Maize fortification: update on organoleptic studies of various types of maize flours and cooked maize porridges

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Food Fortification Initiative
Enhancing Grains for Healthier Lives

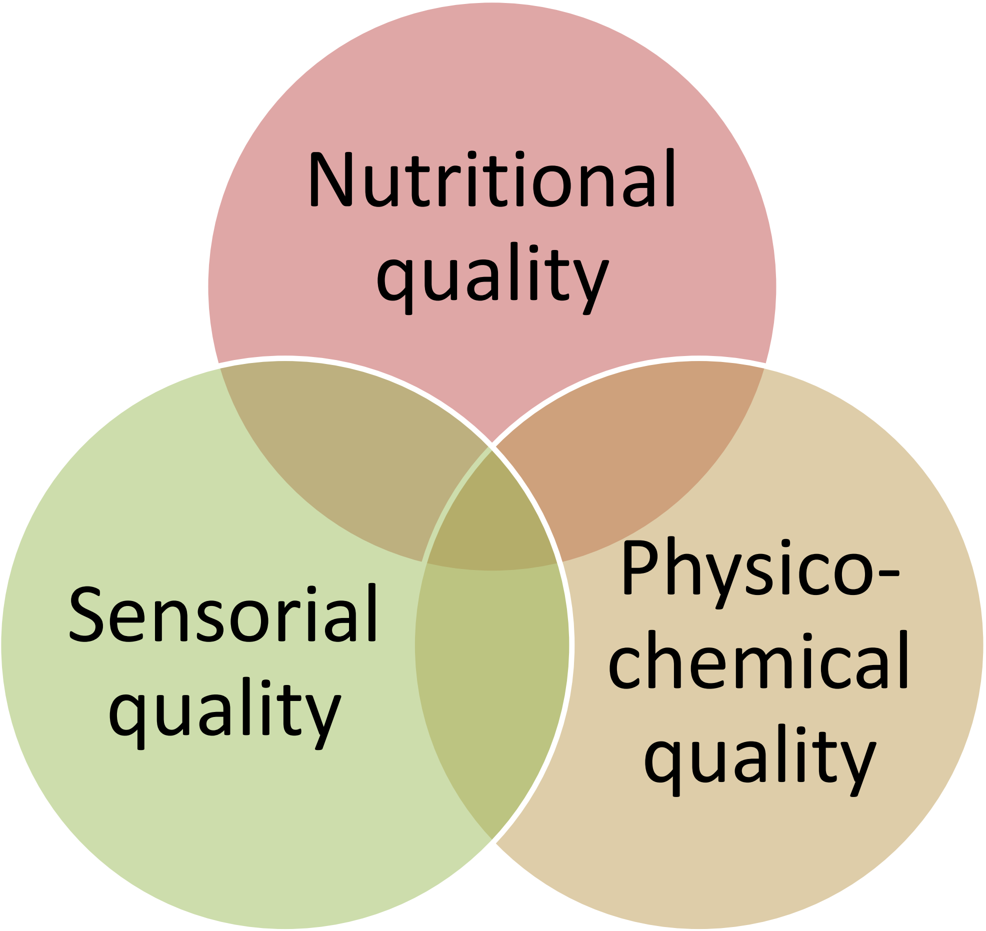
AkzoNobel

Helen Keller INTERNATIONAL

IFSBH

Ministerie van Buitenlandse Zaken

Food Quality



Sensory analysis

TASTE
sweet, sour, salty, bitter, umami

SMELL
aroma

Stywe Pap - we cheated - we cooked it in a non-stick pot - all the better to get to the toasted crust at the bottom - delicious with butter and a grinding of Hot Rocks!

