Why and When is Food Fortification Useful?

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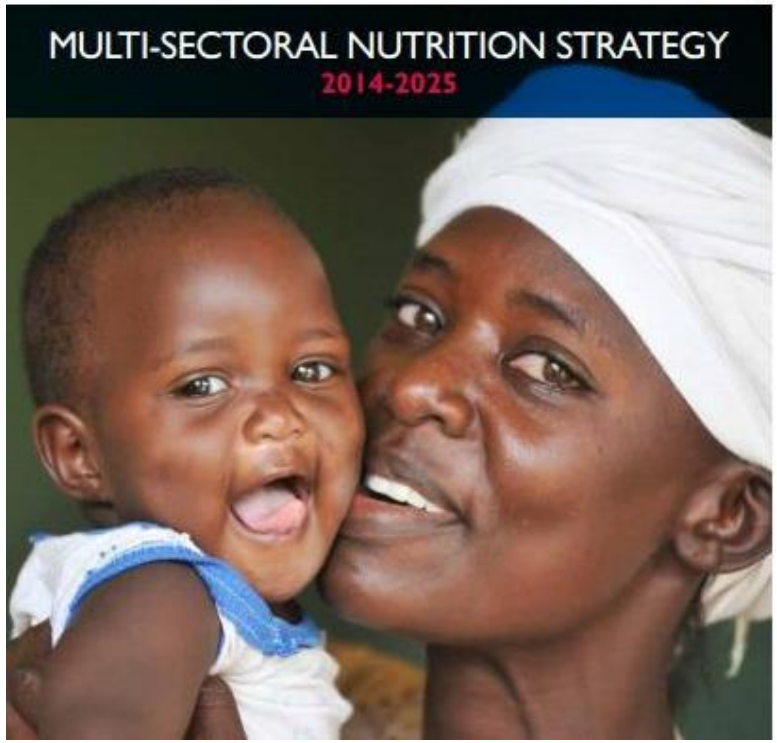

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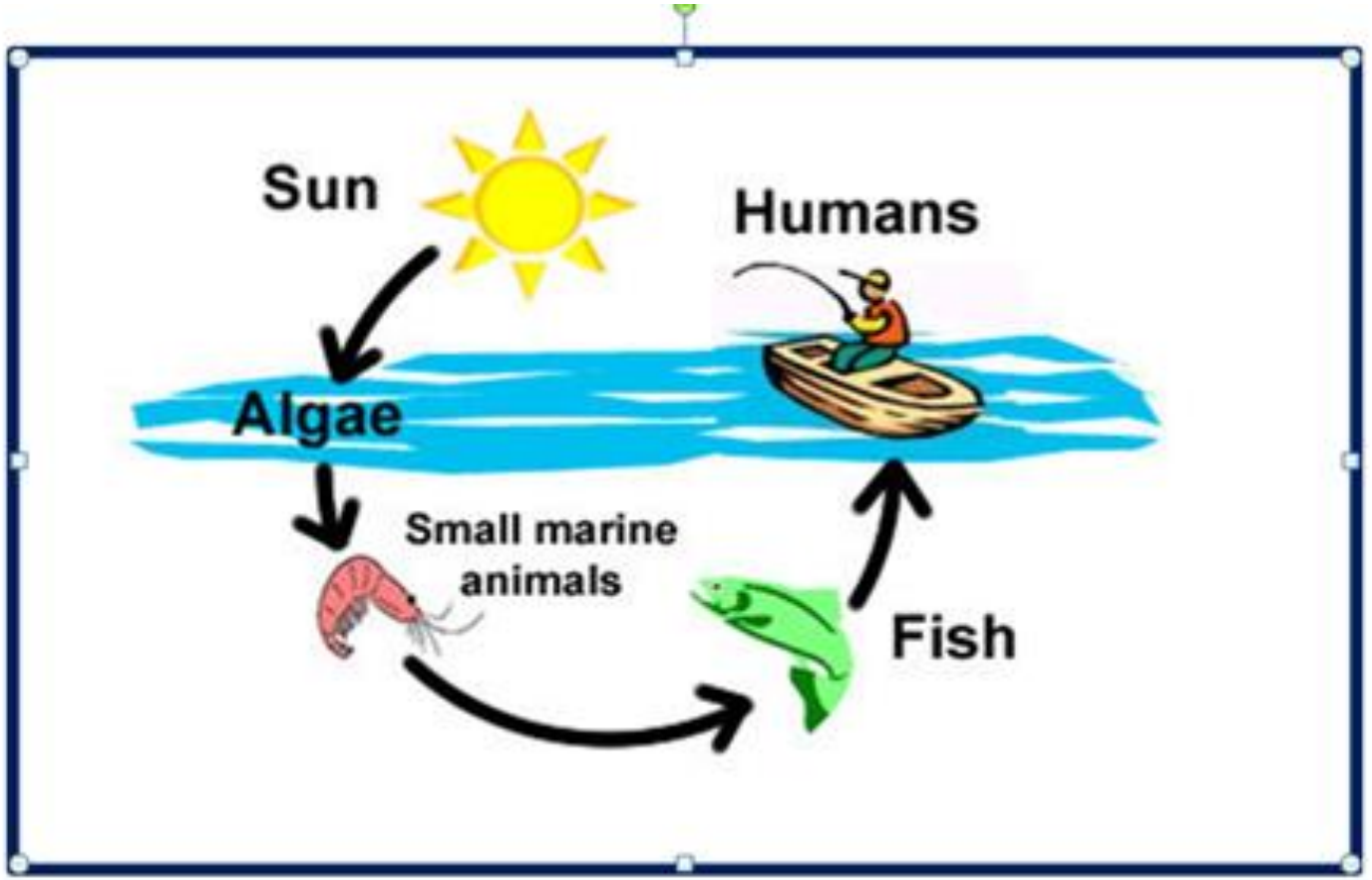
Outline

