Nutrition and food safety of edible insects

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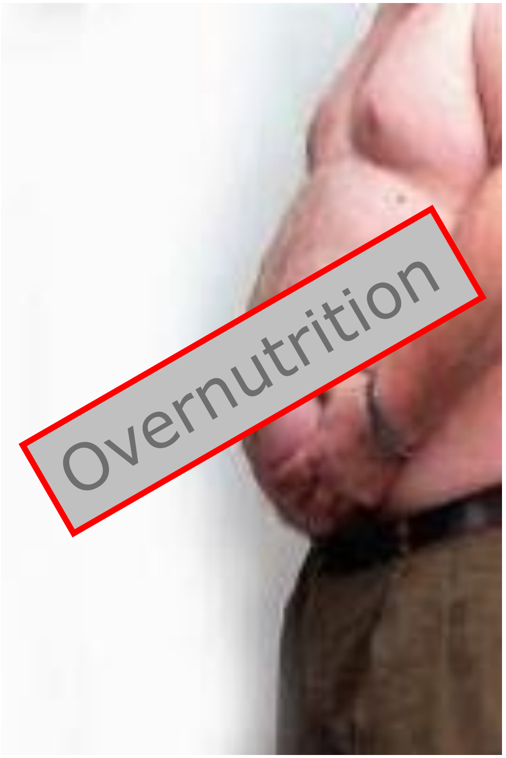
Our perspective: nutritional status



How do nutrients, foods and diets impact nutritional status?

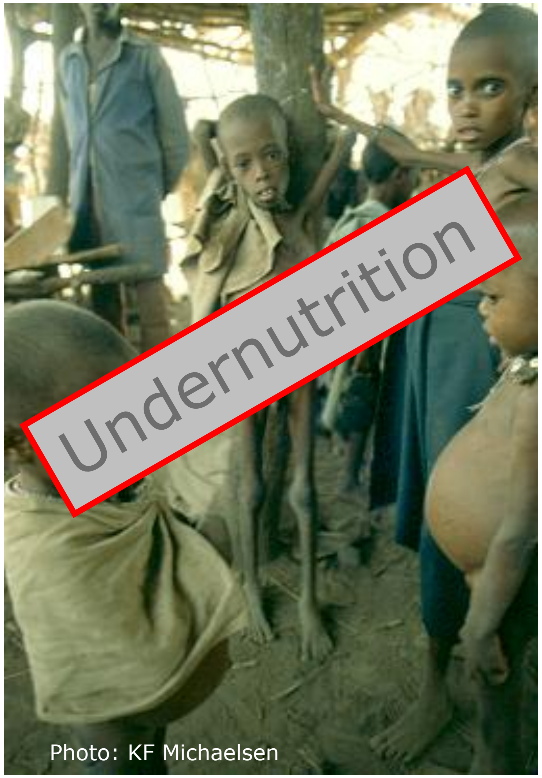
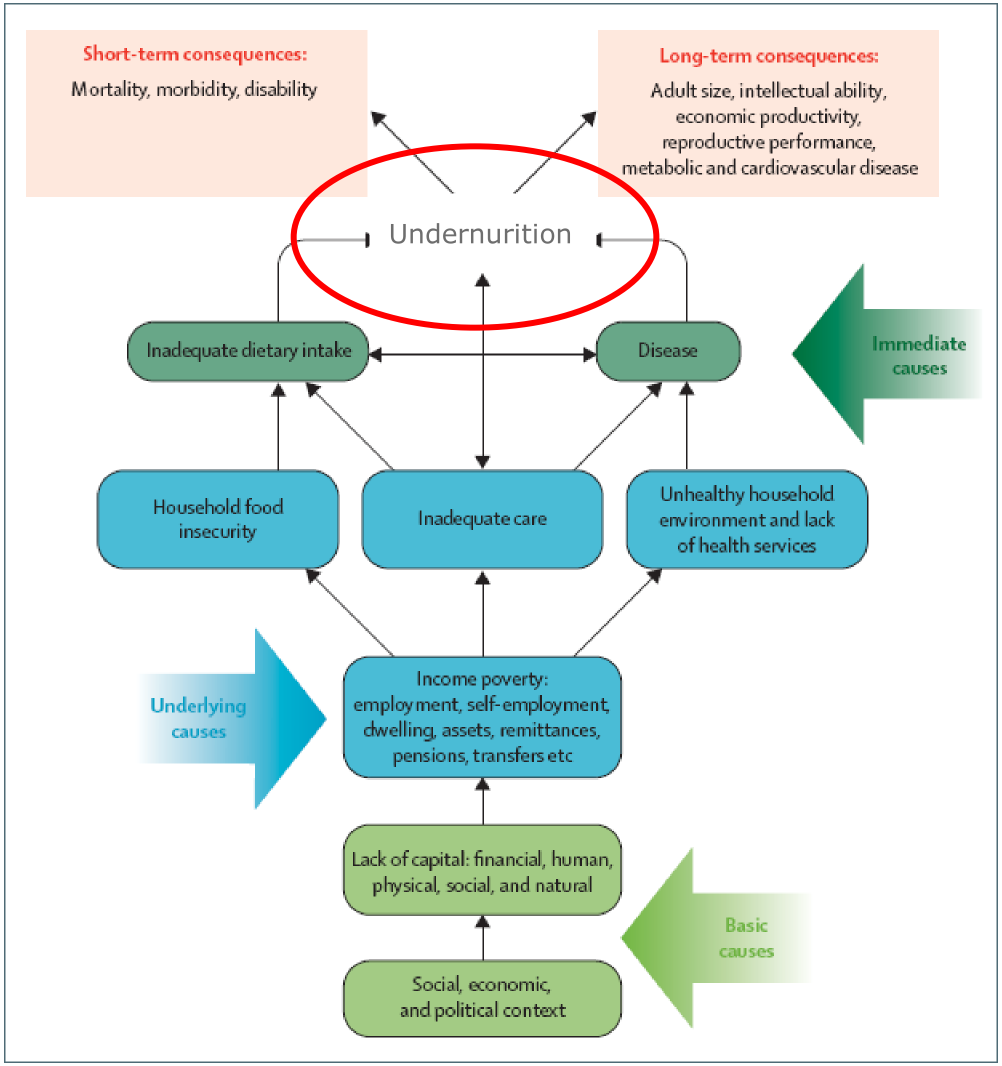