SOUND

TEXTURE
fluid, solid, hard, brittle, sticky

SIGHT
Color, surface structure, reflectance

From maize meal to porridge

Ingredients → Processing → End product

TASTE
sweet, sour, salty, bitter, umami

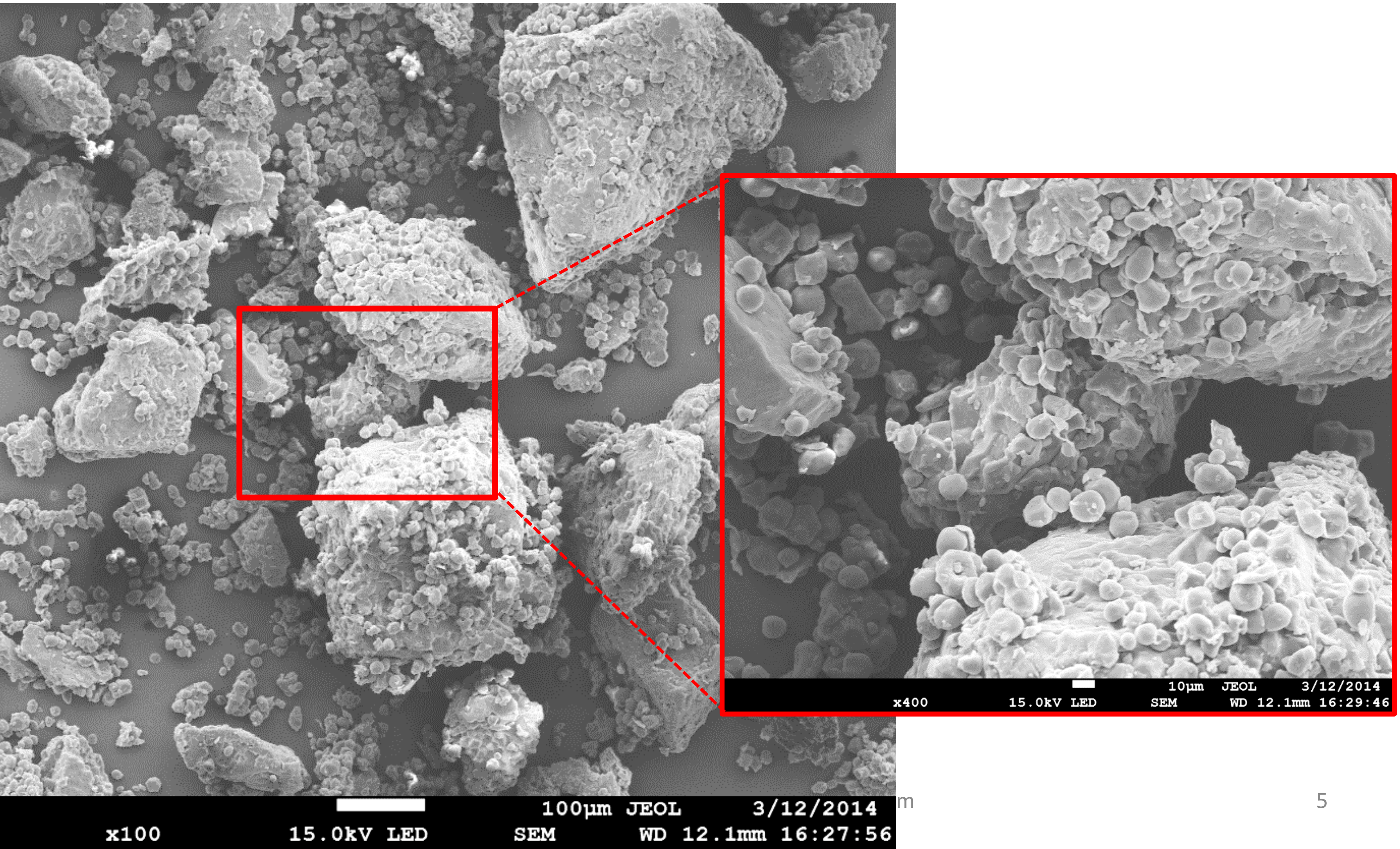
SMELL
aroma

SOUND

TEXTURE
fluid, solid, hard, brittle, sticky

SIGHT
Color, surface structure, reflectance

Ingredients



Ingredients

- Maize meal composition:
  - Maize variety
  - Type of milling
  - Extraction rate

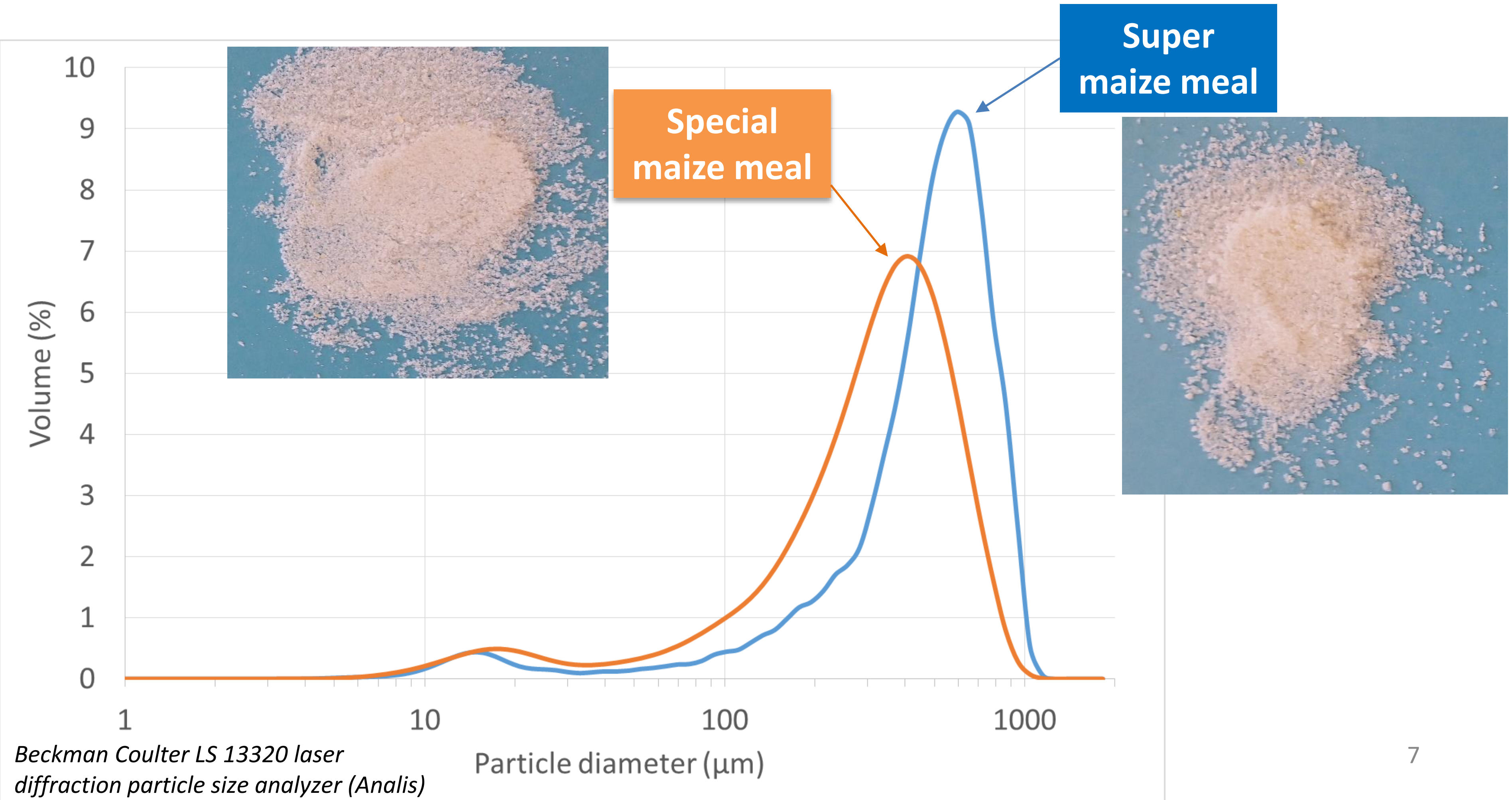
Typical Extraction Rates for Maize meal

Mill size	Maize meal Extraction Rate %	Kernel Components for conversion to maize flour
Large	70 - 75	Endosperm with some pericarp and germ
Medium	65 - 70	Endosperm, pericarp and germ
Small	60 - 65	Endosperm little or no pericarp and germ

NOTE:
Pericarp and germ components can influence the taste of the cooked porridge
Bitterness is one of the characteristic tastes from the pericarp and germ
The purer the endosperm used to mill into flour the lower the bitterness taste

Ingredients

- Particle size distribution:



Beckman Coulter LS 13320 laser diffraction particle size analyzer (Analis)