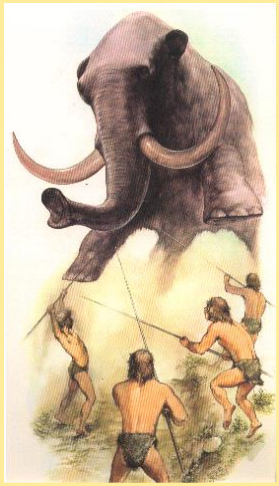
1. The omnivorous nature of the human being
2. Why vegetarian diets are usually nutritionally inadequate?
3. A few examples of consequences of micronutrient deficiencies
4. Strategies to improve micronutrient supply
5. Comparison of fortification of staples vs other micronutrient-delivering strategies

The food chain



Taken from: http://ashleighrebeccakasie.weebly.com/lesson-7-food-cycles.html

The human being evolved as an omnivorous species



Nutrient	Paleolithic *	Modern Developed *	Modern Developing **
Fat	35 %	32 %	18 %
Proteins	30 %	17 %	10 %
Carbo-hydrates	35 %	49 %	≈ 72 %
Alcohol	None	2 %	?

* Arjamaa and Vuorisalo, Am. Scientist 2010; 98: 140-147.

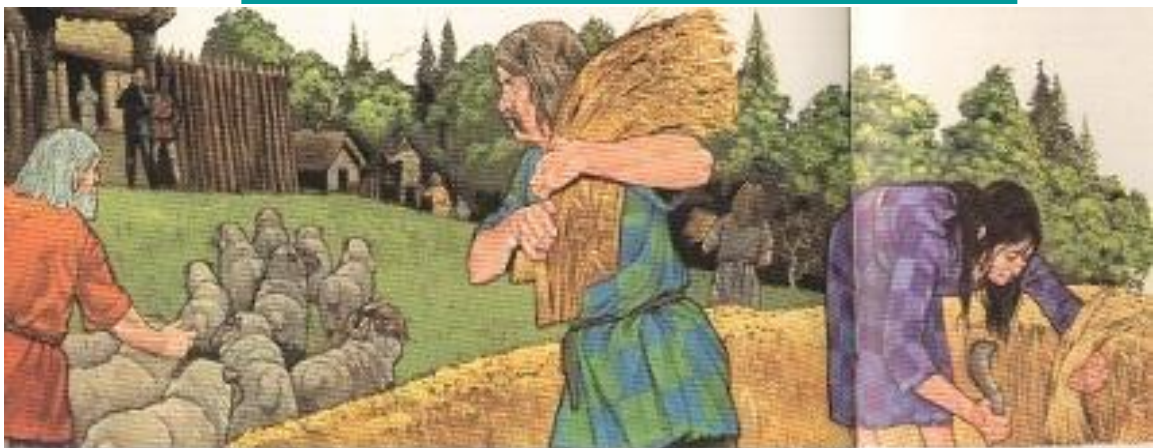
** A2Z, Micronutrient Survey. 15-49 years old women, 2008, Kampala, Uganda.

Types of lingual papillae:

