Bioavailability of micronutrients from whole foods:

Zooming in on dairy, fruit and vegetables

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Organised by the European Milk Forum

Conflict of Interest Disclosure

I have received financial support from the European Milk Forum to cover the costs of travel and accommodation for participation in this conference

EMF had no direct role in the lecture content

Lecture content

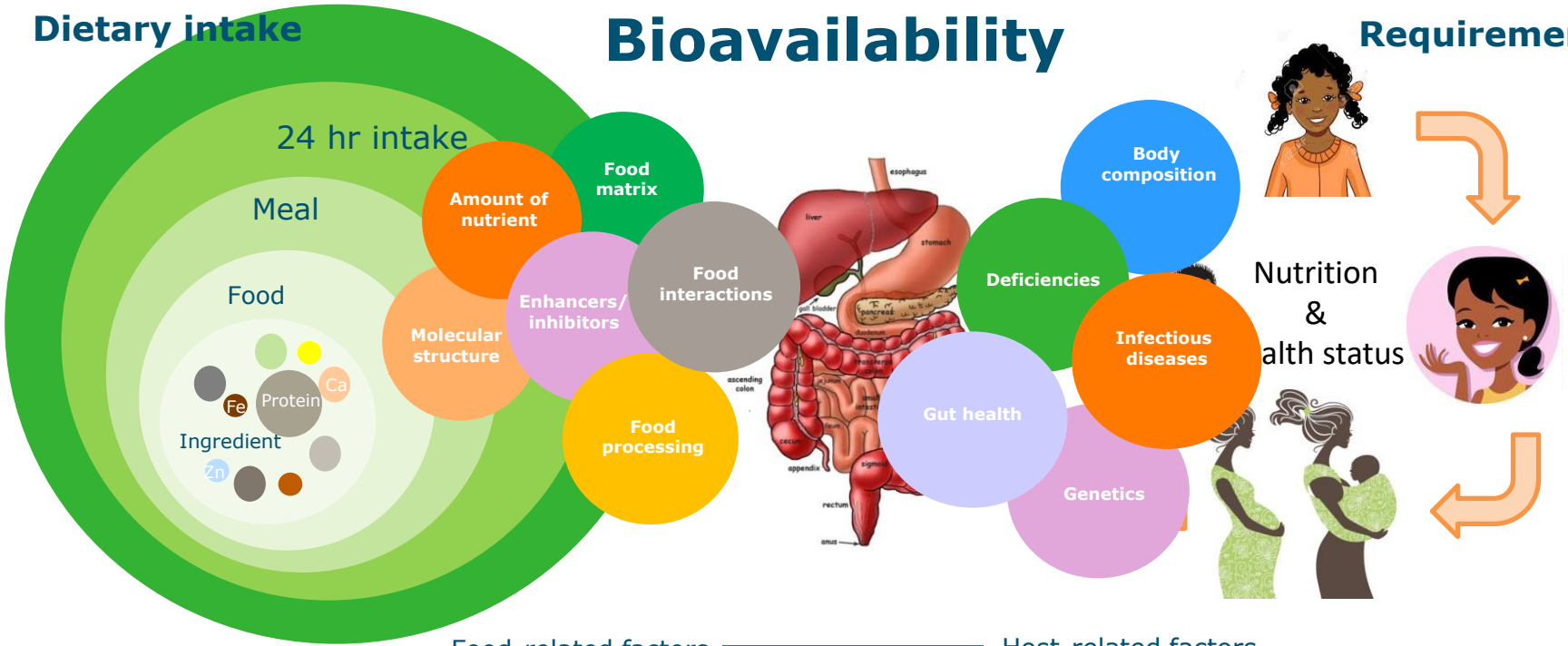
- Terminology, concept, and methodologies
- Overview of bioavailability of micronutrients
    - Milk and dairy
    - Fruits and vegetables
- Some remarks for further thought and exploration

Nutrient bioavailability - terminology

- **Fractional absorption**: fraction of nutrient absorbed from the diet
- **Bioavailability**: fraction of nutrient absorbed from the diet and used for physiological function or storage (retained in the body)
- **Bioconversion**: Proportion of ingested nutrient absorbed and converted to active form of nutrient (vitamins)
- **Bioefficacy**: Proportion of ingested nutrient absorbed and converted to active form of nutrient, and used for physiological function or storage

No clear consensus on terminology!!!