From maize meal to porridge

STORAGE

Ingredients → Processing → End product

TASTE
sweet, sour, salty, bitter, umami

SMELL
aroma

SOUND

TEXTURE
fluid, solid, hard, brittle, sticky

SIGHT
Color, surface structure, reflectance

From maize meal to porridge

- Storage conditions: fat hydrolysis and oxidation

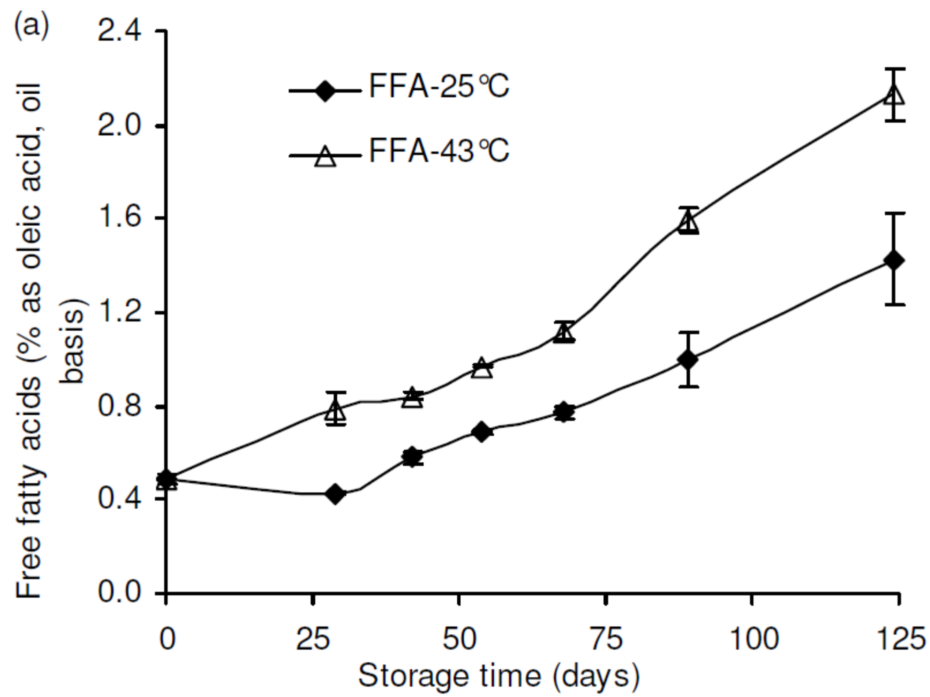


Figure 3.9 Changes in free fatty acids of white maize meal during storage at room temperature (≈25°C) and 43°C

- *John Shindano. PhD thesis (Ghent University, 2007)*

From maize meal to porridge

STORAGE

Ingredients → Processing → End product

Cooking time/temperature

Stirring

Water/maize ratio

TASTE
sweet, sour, salty, bitter, umami

SMELL
aroma

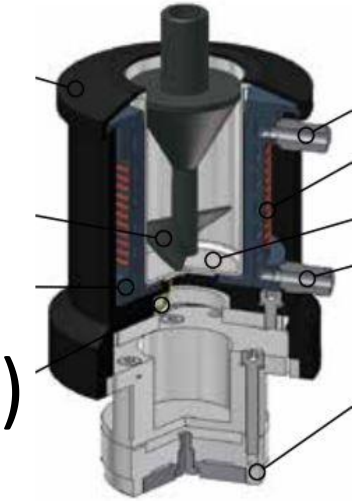
SOUND

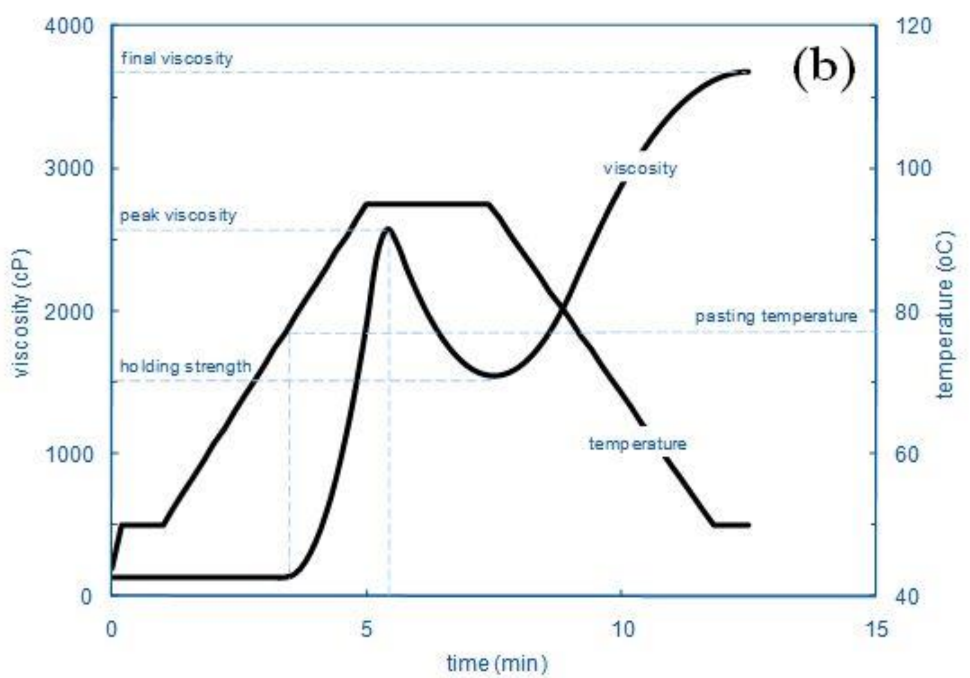
TEXTURE
fluid, solid, hard, brittle, sticky