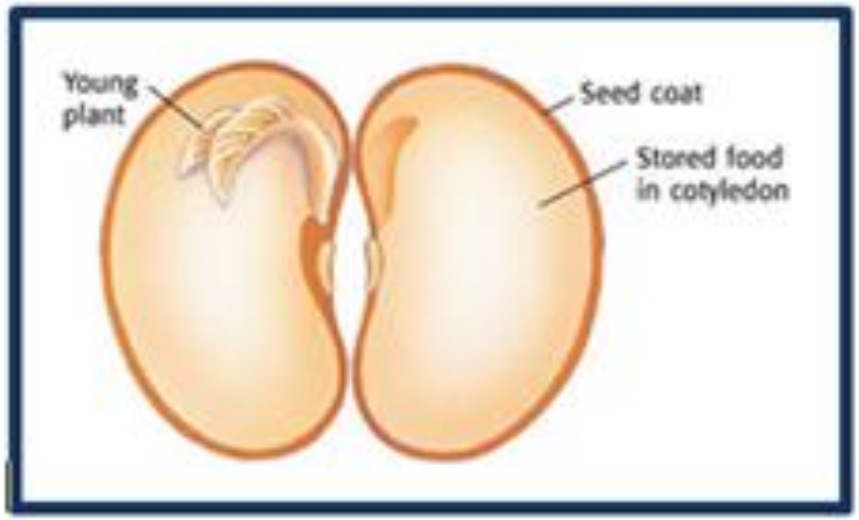
Bitter
Salty
Sweet
Sour

Umami (meat taste)
MSG

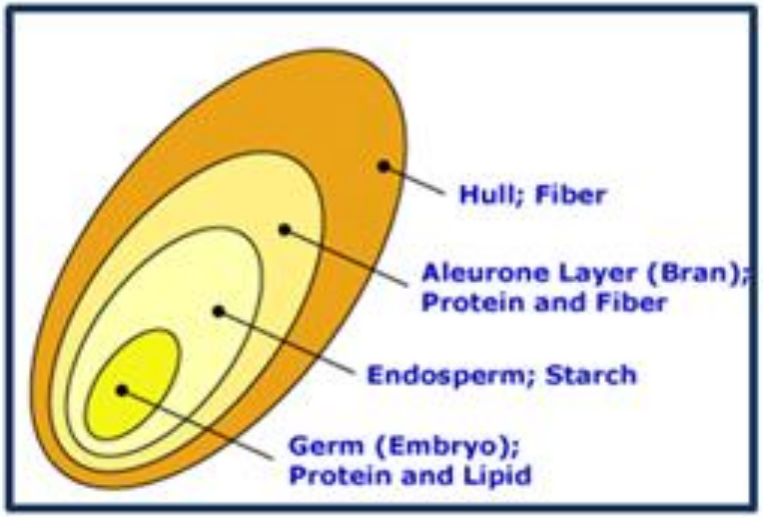
Pictures taken ffrom presentation by Noel Solomons, CESSIAM