Photo: KF Michaelsen

Framework for causality of undernutrition



Modified from Black et al 2008

Summery paper 'Nutrition and food safety of edible insects': Conclusions I

Role of insects in traditional diets

- Highly variable with strong cultural determination
- Insects mainly belong in traditional and informal food systems
- Documentation of the nutritional contribution from insects to diets is limited

Protein quality

- Protein quality is generally high, similar to other animal-source foods
- Insects could improve overall protein quality in plant based diets – protein digestibility-corrected amino acid score (PDCAAS) values needed

Fat

- Fat content very variable
- Some species a good source of essential poly unsaturated fatty acids (PUFA)
- Long-chained PUFA (eg docosahexaenoic acid DHA) limited/lacking

Summery paper: Conclusions II

Vitamins and minerals

- Insects could be a significant source of micronutrients known to be deficient in diets in developing countries (iron, zinc, vitamin A) causing severe public health problems
- Mineral contents in insects are variable but generally high
- Few species have high vitamin A contents
- Bioavailability of minerals, especially iron, needs more research

Food hygiene

- Standards for insects as food is lacking

Allergy

- Specific insect allergy unknown
- Prevalence of allergy much higher in 'Western' countries compared to developing countries. The 'hygiene-hypothesis' predicting that early-life exposure to chitinous substances may suppress development of allergy needs to be confirmed/rejected for insects consumption

Codex Alimentarius

- Standards are needed

Protein quality – how much can insects contribute to improve protein quality of diets?

TABLE 3. PDCAAS values (%) with limiting amino acid in parentheses if various proportions of the *weight* of a cereal, legume, or root are replaced by animal protein

		Milk (dry skimmed milk)			Meat (beef)		
Food item	0%	10%	25%	50%	10%	25%	50%
Wheat	37 (Lys)	55 (Lys)	75 (Lys)	98 (Lys)	49 (Lys)	66 (Lys)	92 (Lys)
Rice	54 (Lys)	75 (Lys)	93 (Lys)	110 (Lys)	70 (Lys)	88 (Lys)	98 (Trp)
Maize	35 (Lys)	56 (Lys)	78 (Trp)	95 (Trp)	50 (Lys)	62 (Trp)	76 (Trp)
Oats	60 (Lys)	73 (Lys)	88 (Lys)	105 (Lys)	69 (Lys)	82 (Lys)	96 (Trp)
Soybeans	93 (Lys)	96 (Lys)	99 (Lys)	106 (Lys/Trp)	95 (Lys)	98 (Lys)	100 (Trp)
Black beans	45 (SAA)	56 (SAA)	71 (SAA)	93 (SAA)	50 (SAA)	60 (SAA)	77 (SAA)
Potato	71 (SAA)	106 (SAA/Thr)	113 (Trp)	112 (Trp)	94 (SAA)	99 (Trp)[a]	96 (Trp)[a]
Cassava	44 (Lys)	85 (Lys)	103 (Thr)	111 (Trp)	74 (Thr)	92 (Thr)	95 (Trp)
Yam	55 (Lys)	96 (Trp)	105 (Trp)	110 (Trp)	78 (Trp)	87 (Trp)	91 (Trp)

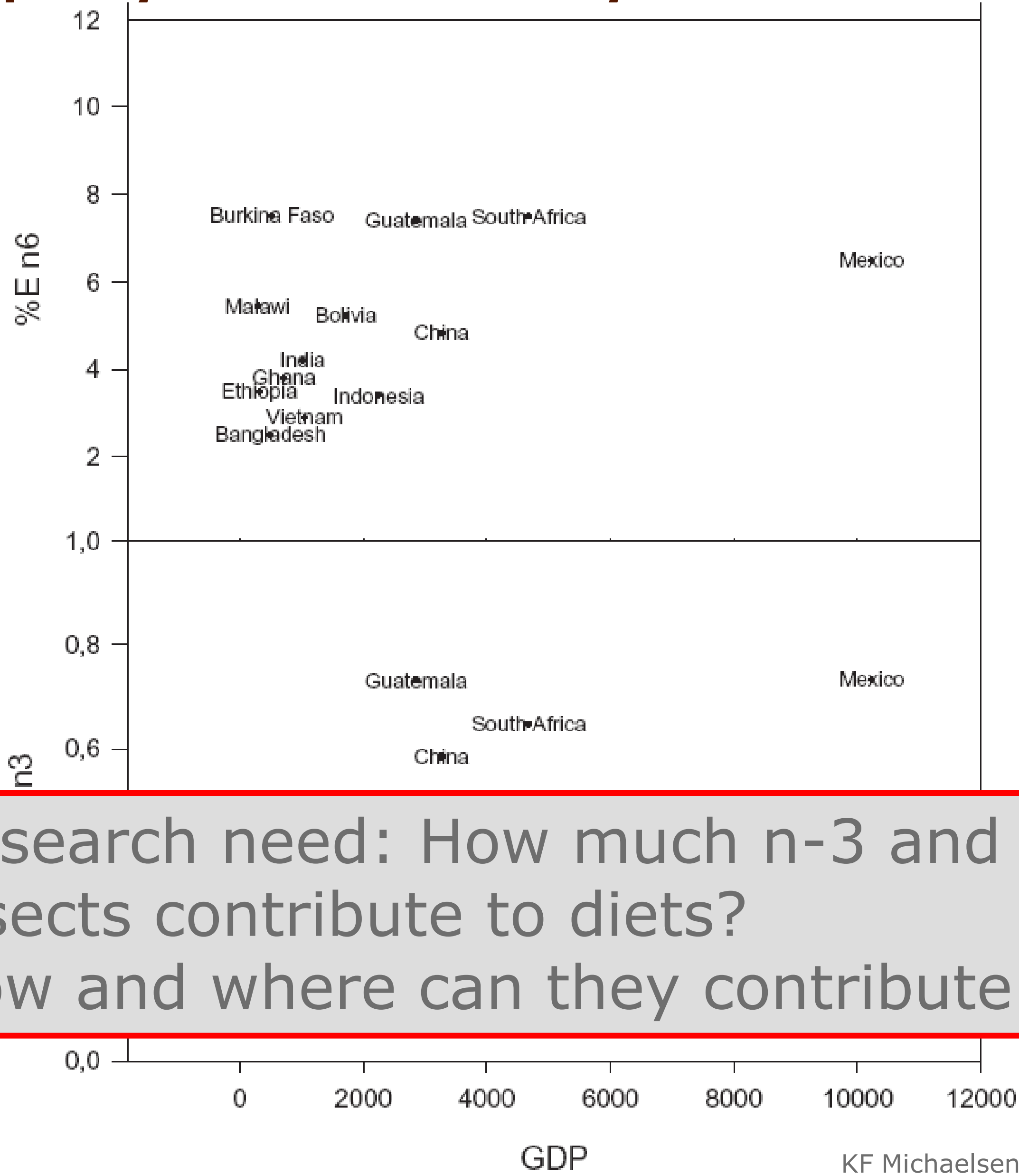
PDCAAS, protein digestibility-corrected amino acid score; SAA, sulfur amino acids