Bioavailability is an important intermediate between dietary intake and requirements



SLAMENGHI:
A mnemonic for carotenoid bioavailability

- **S**pecies of the nutrient
- Molecular **L**inkage
- **A**mount eaten in a meal
- **M**atrix in which the nutrient is located
- **E**ffectors of absorption & bioconversion
- **N**utrient status of the host
- **G**enetic factors
- **H**ost-related factors
- Mathematical **I**nteractions

West & Castenmiller, Int J Vit Nutr Res 1998;68:371-377

Dr. Clive E West

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Methods to assess micronutrient bioavailability

In vitro techniques

- Designed to simulate the *in vivo* environment
- Based on simulated digestion process
- Assessment of element availability

Bioaccessibility, dialysability, cellular uptake

Advantages: Fast, inexpensive, highly controllable
Disadvantages: semi-qualitative, only provides a proxy to *in vivo* bioavailability

In vivo techniques

- Animal vs. human studies
- Various techniques (e.g. chemical balance, isotopic)

Apparent/true absorption, bodily retention, bioavailability, bioconversion, bioefficacy

Advantages: Quantitative

Disadvantages: Complex, expensive, less well controllable

Screening, hypothesis testing —*Designing*→ *In vivo* experiment

Explaining unexpected findings

Micronutrient bioavailability from milk and dairy

Vitamins	Bioavailability	Enhancers	Inhibitors
Vitamin A	15%	Fat	
Vitamin B2	67%	Non-covalent binding to protein	Covalent binding
Vitamin B_{12}	65%	Binding to transcobalamin or casein	Binding to haptocorrin
Vitamin K-2	??	Dietary fat Fermentation products Long chain menaquinones (MK7-9)	Medium-chain menaquinones (MK4)

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Micronutrient bioavailability from milk and dairy

Minerals	Bioavailability	Enhancers	Inhibitors
Calcium	40%	Binding to casein and whey peptides Lactose, amino acids Vitamin D (fortification)	Phosphorous Sulfur-containing proteins
Phosphorus	??	Binding to casein and whey peptides; binding to phospholipids	Complexing with unbound phosphorus
Magnesium	25-75%	Binding to casein and whey peptides; lactose	High dosing
Zinc	25-30%	Mild acidic conditions; binding to casein and whey peptides; low molecular ligands (amino acids, organic acids)	
Iodine	90%	Inorganic, unbound	

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Micronutrient bioavailability from vegetables & fruits

Vitamins	Bioavailability	Enhancers	Inhibitors
Provitamin A	0-36%	Lipid droplets; dietary fat	Entrapment in cell matrix/structure; crystallization; dietary fiber
Folate	60-98%	5-Methyltetrahydrofolate vitamer	Presence of polyglutamate chain
Vitamin C	80-90%	Vitamin E	Flavonoids
Vitamin K1	5%	Fermentation products	Entrapment in cell matrix/structure

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Micronutrient bioavailability from vegetables & fruits

Minerals	Bioavailability	Enhancers	Inhibitors
Potassium	60-85%		Food matrix of unprocessed vegetables and fruits
Calcium	20-40%		Phytate; oxalate
Magnesium	25-35%	Protein; medium-chain triglycerides; indigestible carbohydrates	Phytate; oxalate; cellulose; lignin; pectin
Iron	~12%	Vitamin C; lactic fermentation	Entrapment in cell matrix/structure; phytic acid

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Further reading

REVIEW
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Bioavailability of Micronutrients From Nutrient-Dense Whole Foods: Zooming in on Dairy, Vegetables, and Fruits