Nutrients in legume and cereal seeds

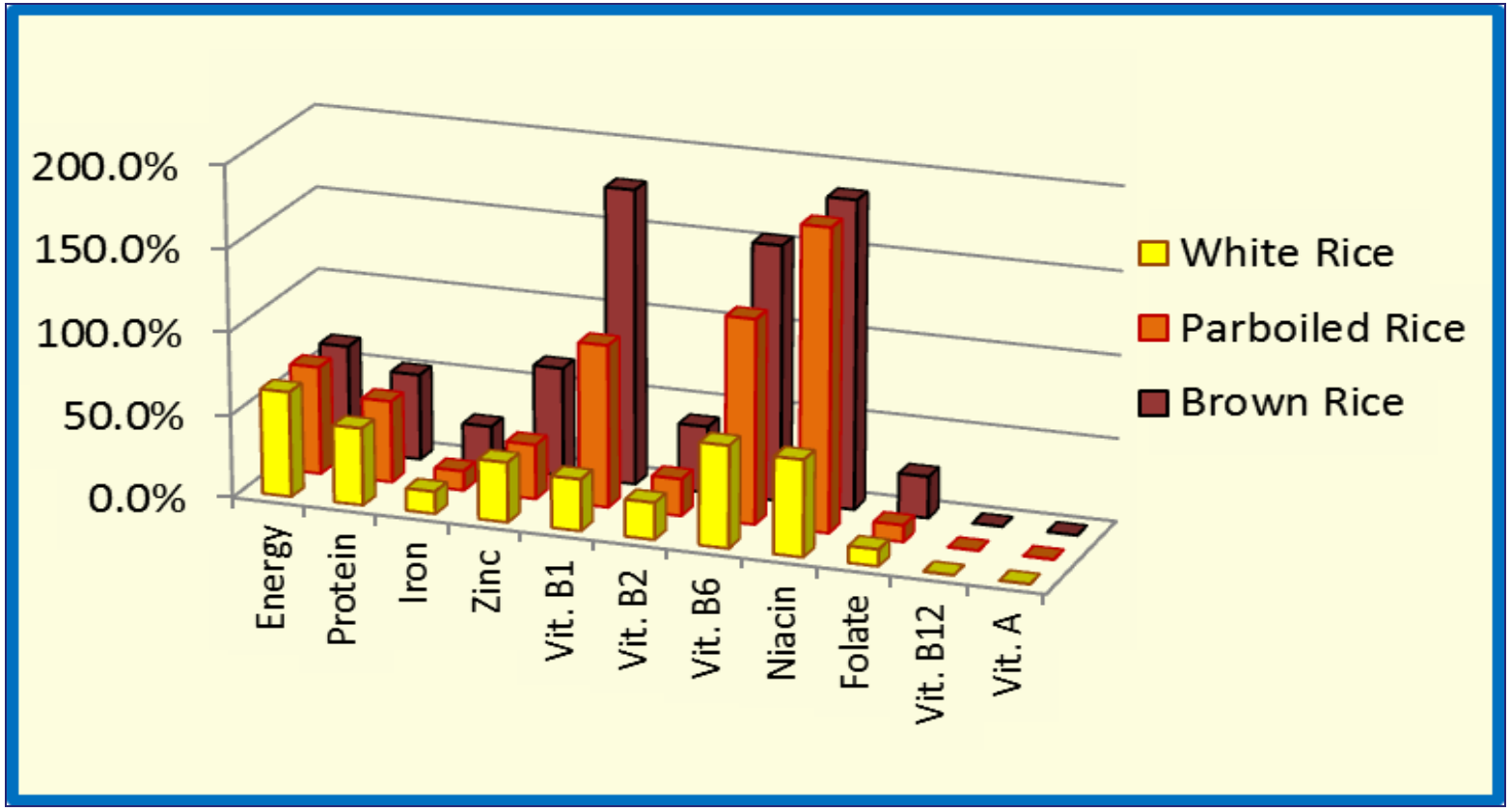


Taken from:
http://www.aaps.k12.mi.us/reced.greencamp/jason_s_class



Taken from:
https://courses.ecampus.oregonstate.edu/ans312/two/cereal_trans.htm

Nutrient contribution (% EAR) of 400 grams rice per day for women of child-bearing age



Source of nutrient content of rice : USDA Food Composition Table (http://ndb.nal.usda.gov/)

Note: Absorption of iron and zinc for brown rice may be half.

Nutrient Intakes: Supply of minerals by different food groups

Minerals/ Others	Milk	Eggs	FMP[1]	Cereals, roots tubers	Pulses nuts seeds	ProVA fruits & vgt.	Other fruits & vgt.	Oil, ref. flours, sugar
Iron	-	(+)	+++	(++)	(+++)	(++)	(++)	-
Zinc	-	-	+++	(+)	(++)	(+)	(+)	-
Copper		++	++	-	(++)	(+)	(+)	-
Calcium	+++	+	+	(+)	(++)	-	(+)	-
Iodine	-	-	-	-	-	-	-	-
Fiber	-	-	-	XX	XX	X	XX	-
Phytates	-	-	-	X	XX	-	-	-
Polyphenols	-	-	-	-	XX	-	-	-
Oxalates	-	-	-				XX	-

Notes: [1] FMP = Fish, meat, poultry; X = relative density, non-nutrient;
+ = Relative density of the micronutrient.; ( ) low absorption in humans

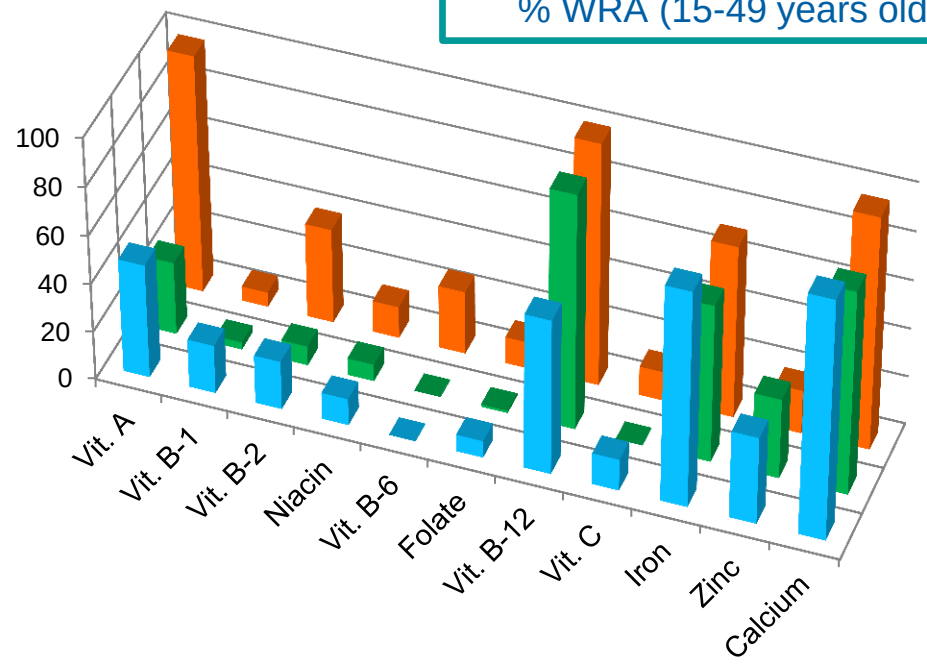
Nutrient Intakes: Supply of vitamins by different food groups