a. Values decrease, as trypsin is lower in beef than in soybeans.

Research need: How much can insects improve protein quality of plant-based diets?

Michaelsen et al. Food and Nutrition Bulletin 2008

Fat quality: n-6 and n-3 fatty acids are limited nutrient resources



The average country supply of n-6 and n-3 fatty acids expressed as energy % of total dietary energy relative to the gross domestic product (GDP) in US$. Source for supply: FAOSTAT (2010). Source for GDP World Bank (2008)

Research need: How much n-3 and n-6 fatty acids do insects contribute to diets?
How and where can they contribute more?

KF Michaelsen et al. 2011

n-6 and n-3 fatty acid profiles

Table 6. Composition of selected fatty acids in fish and other animals (percentage of total fatty acid)

	LA	ALA	AA	EPA	DHA	Total n-6 PUFA	Total n-3 PUFA	n-6:n-3 PUFA
Marine fish								
Atlantic herring (*Clupea herengus*)*	0.7	0.3	0.4	7.4	3.9	1.1	11.6	1:10
Cod (*Gadus morhua*)†	1.1	0.2	4.8	14.0	26.3	5.9	40.6	1:6
Thai sardine (*Sardinella gibbosa*)*	1.2	0.5	2.7	6.1	9.7	3.9	16.3	1:4
Cod liver oil	1.8	0.7	1.7	8.9	9.3	3.5	18.9	1:5
Cold-water freshwater fish								
Rainbow trout (*Oncorhynchus mykiss*)*	4.6	5.2	2.2	5	19	6.8	29.2	1:4
Perch (*Perca fluviatilis*)*	1.5	0.5	9.1	8.8	26.5	10.6	35.8	1:3
Roach (*Rutilus rutilus*)*	4.5	2.8	5.5	10.7	14.9	10	28.4	1:3
Atlantic salmon (*Salmo salar*)*	2.7	4.6	4.2	5.1	17.6	6.9	27.3	1:4
Warm-water freshwater fish								
Snakehead (*Channa striatus*)*	8.2	0.5	2.2	0.3	1.5	10.4	2.3	5:1
Common carp (*Cyprinus carpio*)*	7.9	2.9	8.6	8.8	6.5	16.5	18.2	1:1
Nile tilapia (*Oreochromis niloticus*)*	9.0	0.8	1.5	0.8	9	10.5	10.6	1:1
Eel (*Monopterus albus*)‡	5.6	0.9	0.7	2.7	0.2	6.3	6.1	1:1
Catfish (*Clarias macrocephalus*)*	6.6	2.7	13.5	3.2	6.7	20.1	12.6	2:1
Climbing perch (*Anabas testudineus*)*	5.4	1.3	12.4	1.1	9.2	17.8	11.6	2:1
Other animals								
Field cricket (*Teleogryllus testaceus*)§	26.6	9.0	0	0	0	26.6	9	3:1
Chinese edible frog (*Haplobatrachus rugulosus*)§	9.2	2.3	10.8	1.7	3.5	20	7.5	3:1
Cambodian spider (*Haplopelmaalbostriatum*)¶	7.6	3.6	11.2	1.6	1.7	18.8	6.9	3:1

Sources: *Cited from Karapanagiotidis *et al.* (2010); †US Department of Agriculture. USDA National Nutrient database; ‡Rahman *et al.* (1995); §Nurhasan *et al.* (2010); ¶Own data (Roos N, unpublished). Total n-6 PUFA is the sum of LA and AA and total n-3 PUFA is the sum of ALA, EPA and DHA. PUFA, polyunsaturated fatty acids; LA, linoleic acid; ALA, α-linolenic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

Michaelsen et al 2011

Fatty acid profiles in other animal source foods

Table 5. Fatty acid composition in animal source foods (g/100 g)

