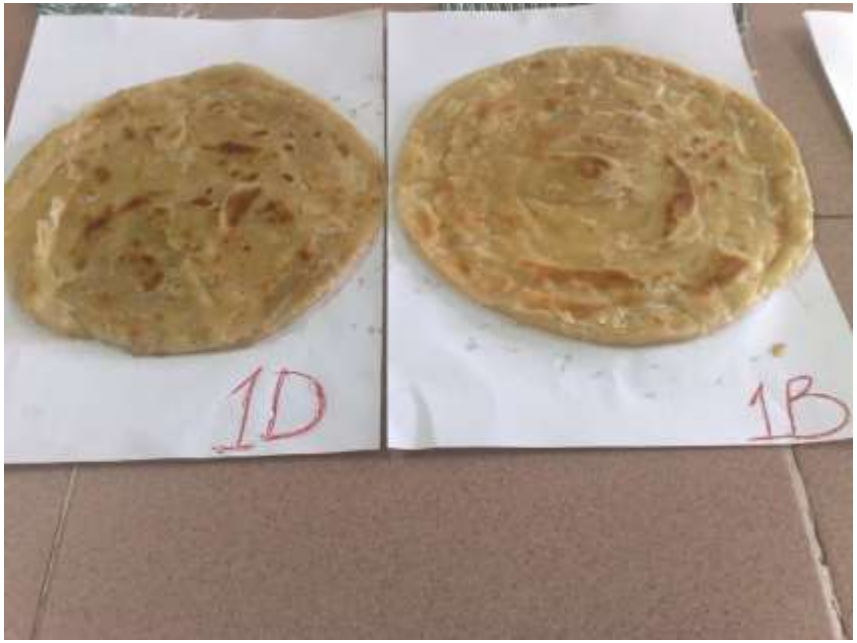
- Chapatti score:
  - Bakhresa Mills (Tanzania)
    - Slight differences in colour (original and retention)
    - Eating quality = normal
  - Food and Nutrition Centre (Tanzania)
    - No differences (panel scoring)
  - UNGA Mills
    - No differences