Vitamins	Milk	Eggs	FMP[1]	Cereals, roots tubers	Pulses nuts seeds	ProVA fruits & vgt.	Other fruits & vgt.	Oil, ref. flours, sugar
Vit. B-1	+	++	+	++	+++	+	++	-
Vit. B-2	+++	++	++	+	+	+	++	-
Niacin (B-3)	+	+	+++	++	++	+	++	-
Vit. B-6	++	++	++	++	++	++	++	-
Folate (B-9)	-	+	+	+	++++	+	++	-
Vit. B-12	++	++	+	-	-	-	-	
Vit. C	+	-	-	-	-	+++*	+++*	-
Vit. A	++**	+++	+	-	-	++	(+)	-
Vit. D	++**	++	+	-	-	-	-	-
Vit. E	+**	+	+	++	+	++	++	+[oil]

Notes: [1] FMP = Fish, meat, poultry; * if consumed fresh and raw; ** non-defatted

+ = Relative density of the micronutrient.; ( ) low absorption in humans

Micronutrient inadequacies in Uganda



Harvey *et. al Determining the Dietary Pattern of Ugandan Women and Children.* A2Z Project. 2010.

Main Deficiencies: Vit. A, vit. B-12, iron, and calcium, mild zinc;
Kampala: some vitamin B-1, B-2, niacin, folate, and vit. C;
Northern region: Some vit. B-1, B-2, niacin, vit. B-6, folate, and vit. C.

Specific nutritional deficiencies or now "Hidden hunger"

Characteristics	Consequences are independent from the protein-energy intake (i.e. quality of the diet is essential)	
Traditional (1990 Children Summit)	Iodine-now in iodized salt, Vitamin A –in capsules-, Iron (the "big three")	
Nowadays* (in addition to the big 3)	**Developed**	**Developing**
	Folate, Vit. D, Vit. C	Vit. B_{12}, Zinc, Vit. B_2
	Calcium	

* In general, but with contextual exceptions

Consequences of zinc deficiency

- **Impairment of the immunological response**
- **Growth and cognitive retardation**
- **Hypogonadism**
- **Oxidative stress (zinc in the super-oxide dismutase enzyme)**
- **Neurotransmission malfunctions, lethargy, non-discriminating taste**
- **Skin lesions**
- **Alteration on DNA-structure and transcription**

Consequences of folate and/or B_{12} deficiencies

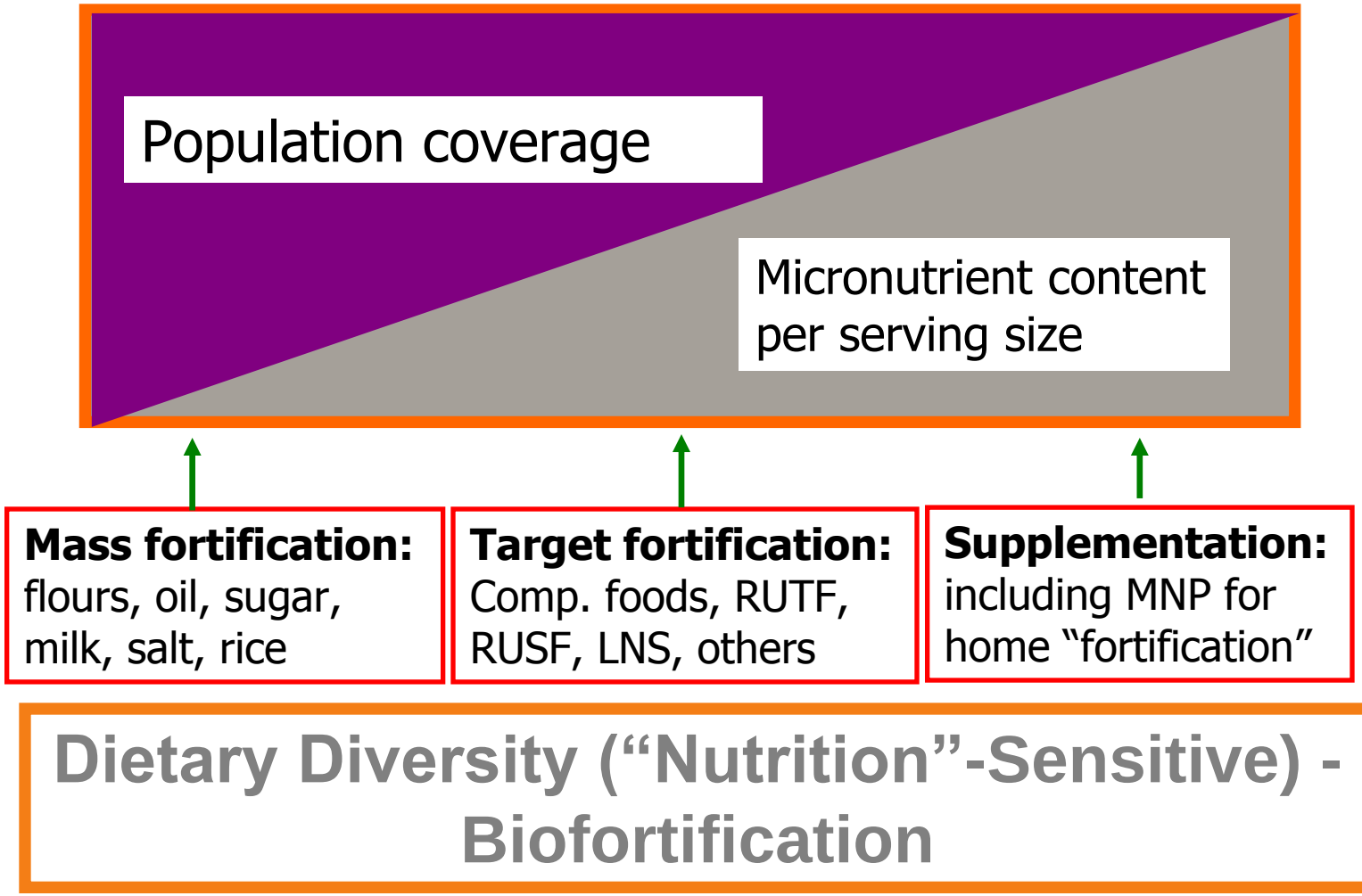
Neural tube defects within 28 days after conception.