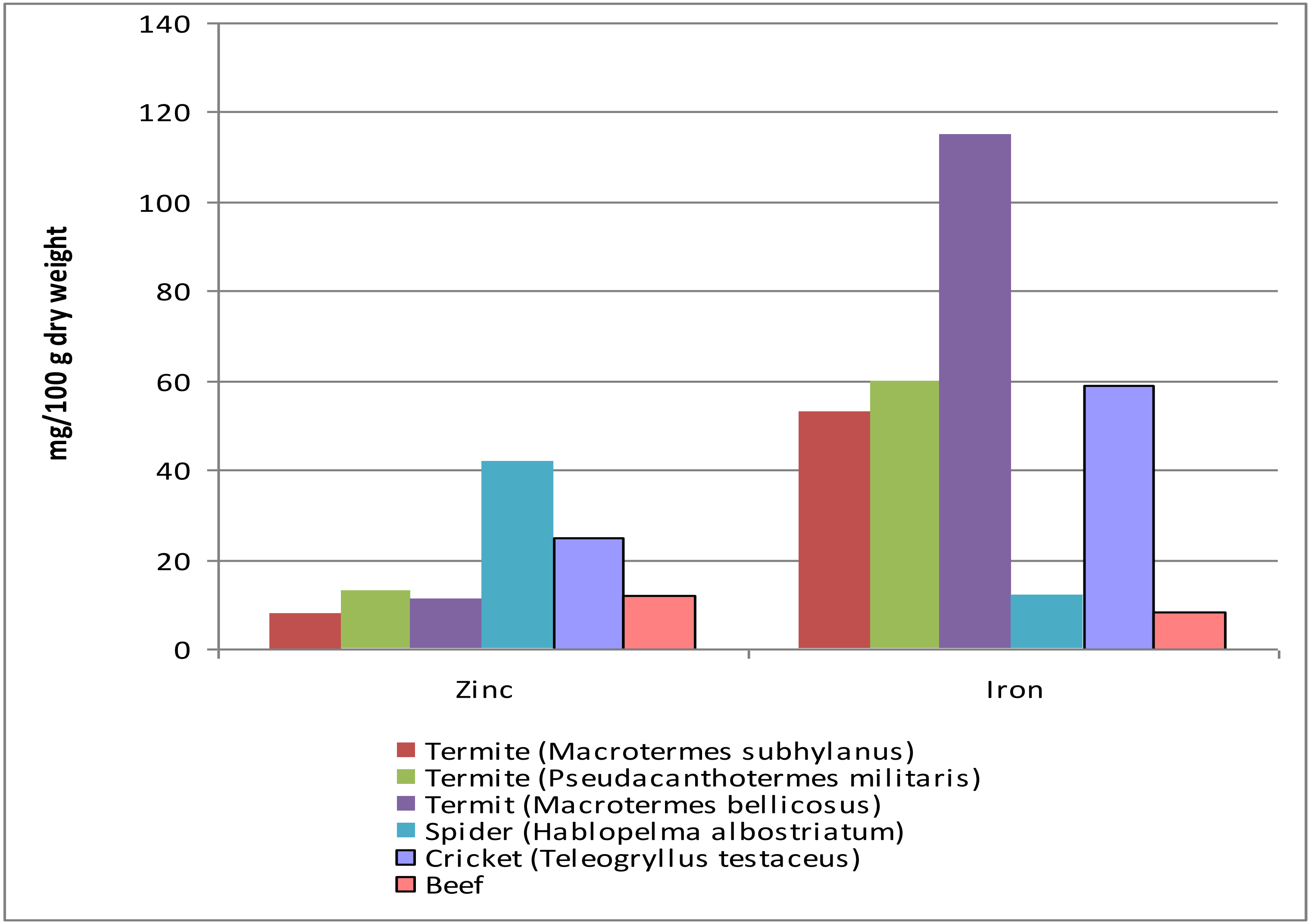
	Total fat	Total PUFA	LA	ALA	AA	EPA	DHA	n-6 PUFA	n-3 PUFA	n-6:n-3 PUFA
Meat (raw)										
Minced pork (9.4% fat)	9.4	1.2	0.98	0.09	0.06	0.00	0.03	1.04	0.12	9:1
Minced beef (10.8% fat)	10.8	1.2	0.54	0.13	0.23	0.09	0.02	0.77	0.39	2:1
Minced lamb (6.9% fat)	6.9	0.5	0.22	0.11	0.03	0.02	0.01	0.25	0.17	1:1
Poultry (raw)										
Duck, lean and skin	36.9	4.5	4.09	0.24	0.13	0.00	<0.01	4.22	0.24	17:1
Quail, flesh and skin	11.0	2.6	2.24	0.17	0.10	0.00	0.03	2.34	0.20	12:1
Turkey breast	8.5	2.3	2.05	0.16	0.05	0.00	0.01	2.10	0.17	12:1
Chicken breast	9.4	1.3	1.13	0.09	0.04	0.00	0.01	1.17	0.11	11:1
Eggs and milk										
Chicken egg, hard boiled	8.6	1	0.72	0.02	0.19	0.00	0.07	0.91	0.10	9:1
Duck egg, hard boiled	13.2	0.9	0.54	0.10	0.31	0.00	<0.01	0.85	0.10	9:1
Milk (full fat)	4.0	0.1	0.08	0.03	0.00	0.00	0.00	0.08	0.04	2:1

Source: Food Standard Australia New Zealand.