SIGHT
Color, surface structure, reflectance

Processing

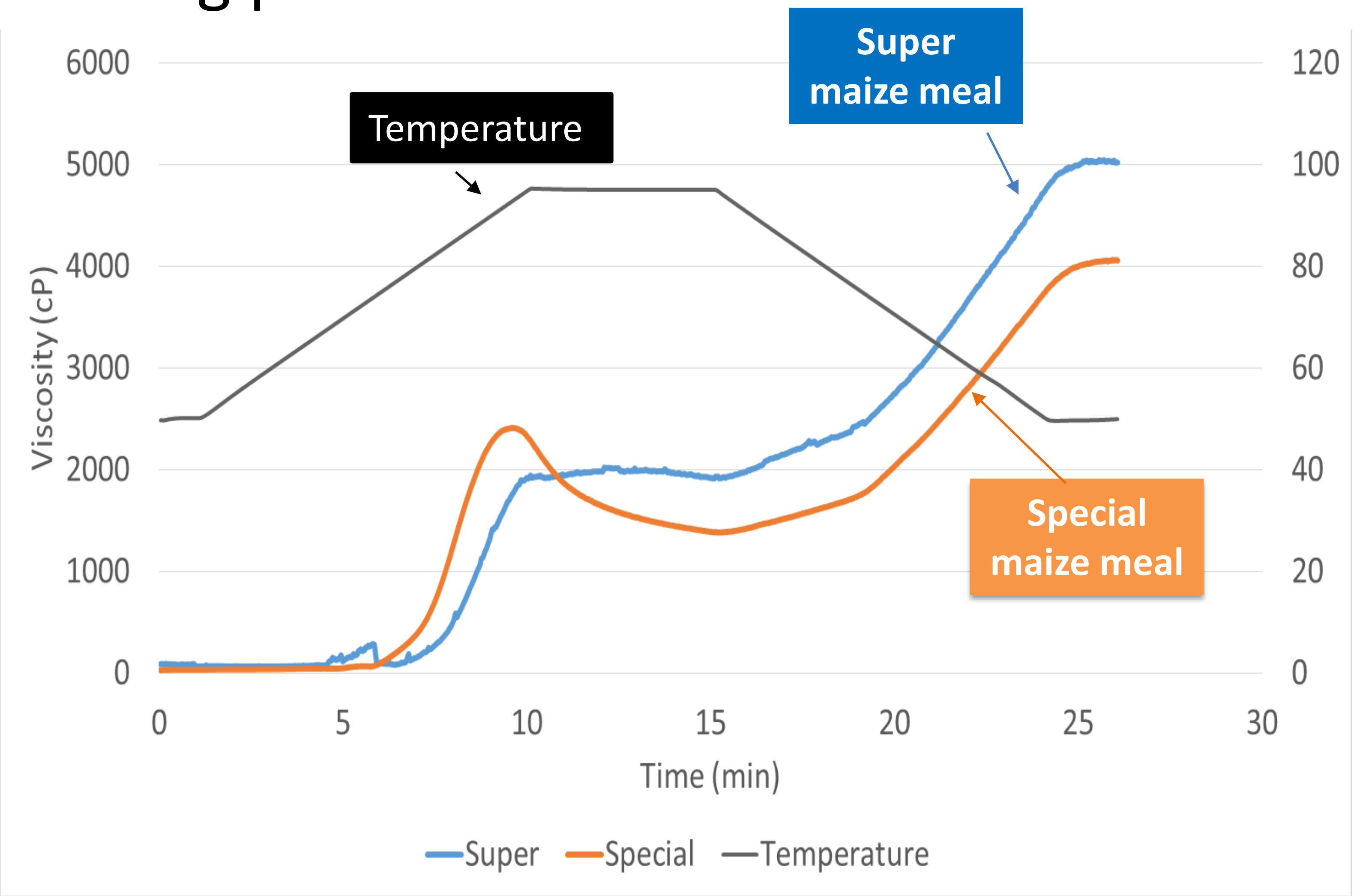
- Cooking test
- Pasting (RVA)





Processing

- Pasting profile:



From maize meal to porridge

STORAGE

Ingredients → Processing → End product

STORAGE

Cooking time/temperature

Stirring

Water/maize ratio

TASTE
sweet, sour, salty, bitter, umami

SMELL
aroma

SOUND

TEXTURE
fluid, solid, hard, brittle, sticky

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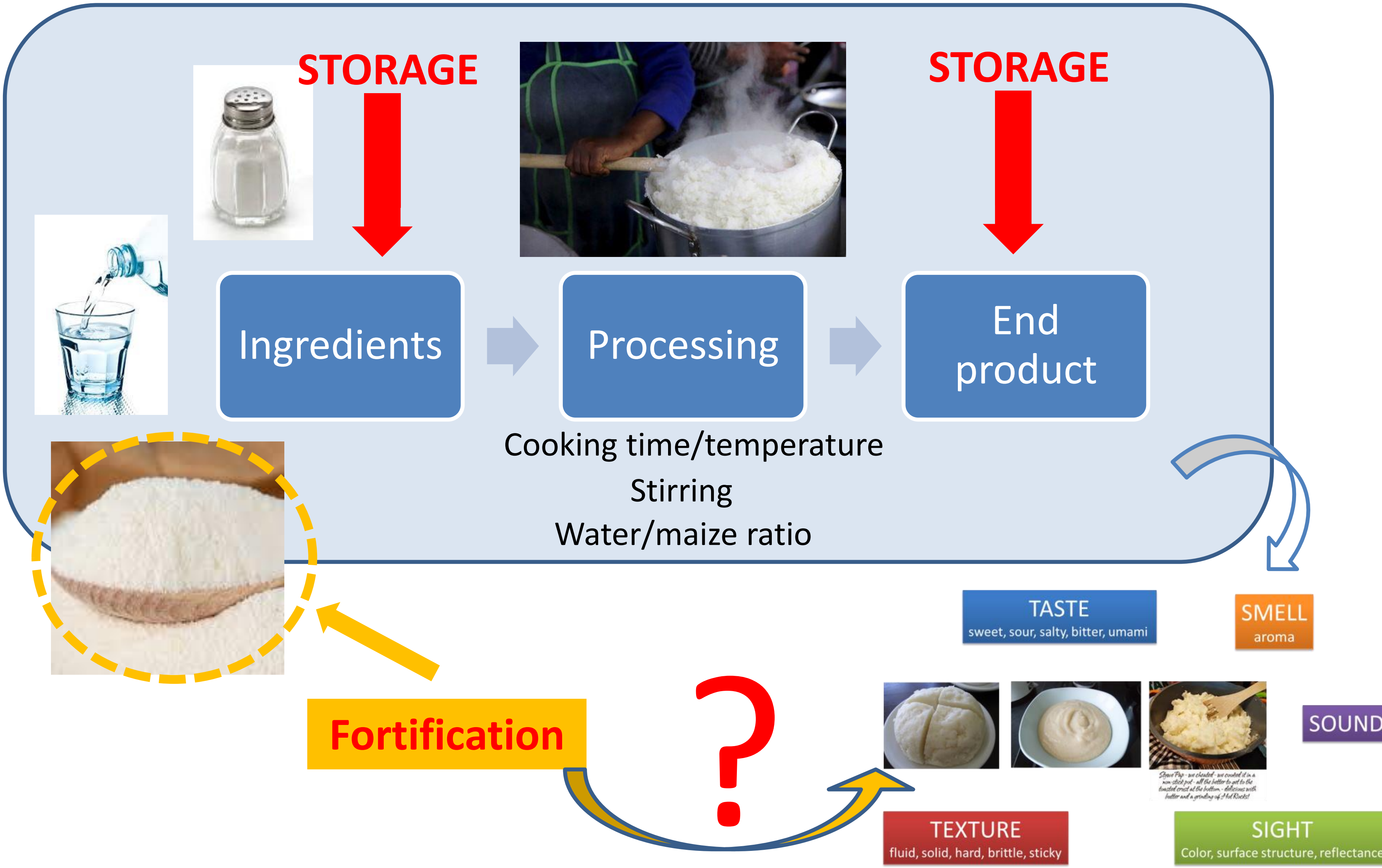
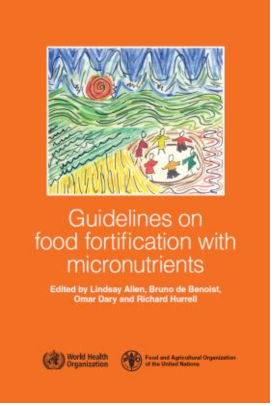
Color, surface structure, reflectance

Problem statement





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.