Discapacities:

- Leg paralysis
- Hydrocephaly
- Bad control of bladder and intestinal evacuations
- Learning difficulties

Modified from Jorge Rosenthal

Strategies for micronutrient-delivering



Comparing mass-fortification (i.e. fortification of staples) with other micronutrient strategies

Item	Supplement MNP - 1 g	LNS's – 20 g	Blended flours 42 g	Fortified staple – 50 g
13 micronutrients*	$0.0030	$0.0015	$0.0027	$0.0028**
+ Ca and Mg ***	-	$0.0034	$0.0050	-
Cost product	**$0.03-0.04**	**$0.10-0.14**	**$0.14**	**$0.025**
Energy (kcal)	4	118	180	180
Protein (g)	-	2.6	16.0	4.9
Ess. Fatty acids	NO	YES	YES	NO
Distribution Cost	$0.03-0.04	$0.03-0.14	$0.10-0.20	$0.00

* Cost in 2013 for the WHO formula of MNP to use in emergencies (i.e. 100% RDA/AI, exc. iron -86%- zinc -49%) for 1-3 years old children, and without considering cost of selenium and copper. In this case, about 50% of the cost is due to the addition of vitamin E, and vitamin C.
** Although vitamin C would be difficult to be added in most staple foods, and providing sufficient amounts of some micronutrients may be uncertain. *** LNS and blended flours may also contain Phosphorus, Potassium, and vit. K, but their costs were not added here.

Thus: Consideration of other complementary strategies is always needed

Characteristic	Biofortification	Food Fortification	Supplementation
Impact	Additional quantity and quality of the supplied micronutrients (very little to do with the carrying vehicle).		
Principle	Increase nutrient content through selection and breeding of basic vegetable crops	Incorporation of micronutrients to the edible vehicles during the manufacturing process	Syrups/tablets/powders, of micronutrients consumed with/without foods (home-"fortification")
PROGRAMMATIC EFFICIENCY (Sustainability)			
Feasible to produce	√	√√	√√√
Easy to deliver	√√√	√√*	√
Accessed by consumers	√√	√√√*	√
Practical to monitor	√	√√*	√√√
Viable <u>total</u> cost.	√√	√√√*	√

* If produced by centralized and reasonable-developed food industries.

Fortification requires participation of medium/large size industries

Item	Medium 50-250 MT/day	Small 20-50 MT/day	Village 1 – 5 MT/day
#Factories	10	50	500
Inspections/year*	20	100	1,000
Analysis/year **	100	500	5,000
Cost (US$)	US$ 3,000	US$ 15,000	US$150,000

Assumptions: * US$100/visit, ** US$10/sample

Deduction: Although fortified product manufactured by small industries might be efficacious –impact depends on the micronutrient supply and not in the delivering vehicle; programmatic efficiency and sustainability are very difficult or impossible.

Understanding the evolving concept of food fortification

Food Fortification: It is the addition of micronutrients to foods, whether or not they are normally contained in the food, for the purposes of preventing or correcting a demonstrated deficiency. *Codex Alimentarius*

Food Fortification: It is the practice of deliberately increasing the content of essential micronutrients in a food so as to improve the nutritional quality of the food supply and to provide a public health benefit with minimal risk to health.

WHO/FAO Guidelines on Food Fortification.

Food Fortification: It is the use of edible products, manufactured by the food industry, as carrying vehicles of micronutrients (vitamins and minerals) to increase their supply to populations at risk of inadequacies.