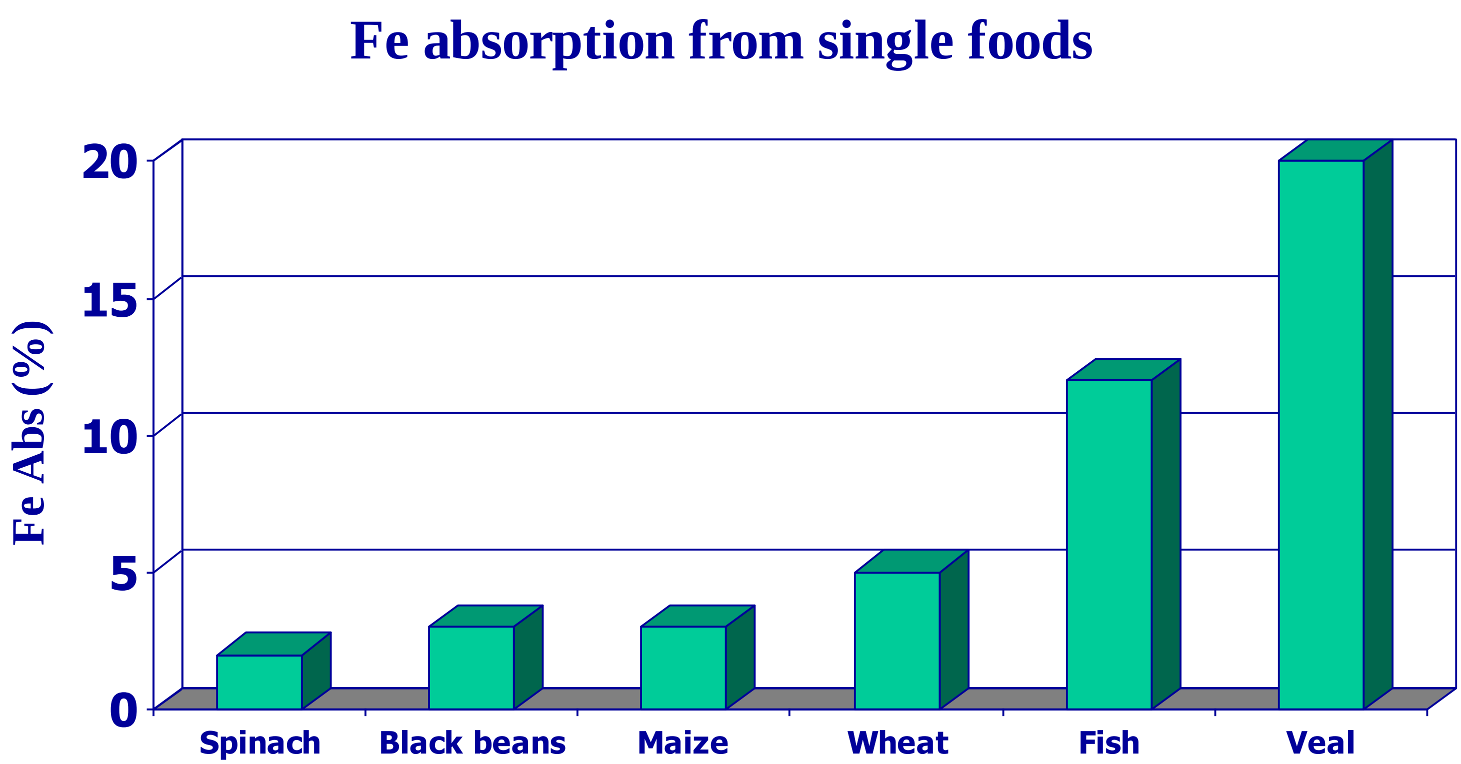
PUFA, polyunsaturated fatty acids; LA, linoleic acid; ALA, α-linolenic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

Michaelsen et al 2011

Minerals


mg/100 g dry weight
140
120
100
80
60
40
20
0
Zinc
Iron
Termite (Macrotermes subhylanus)
Termite (Pseudacanthotermes militaris)
Termit (Macrotermes bellicosus)
Spider (Hablopelma albostriatum)
Cricket (Teleogryllus testaceus)
Beef

Iron bioavailability is critical for the nutritional value



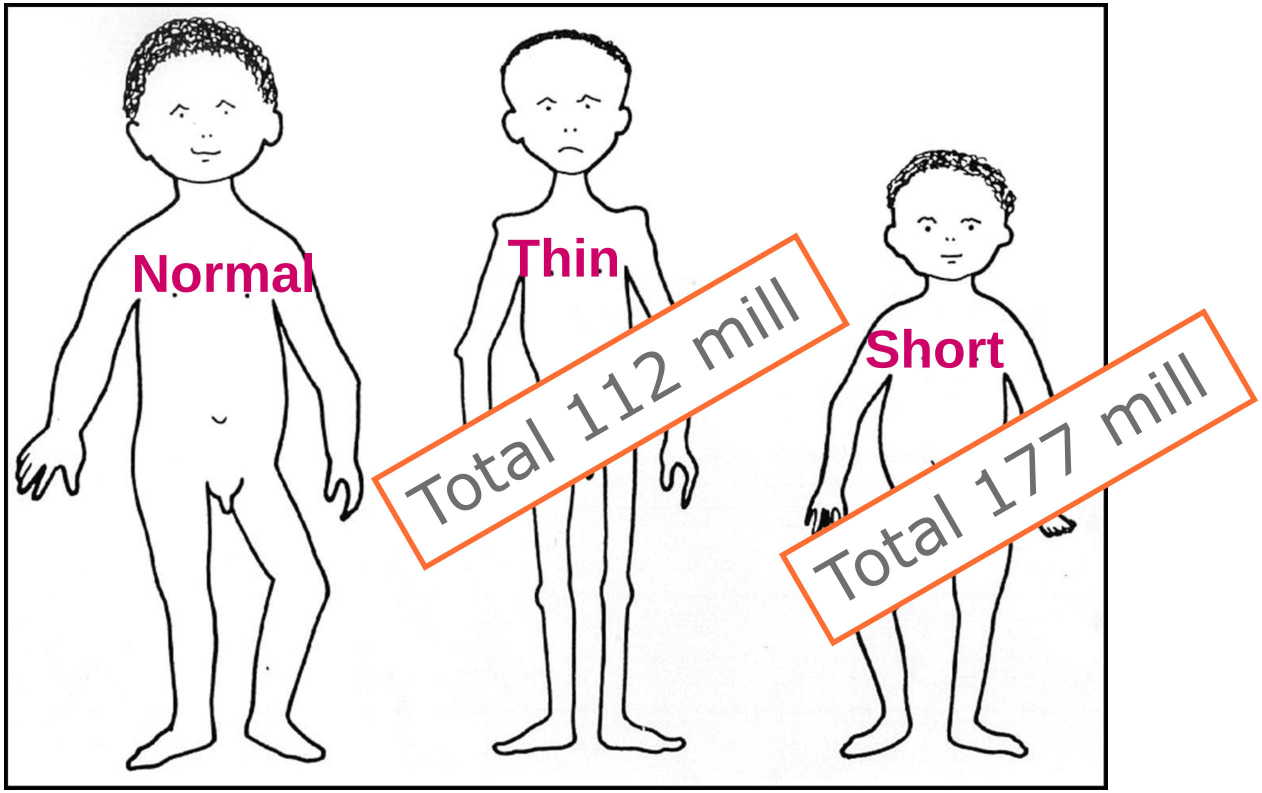
Research need:
- What is the iron absorption from insects?
- What is the 'meat-factor' effect of insects on non-heme iron absorption from composite meals?