Tanzanian Wheat Flour - Mill

EDTA - Control



Sulphate - Control

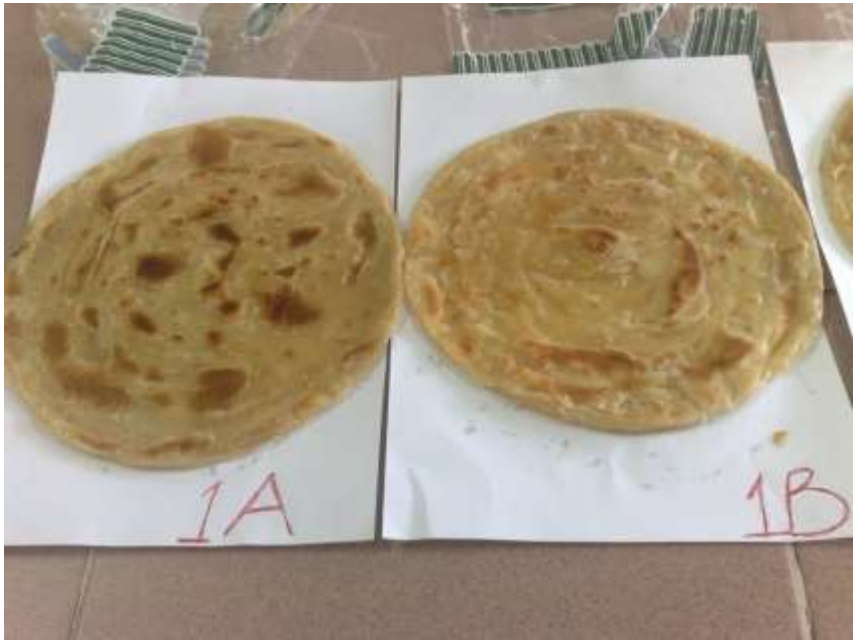


Tanzanian Wheat Flour - Mill

Fumerate - Control

Mill - TFNC

EDTA - Control



Sulphate- Control
EDTA - Fumerate

Results: wheat flour

- Chapatti score: Kenyatta University, Kenya

Characteristic	Control	Ferrous fumarate	Ferrous sulfate	NaFeEDTA
Original samples				
Appearance	6.8 (1.5)	6.9 (1.6)	7.4 (1.5)	6.5 (1.3)
Color	6.9 (1.5)	6.9 (1.5)	7.8 (0.6)	6.6 (1.6)
Odor	6.8 (1.5)	6.4 (1.7)	7.6 (0.8)	6.6 (1.6)
Texture	7.2 (1.0)	6.4 (1.8)	7.5 (1.0)	6.4 (1.3)
Taste	6.5 (1.6)	6.3 (1.7)	7.3 (0.9)	6.5 (1.3)
Overall	6.6 (1.7)	6.3 (1.7)	7.5 (0.8)	6.5 (1.6)
Retention samples				
Appearance	6.6 (1.8)	6.8 (1.4)	5.8 (2.1)	6.8 (1.7)
Color	6.5 (1.4)	6.9 (1.6)	5.9 (2.1)	6.9 (1.3)
Odor	6.6 (1.8)	6.7 (1.6)	5.8 (2.0)	6.5 (1.8)
Texture	6.5 (1.8)	6.9 (1.4)	5.7 (2.2)	6.5 (1.7)
Taste	6.2 (1.7)	6.8 (1.5)	4.7 (1.7)	6.3 (1.7)
Overall	6.2 (1.7)	6.6 (1.6)	4.9 (2.0)	6.3 (1.7)

Results: wheat flour

- Chapatti acceptability: Kenyatta University, Kenya

Question	Control	Ferrous fumarate	Ferrous sulfate	NaFeEDTA
Original samples (n=20)				
Is this product generally ACCEPTABLE?	1.2 (0.4)	1.2 (0.4)	1.1 (0.2)	1.1 (0.3)
Would you BUY this product if it was commercially available?	1.3 (0.5)	1.3 (0.4)	1.0 (0.0)	1.2 (0.4)
Would you BUY this product knowing it contained health benefits?	1.1 (0.3)	1.1 (0.2)	1.0 (0.0)	1.1 (0.2)
Retention samples (n=19)				
Is this product generally ACCEPTABLE?	1.2 (0.4)	1.2 (0.4)	1.5 (0.5)	1.3 (0.5)
Would you BUY this product if it was commercially available?	1.3 (0.5)	1.2 (0.4)	1.6 (0.5)	1.3 (0.5)
Would you BUY this product knowing it contained health benefits?	1.2 (0.4)	1.1 (0.3)	1.3 (0.5)	1.2 (0.4)

Conclusion Chapatti

- Slight differences in colour but not related to a particular iron source
- Chapatti quality = normal

Results: Maize meal

- Bakhresa Mills (Tanzania) => Ugali
  - Slight differences in colour (original and retention)
  - Taste = normal
- Food and Nutrition Centre (Tanzania)=> Ugali and Uji
  - No differences

Tanzanian Maize Meal - Mill

EDTA - Control

Control - Fumerate

Tanzanian Maize Meal - TFNC

Tanzanian Maize Meal - TFNC

Results: wheat flour

- Ugali score: Kenyatta University, Kenya

Characteristic	Control	Ferrous fumarate	NaFeEDTA
Original samples			
Appearance	7.5 (0.7)	7.2 (0.8)	7.4 (0.9)
Color	7.8 (0.6)	7.2 (0.8)	7.6 (0.9)
Odor	7.1 (1.0)	7.0 (1.2)	7.2 (1.2)
Texture	7.4 (0.9)	7.1 (1.5)	6.9 (1.3)
Taste	7.1 (1.2)	6.7 (1.2)	7.3 (1.0)
Overall	7.5 0.7)	6.7 (1.2)	7.2 (1.0)
Retention samples			
Appearance	7.0 (1.3)	6.8 (1.3)	6.8 (1.3)
Color	7.2 (1.3)	6.7 (1.3)	6.6 (1.5)
Odor	6.7 (1.6)	6.3 (2.2)	6.5 (2.0)
Texture	6.7 (1.8)	6.9 (1.9)	6.9 (1.7)
Taste	6.7 (1.7)	6.8 (1.7)	6.3 (2.0)
Overall	6.4 (1.6)	6.5 (1.9)	6.5 (1.4)

Results: wheat flour

- Ugali acceptability: Kenyatta University, Kenya

Question	Control	Ferrous fumarate	NaFeEDTA
Original samples			
Is this product generally ACCEPTABLE?	1.2 (0.4)	1.1 (0.2)	1.1 (0.2)
Would you BUY this product if it was commercially available?	1.1 (0.3)	1.1 (0.2)	1.1 (0.3)
Would you BUY this product knowing it contained health benefits?	1.1 (0.3)	1.0 (0.0)	1.1 (0.2)
Retention samples			
Is this product generally ACCEPTABLE?	1.2 (0.4)	1.2 (0.4)	1.2 (0.4)
Would you BUY this product if it was commercially available?	1.2 (0.4)	1.2 (0.4)	1.3 (0.5)
Would you BUY this product knowing it contained health benefits?	1.1 (0.3)	1.2 (0.4)	1.1 (0.3)

Conclusion Porridge

- Slight differences in colour but not related to a particular iron source
- Quality = normal

General Conclusion

- WHO Guidelines for fortification of flour do not lead to changes in the baking and cooking properties of wheat flour and maize meal.
- Some differences only noticeable with hypercritical eye
- Further research needed for a broader range of concentrations and products