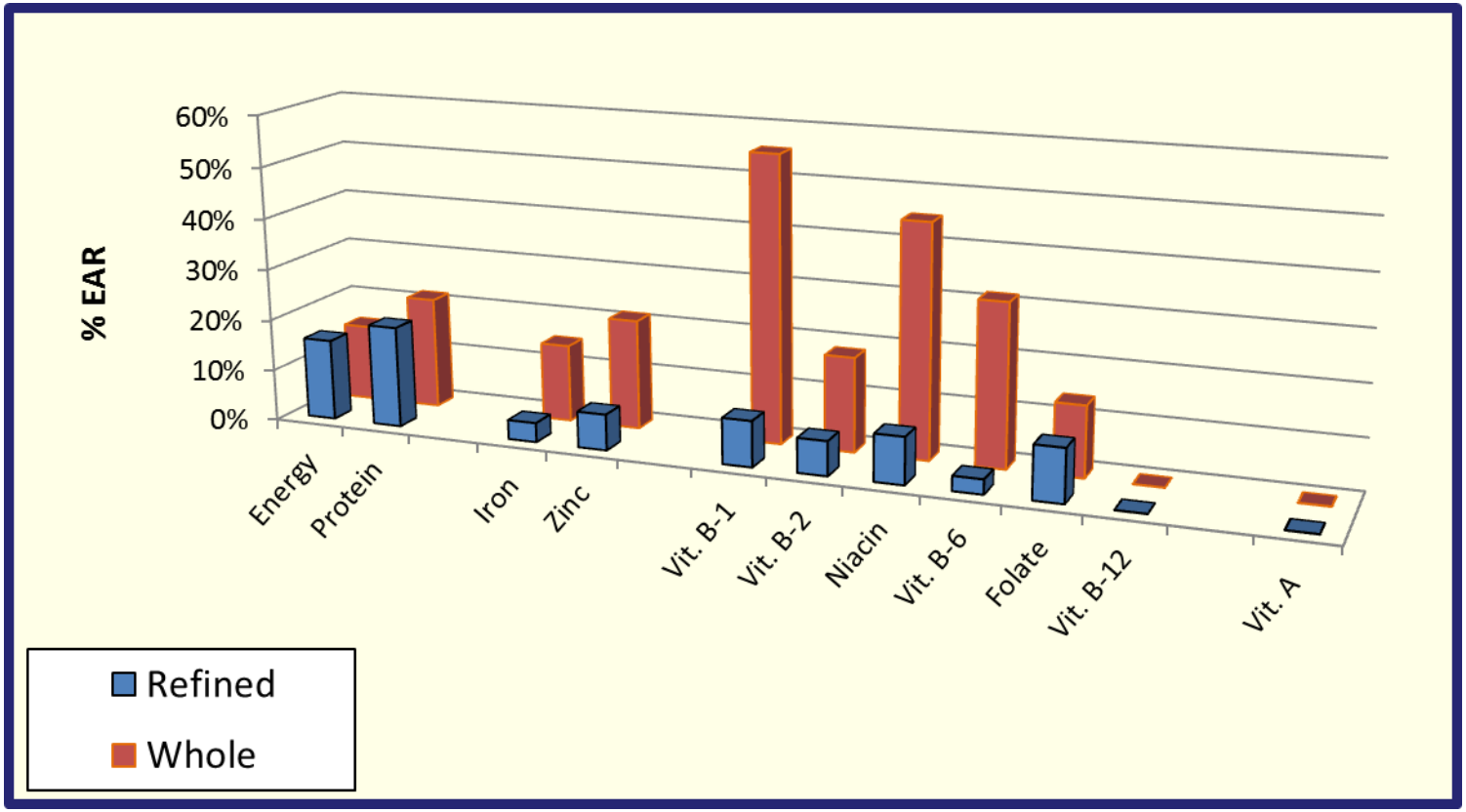
Conclusions-1

1. The omnivorous nature of the human being creates dependence to several food groups.
2. As diets may not contain all the necessary food groups, introduction of micronutrient-delivering strategies is always needed (especially true for certain age- and physiological-groups).
3. Nutrient-density is commonly low in industry-produced foods, and therefore fortification should be a good manufacturing practice;

Conclusions-2

4. Mass-fortification (i.e. fortification of staples) is very attractive mainly because a delivering system (the fortification vehicle) already exists, and therefore its cost is the lowest among the micronutrient-delivering strategies, but only if:
   a) Food is produced by centralized large/medium size food industries;
   b) Food vehicle (fortified food) reaches and is consumed in sufficient amounts by the target population;
   c) The fortified foods (alone or in combination) deliver the insufficient micronutrients with the quality and quantity that are required to fill the nutritional gap.