Perspectives: How can insects contribute to better nutrition?

1) What are the global nutritional challenges

2) Our research: testing complementary foods ('babyfoods') for better child nutrition in Cambodia and Kenya

Child undernutrition – what is the problem?



Wasted

Low Weight-for-height

Underweight (WAZ)

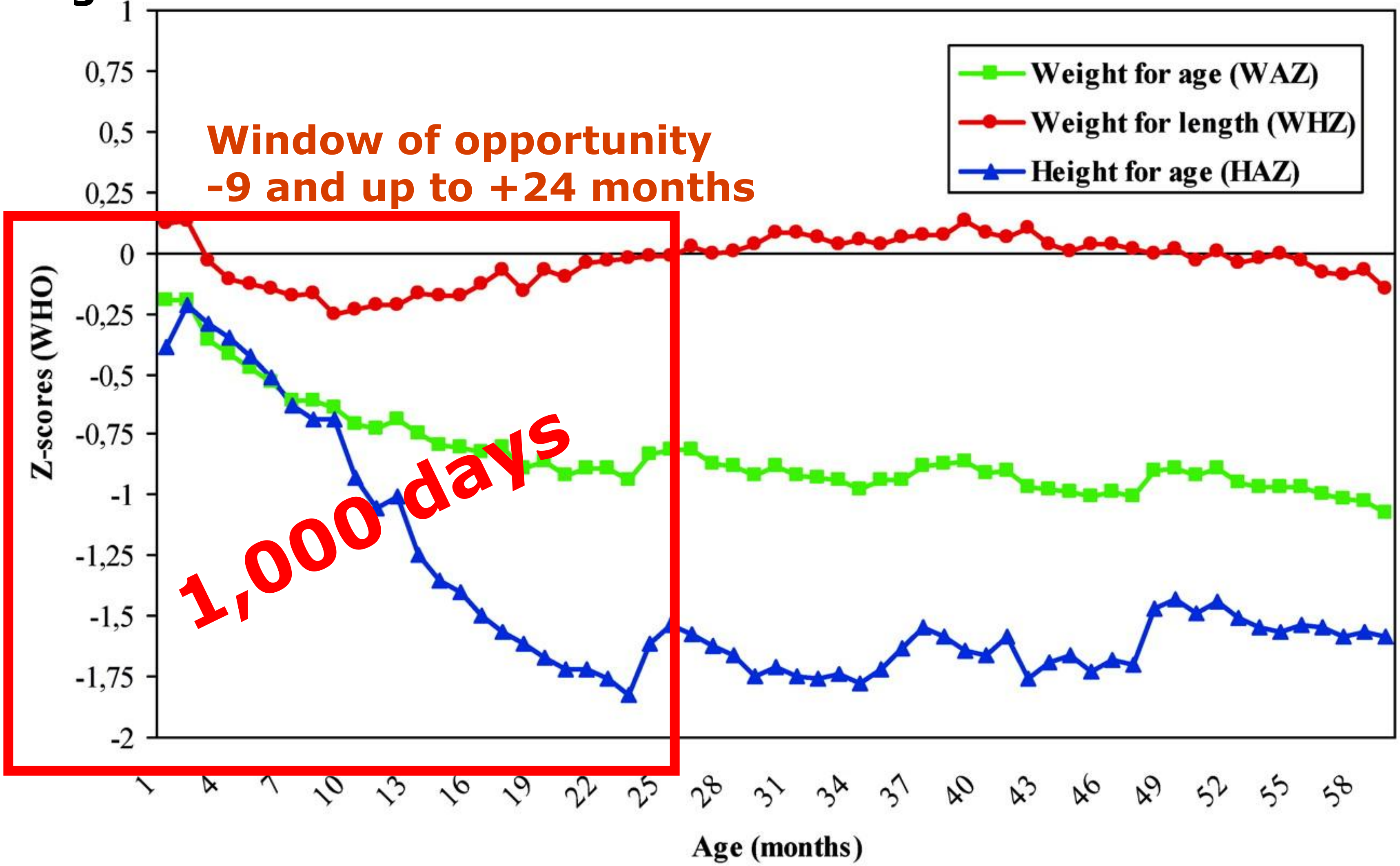
Low Weight-for-Age

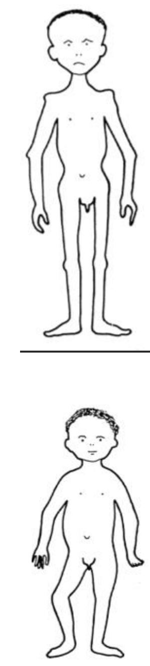
Stunted (HAZ)