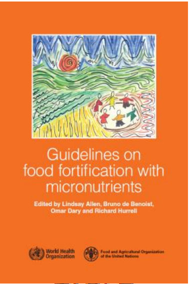
[b] Cost constraints are mainly a consequence of losses during manufacturing, storage, distribution and cooking which mean that a considerable overage is required.

[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.



Fe-sources

TABLE 5.1

Key characteristics of iron compounds commonly used for food fortification purpose: solubility, bioavailability and cost

Compound	Iron content (%)	Relative bioavailability[a]	Relative cost[b] (per mg iron)
Water soluble			
Ferrous sulfate. $7H_2O$	20	100	1.0
Ferrous sulfate, dried	33	100	1.0
Ferrous gluconate	12	89	6.7
Ferrous lactate	19	67	7.5
Ferrous bisglycinate	20	>100[c]	17.6
Ferric ammonium citrate	17	51	4.4
Sodium iron EDTA	13	>100[c]	16.7
Poorly water soluble, soluble in dilute acid			
Ferrous fumarate	33	100	2.2
Ferrous succinate	33	92	9.7
Ferric saccharate	10	74	8.1
Water insoluble, poorly soluble in dilute acid			
Ferric orthophosphate	29	25–32	4.0
Ferric pyrophosphate	25	21–74	4.7
Elemental iron	–	–	–
H-reduced	96	13–148[d]	0.5
Atomized	96	(24)	0.4
CO-reduced	97	(12–32)	<1.0
Electrolytic	97	75	0.8
Carbonyl	99	5–20	2.2
Encapsulated forms			
Ferrous sulfate	16	100	10.8
Ferrous fumarate	16	100	17.4

Best option for cereal flours with high turnover, typically use within 1 month for humid, warm climate and 3 months in dry, cold climate

High bio-availibility, especially in high phytate flours

Ferrous sulphate can cause rancidity depending on fat content, climate and type of flour

More stable, physical separation from food components and thus slow down sensory changes

What is reported in literature?

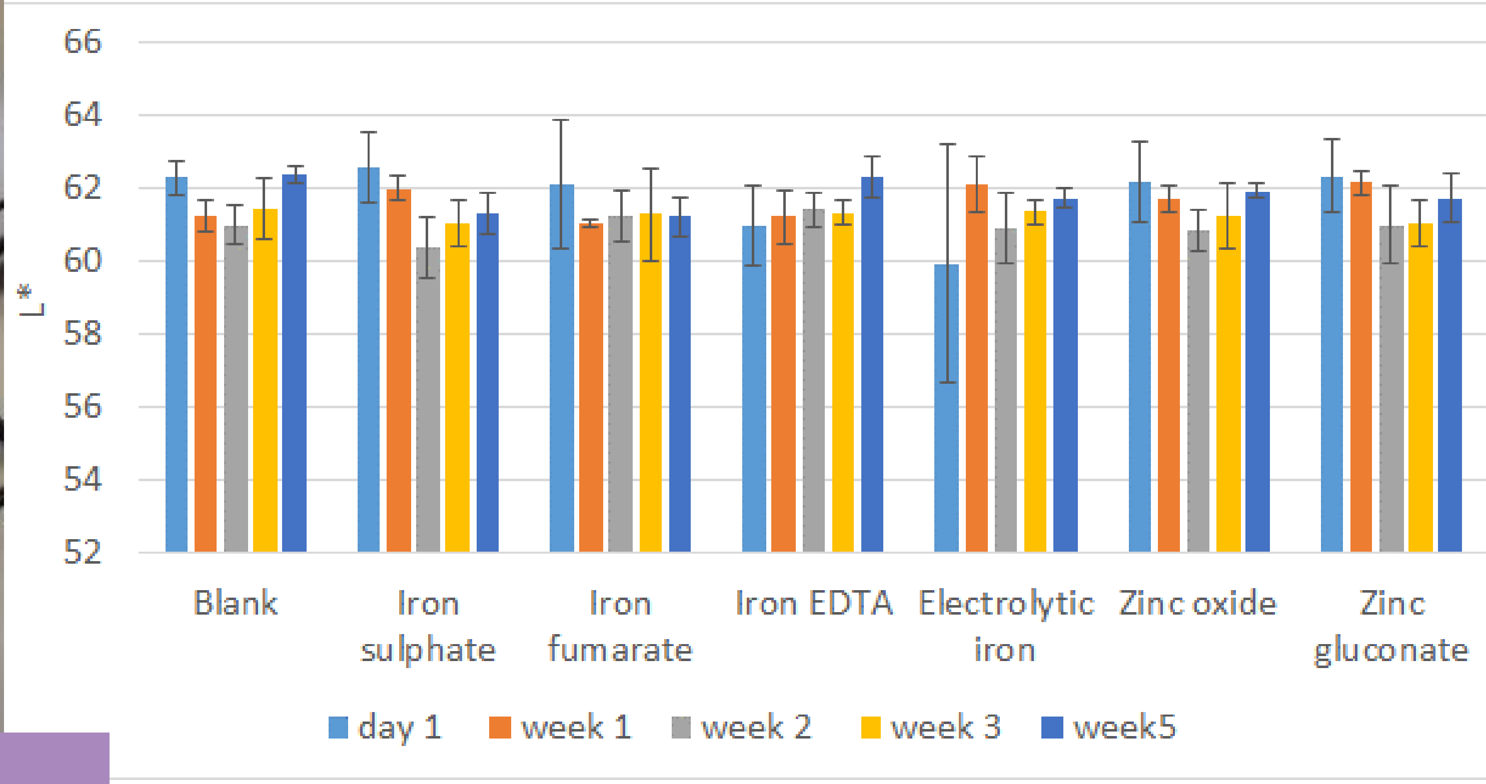
- Tortillas
  - Richins et al. (2008):
    - Iron sources (sulfate, fumarate, pyrophosphate and elec. iron) significantly changed the instrumental and sensory color of fortified tortillas
    - Electrolytic iron and ferric pyrophosphate least amount of change
  - Dunn et al. (2007):
    - Sensory test 100 consumers
    - No sign. difference in acceptability of color, appearance, aroma, texture or flavor
    - Unfortified and fortified with electrolytic iron
  - Rosado et al. (2005):
    - Electrolytic iron
    - No color changes
  - Burton et al. (2008):
    - Fumarate
    - Darker color