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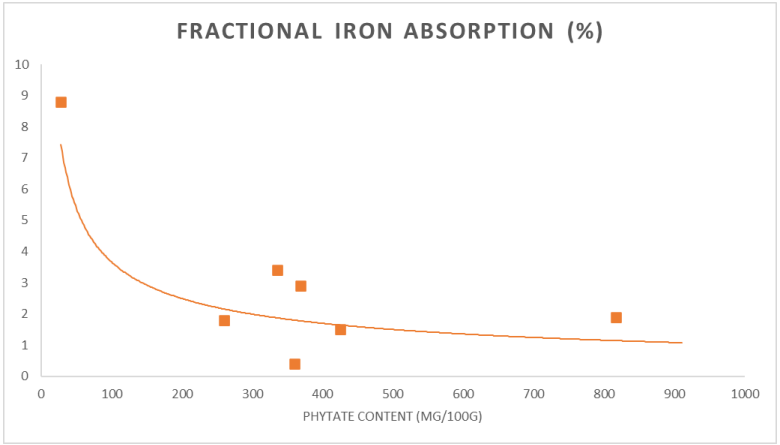
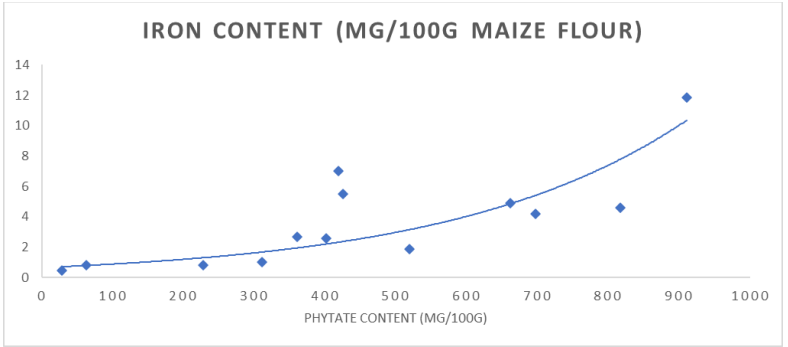
Remarks for further thought and exploration

1. Fractional nutrient absorption should always be seen in the context of total nutrient intake

Iron absorption from whole meal maize flour





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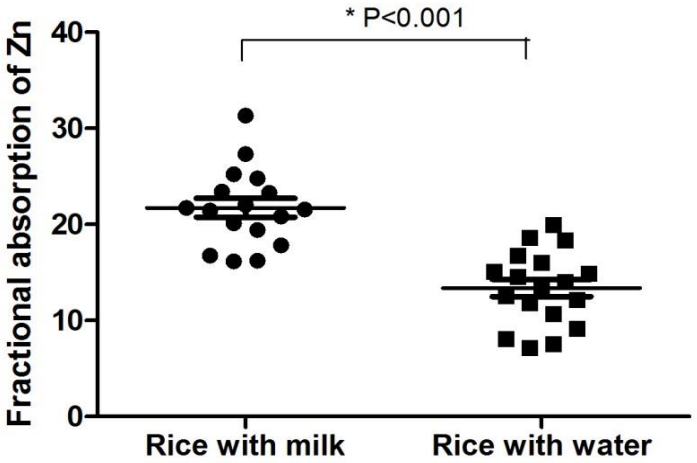
Some remarks for future thought and exploration

1. Fractional nutrient absorption should always be seen in the context of total nutrient intake
2. Nutrient bioavailability depends on meals, not on single foods or ingredients