Low Height-for-Age

Black et al, Lancet 2008

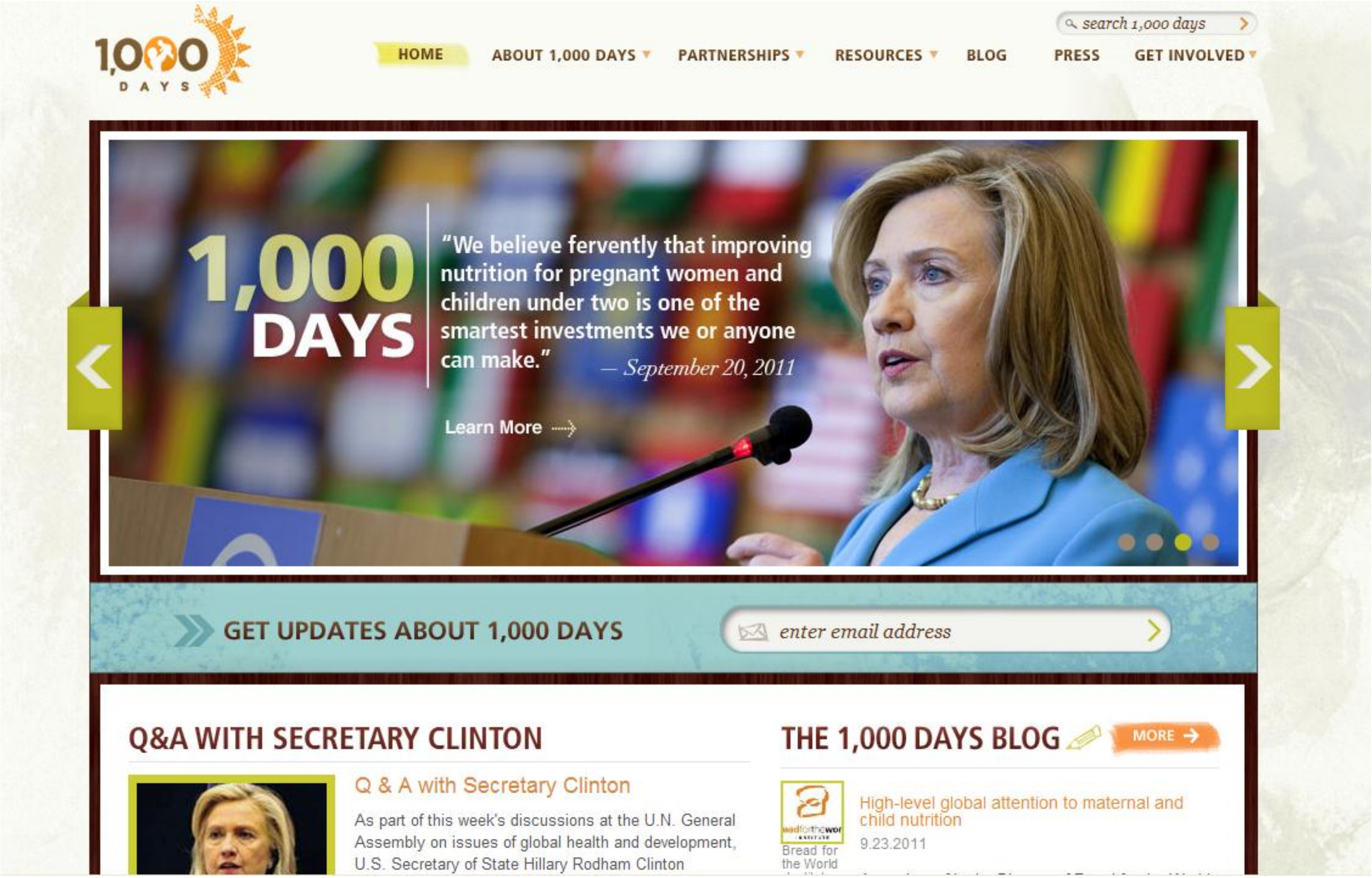
Mean anthropometric z scores in developing countries. Normal growth: Z-score = 0. Moderate malnutriton: Z-score < -2





Victora et al. Pediatrics 2010;125:e473-e480

2010: Launching of the '1000 days' initiative Nutrition during pregnancy and up to 2 years is the most important investment in development



Can insects contribute to better child nutrition?

A key problem for child nutrition in developing countries is diets of poor quality:

- Dominated by staple foods (rice, maize, cassava…)
- Little vegetables, **little or no animal foods**
- Bulky (low in energy and nutrient density)

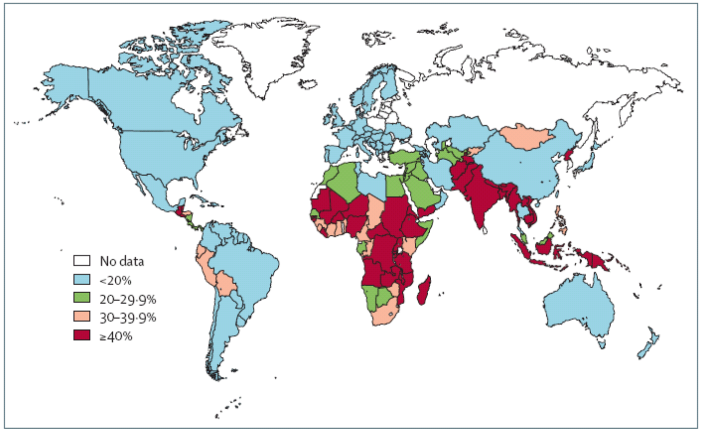
- High anti-nutrient content (phytate inhibit mineral abs)
- Deficient in essential fatty acids (n-6 and n-3)
- Low content and bioavailability of micronutrients, especially, vitamin A, iron and zinc

Animal-source food is a key to better child nutrition:

- Contribute essential fatty acids
- Bioavailable micronutrients
- Enhance iron bioavailability from plant foods ('meat factor')
- Milk: support liniear growth (IGF1 – Insulinlike Growth Factor I)
- Meat/fish: support cognitive development
- **INSECTS?**

Global malnutrition – where can insects contribute to better diets ?