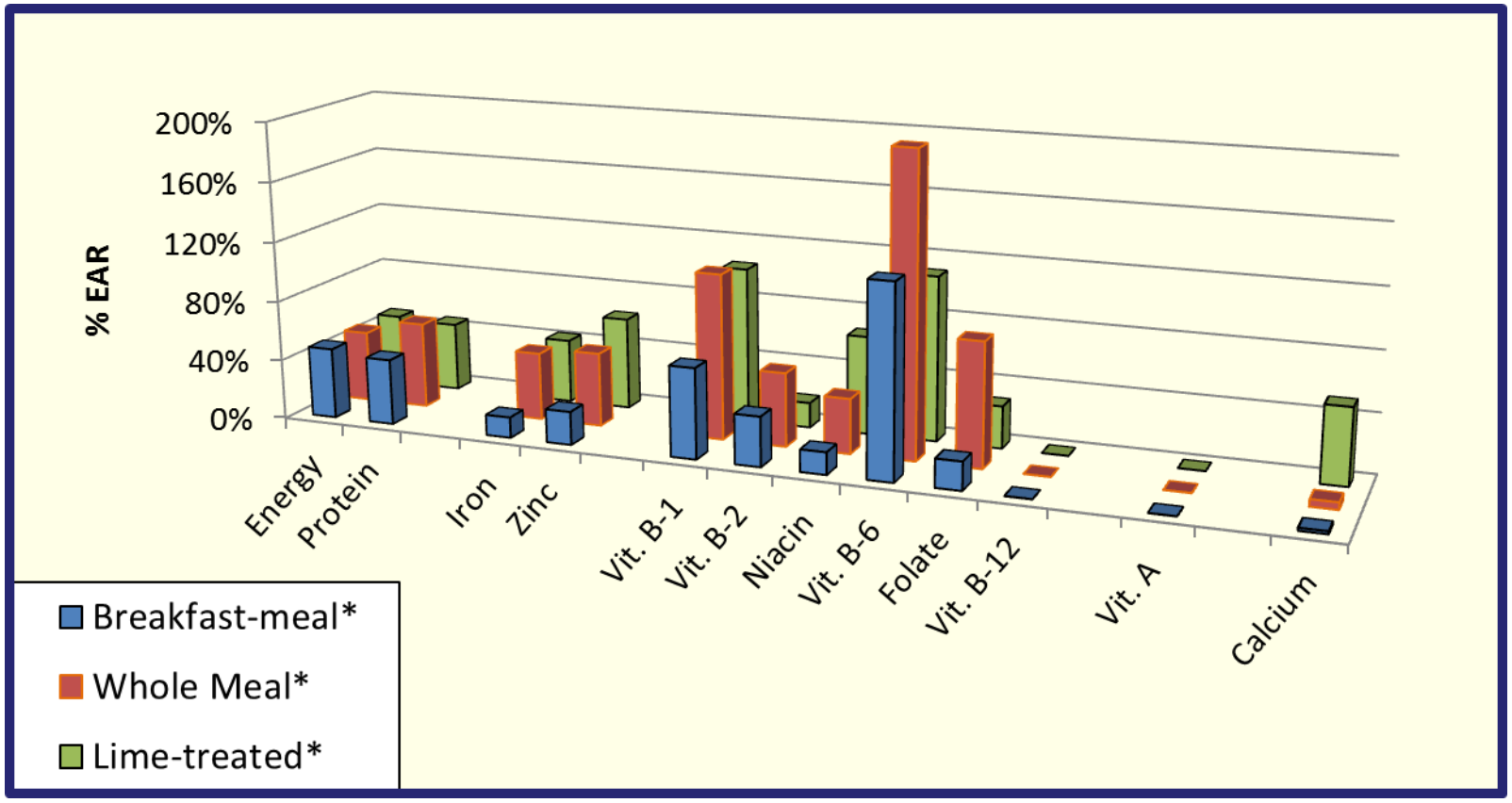
Nutrient contribution (% EAR) of 100 grams of wheat flour per day for women of child-bearing age



Source of nutrient content of w.flour : USDA Food Composition Table (http://ndb.nal.usda.gov/)

Note: Absorption of iron and zinc for whole wheat flour may be half or lower.

Nutrient contribution (% EAR) of 300 grams maize flour per day for women of child-bearing age



Source of nutrient content of maize flour : Data from Zambia, and lime-treated maize flour from the Institute of Nutrition of Central America and Panama, and completed with USDA Food Composition Table (http://ndb.nal.usda.gov/)

Note: Absorption of iron and zinc for whole and lime-treated maize flour may be half or lower.

Consequences of vitamin A deficiency

- Deterioration of ocular conjunctive and cornea
- Less capacity to fight infections
- Alterations in growth and development
- Impaired visual and reproductive capability
- Permanent blindness
- Death

Consequences of iron deficiency

- **Tiredness, lack of energy**
- **Deterioration in detoxifying process**
- **Impairment of the immunological response**
- **Irreversible cognitive retardation (< 2 years old)**
- **Anemia**
- **Maternal mortality**

Consequences of iodine deficiency

Fetus	**Abortion** **Stillborn** **Congenital abnormalities** **• Perinatal mortality** **• Infant mortality** **Neurologic cretinism:** **Mutism, mental retardation – deafness** **Endemic cretinism: dwarfism/ mental deficiency** **Psychomotor impairment**
Infant	**Hypothyroidism / Irreversible mental retardation**
Children and adolescent	**IQ reduced / Goiter / Hypothyroidism / Impaired physical and mental development**
Adult	**Goiter and complications** **Hypothyroidism**