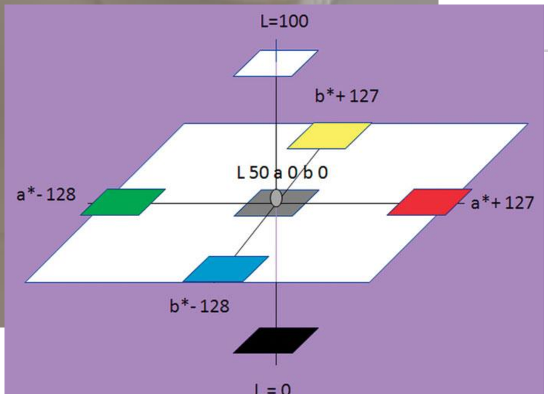
What is reported in literature?

- Porridge:
  - Bovell-Benjamin et al. (1999):
    - unfortified <-> fortified maize porridge
    - Whole meal porridge
    - Brighter yellow color for unfortified
    - Sulfate, bisglycinate, trisglycinate, EDTA
    - Biglycinate highly increased racidity in maize flour

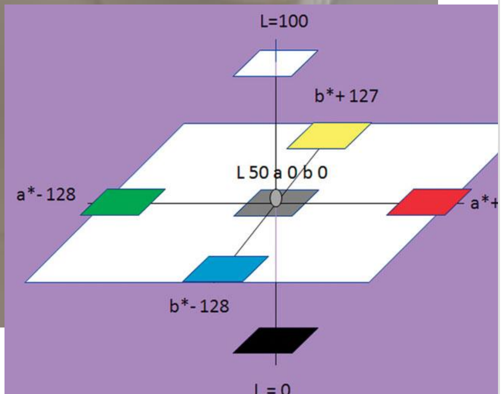
Q1: DO IRON SOURCES IMPACT COLOUR PROFILE OF PORRIDGE?