Milk enhances absorption of zinc from high-phytate rice



FAZ, %	**20.8 ± 3.8[a]**	**12.8 ± 3.7[b]**

Talsma et al., J Nutr 2017;147:1086-1093

Guava fruit enhances absorption of iron, but not of zinc, from a rice-based meal

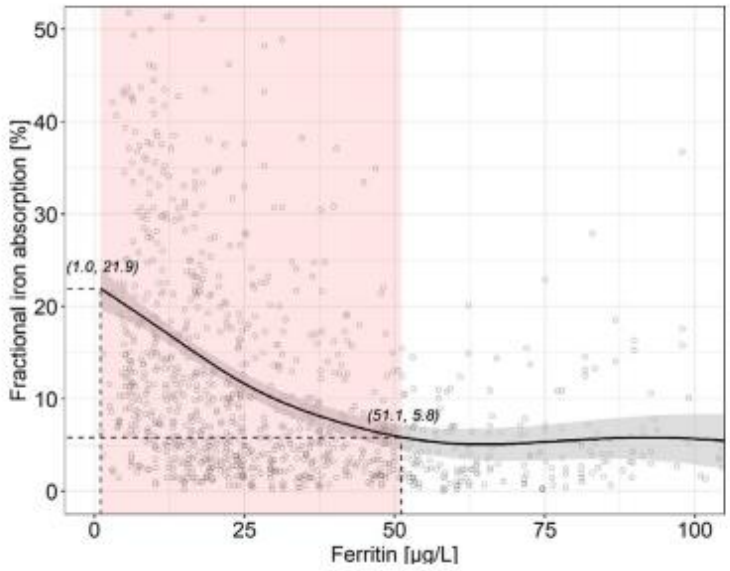
	Girls		Boys	
Mineral	Regular	Modified	Regular	Modified
Iron	9.7 ± 6.5	23.9 ± 11.2	8.6 ± 4.1	19.2 ± 8.4
Difference		14.2 ± 14.5*		10.6 ± 10.4*
Zinc	26.9 ± 6.4	27.3 ± 7.4	32.5 ± 16.6	37.1 ± 3.0
Difference[3]		0.5 ± 6.3		4.6 ± 10.9
Reference dose: ^{58}Fe[4]	58.2 ± 22.2		48.9 ± 16.0	

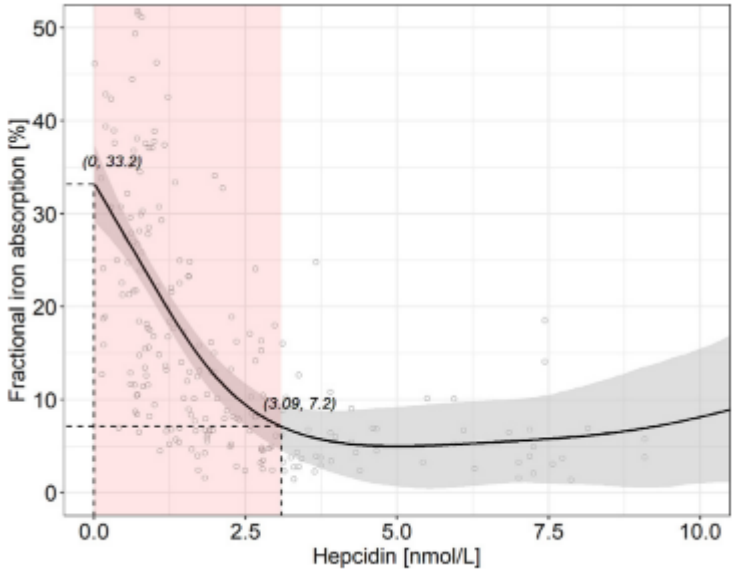
Nair et al., J Nutr 2013;143:852-858

Some remarks for future thought and exploration

1. Fractional nutrient absorption should always be seen in the context of total nutrient intake
2. Nutrient bioavailability depends on meals, not on single foods or ingredients
3. Host-related factors can also strongly determine nutrient bioavailability

Iron absorption strongly depends on iron status of the host





Galetti et al., EClin Med 2021;39:101052

Key messages

- Bioavailability is an important intermediate between dietary intake and nutritional requirements
- Milk and dairy products generally contain many enhancers and few inhibitors of nutrient absorption and bioavailability
- Vegetables and fruits have more complex structures that can hamper nutrient absorption
- Nutrient bioavailability is not a fixed number, but the resultant of complex interplay between food-related and host-related factors

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Nutritional Methodologies and Mathematical Modeling

Iron Bioavailability Should be Considered when Modeling Omnivorous, Vegetarian, and Vegan Diets

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Thank you