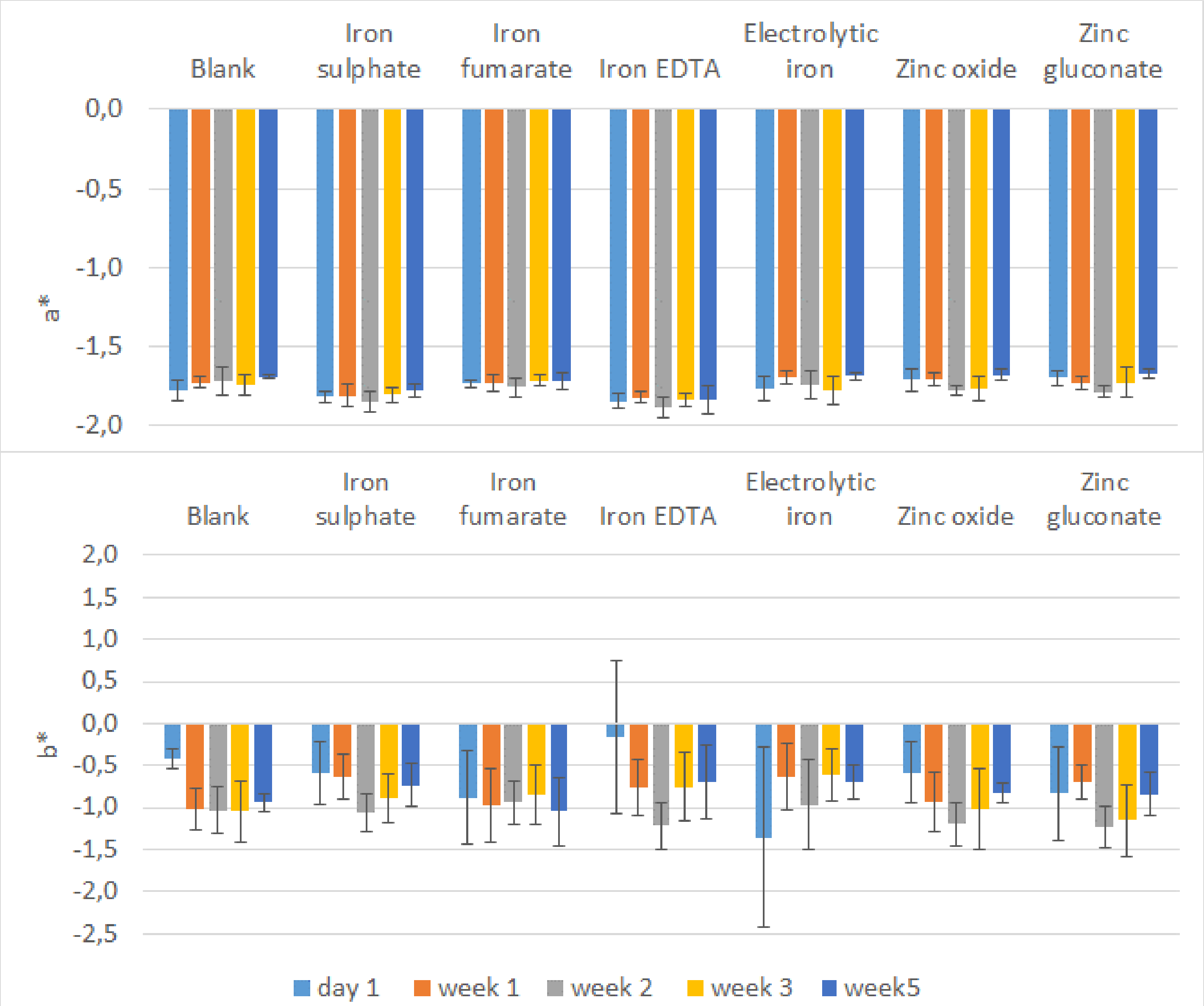
Impact of Fe/Zn-source on colour



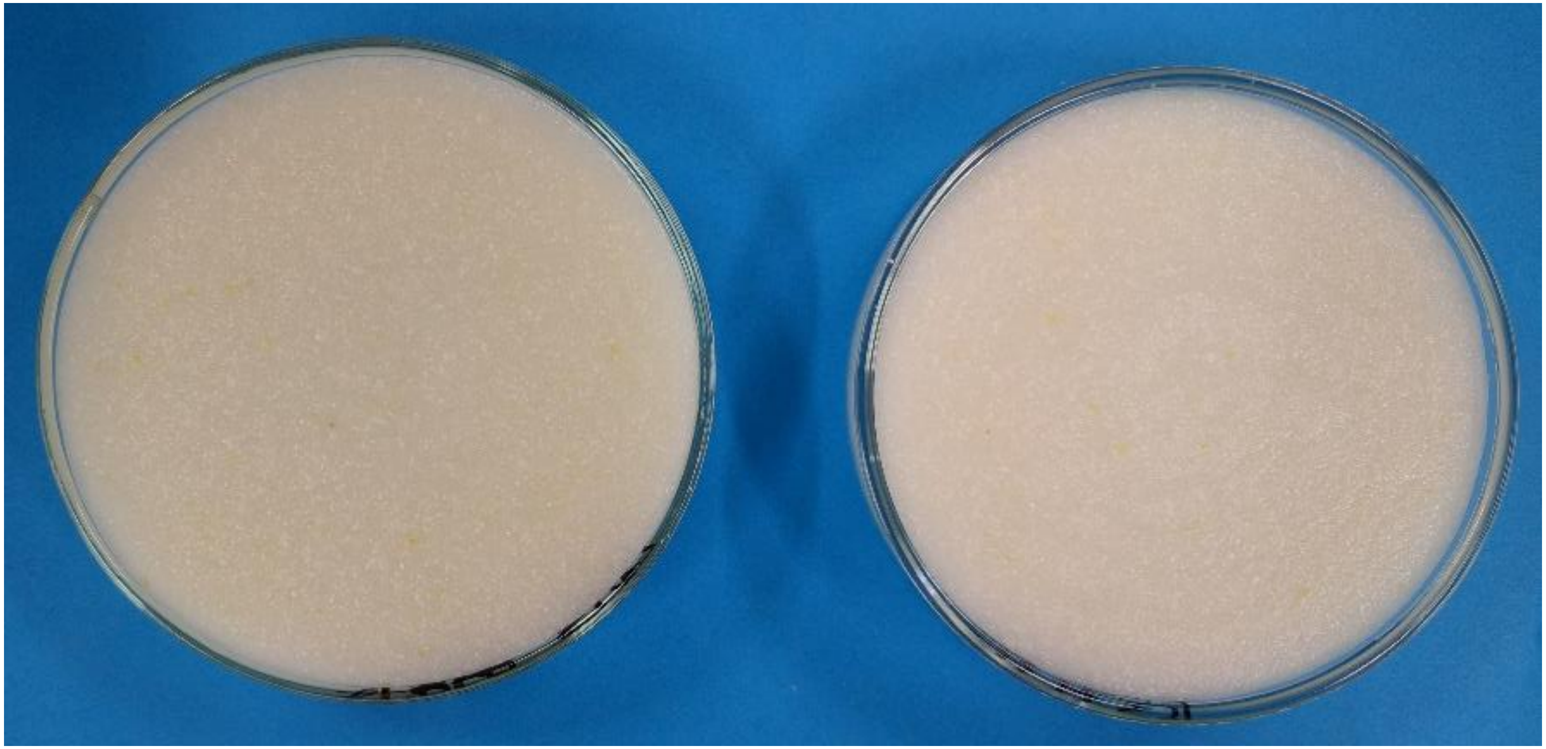


Impact of Fe/Zn-source on colour



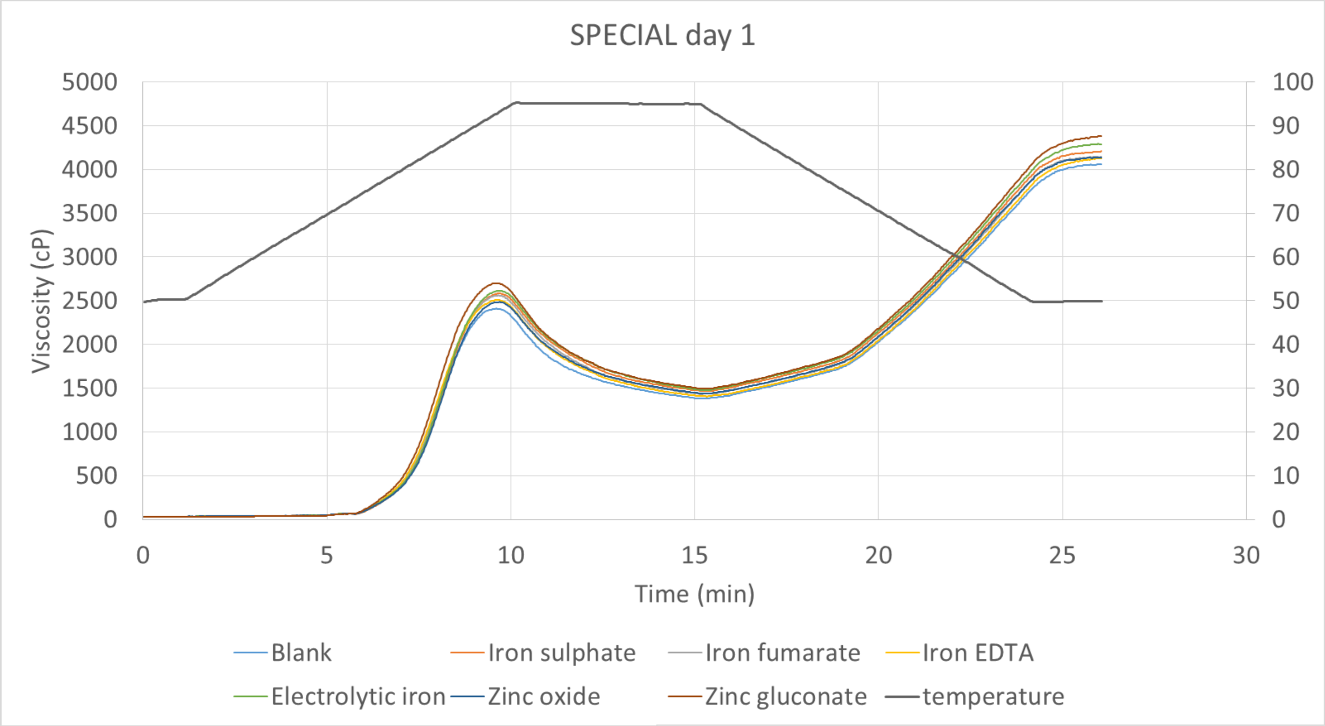


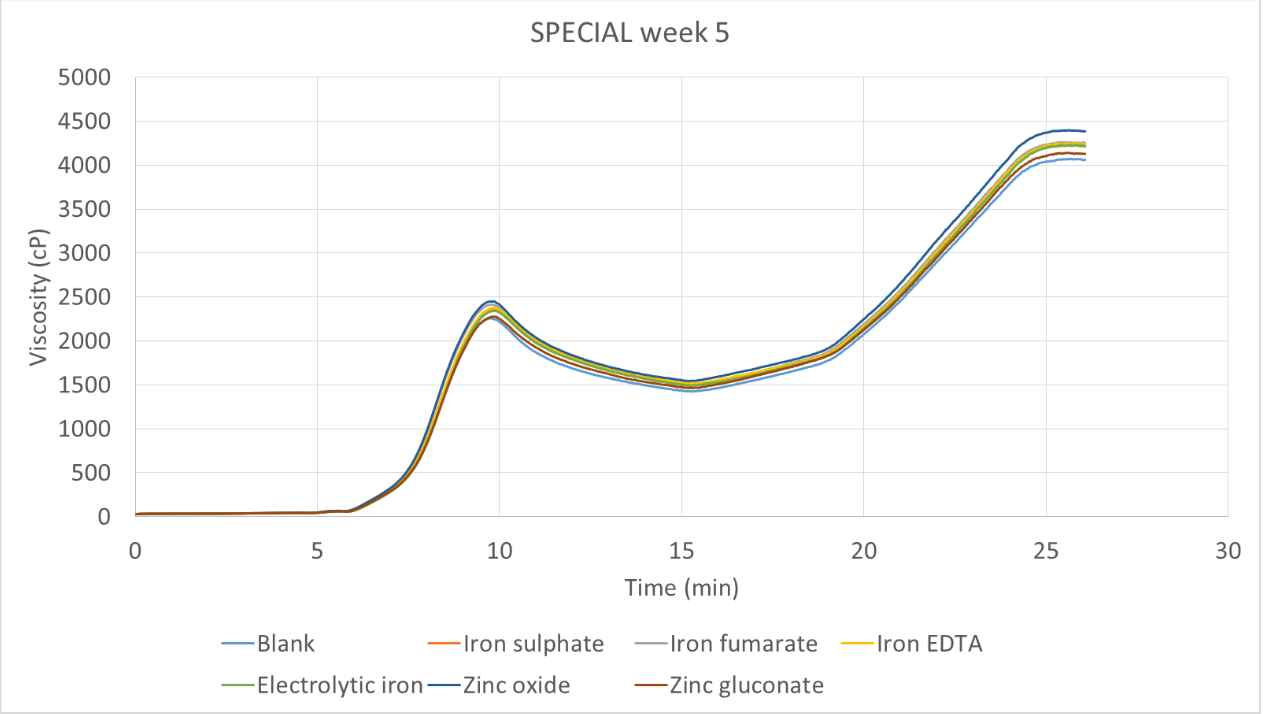
Which one is fortified?



SupperSun - Iwisa

Q2: DO IRON SOURCES IMPACT PASTING PROFILE OF MAIZE MEAL?


SPECIAL day 1
Viscosity (cP)
Time (min)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
Blank
Iron sulphate
Iron fumarate
Iron EDTA
Electrolytic iron
Zinc oxide
Zinc gluconate
temperature


SPECIAL week 5
Viscosity (cP)
Time (min)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0
5
10
15
20
25
30
Blank
Iron sulphate
Iron fumarate
Iron EDTA
Electrolytic iron
Zinc oxide
Zinc gluconate

Q3: DO IRON SOURCES ALTER THE SENSORY PERCEPTION OF MAIZE MEAL PORRIDGE?

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

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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 (SAGL)

Flour Fortification

14. Waddel J. The bioavailability of iron sources and their utilization in food enrichment. Fed Proc 1974;33:1779–83.
15. Borenstein B, Gordon H.T. Van Nostrand Reinhold, 2nd ed. In: Fennema OR, ed. Food chemistry. New York: Marcel Dekker (USA) 1988.

and maize meal:

Ferrous sulfate was not added to the maize meal because it had previously been reported [14, 15] that it could cause undesirable blue or green colors in cooked products made from maize meal.

consumption (WHO

- Ferrous fumarate ($FeC_4H_2O_4$): 60 ppm Fe
- Ferrous sulfate ($FeSO_4$): 60 ppm Fe

– Maize meal: @>300 g/day consumption (WHO guideline level)

- NaFeEDTA: 15 ppm Fe
- Ferrous fumarate ($FeC_4H_2O_4$): 25 ppm Fe

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?

Tanzanian Maize Meal – Mill (uji)

EDTA - Control

Control - Fumerate

Tanzanian Maize Meal - TFNC

Tanzanian Maize Meal – TFNC - ugali

Results

- Bakhresa Mills (Tanzania) => Ugali
  - "Some slightly different colour" with EDTA and Fumerate described as faintly "greenish white" when directly compared to each other but all considered acceptable.
  - Taste = normal

- Food and Nutrition Centre (Tanzania)=> Ugali and Uji
  - No differences

Results

- 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: maize meal

- 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 Sensory properties of the porridge

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

General Conclusion

- No differences in colour were found for super maize meal porridge by using colorimeter measurements.
- Some slight differences in colour were noticed in Tanzania sensory trials but all acceptable
- Fe-sources do not lead to changes in the cooking properties of maize meal.
- Further research needed on storage conditions of maize meal and impact of all premix components

What to do when starting with fortifying?

- Before starting up with fortifying -> check impact on product quality
- Make sure premix specifications (types, conc, quality…) are set right and clear from the beginning
- Use slightly higher concentrations (overdosage taking into account mill variation)
- Use in-land procedures and products
- Act smart: do we observe a difference? -> Is this difference acceptable

Nil Volentibus Arduum

(nothing is impossible to the valiant)