A: Prevalence of stunting



B: Risk of child zinc deficiency

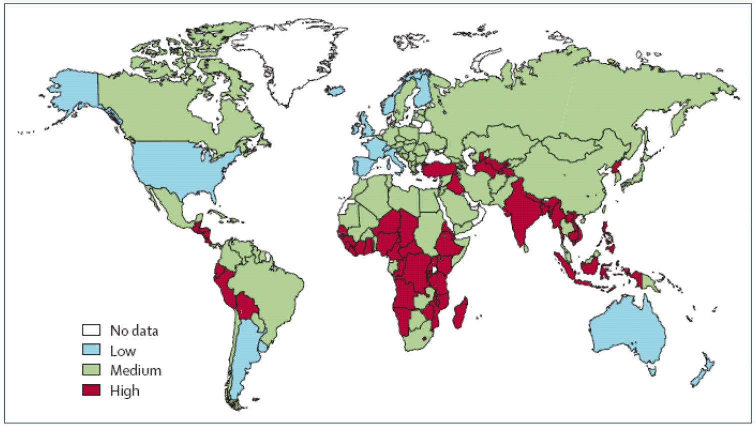
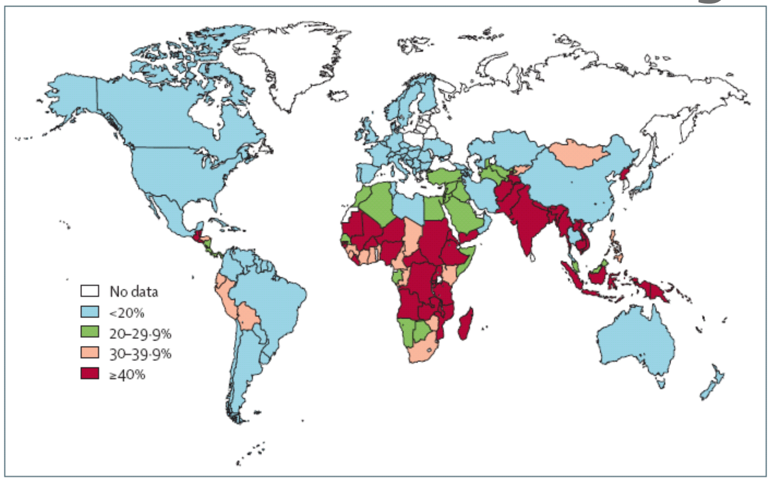


Figure 6: National risk of zinc deficiency in children under 5 years

Black et al. Lancet vol 371, 2008

Global malnutrition – can insects contribute to better diets ?

Prevalence of stunting



Edible insects

Table 2. Number of edible insects per continent and number of consumer countries

Continent	Number of species recorded	Percent of total	Number of consuming countries
Asia	349	20	29
Australia	152	9	14
Africa	524	30	36
Americas	679	39	23
Europe	41	2	11
Total	1 745*	100	113

* The world total is actually 1 681; some species occur in more than one continent, hence the higher total.
Source: Ramos-Elorduy (2005).

Human bite back, FAO 2010

Are there geographical and cultural '**hot-spots**' where insects are already accepted and could contribute (more) to better nutrition?

Black et al. Lancet vol 371, 2008

Our research: The WinFood project

Aim:

To develop nutrient dense complementary food ('babyfoods') based on locally available/traditional food

To test these 'WinFoods' in human intervention studies for impact on nutritional status

Funded by Danida, Ministry of Foreign Affairs, Denmark

Partners:

- Department of Fisheries Post-Harvest Technologies and Quality Control (DFPTQ), Fisheries Administration, Phnom Penh, Cambodia
- National Nutrition Programme, Ministry of Health, Cambodia
- Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
- University of Nairobi, Institute of Tropical and Infectious Diseases (UNITID), Kenya
- World Food Programme (WFP)
- Institut de Recherche pour le Développement (IRD), Hanoi, Vietnam
- Nutrition and Public Health Research Unit at London School of Hygiene and Tropical Medicine London, UK

WinFood development in Cambodia -

Rice based porridge with

Dry weight %	1	2	3
Dried small fish	10.8	5.8	14.8
Cricket	1.8	1.0	3.3
Spider	1.8	1.0	3.3

Final Winfood composition – Cambodia

Food item	Winfood
Rice	77%
Fish (*Esomus longimanus*)	6,1%
Fish (*Paralaubuca typus)*	6,1%
Spider (*Hablopelma albostriatum*)	1,8%
Oil	4,8%
Sugar	4,8%

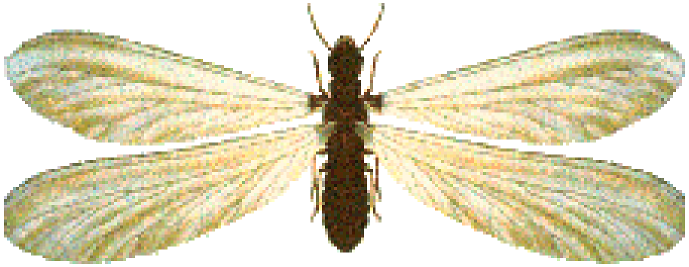
Winfood Cambodia: WinFood 'Lite' version

Food item	Winfood	Winfood Lite
Rice	77%	79%
Fish (*Esomus longimanus*)	6,1%	-
Fish (*Paralaubuca typus)*	6,1%	-
Spider (*Hablopelma albostriatum*)	1,8%	-
Fish mix	-	9,4%
Micronutrient mix	-	0,9%
Oil	4,8%	4,8%
Sugar	4,8%	4,8%

- WinFood 'Lite' a simplified composition prepared for scaled up commercial production
- Spiders difficult to include in a scaled up commercial production due to lack of production and food standards, and due to lack of knowledge about the sustainability of supply from wild sources

Final Winfood composition - Kenya

Food item	Winfood
Amaranth grain	71%
Maize	10%
Fish (*Rastrineobola argentea*)	3%
Termite (*Macrotermes sunhylanus*)	10%
Oil	0.6%
Sugar	5%



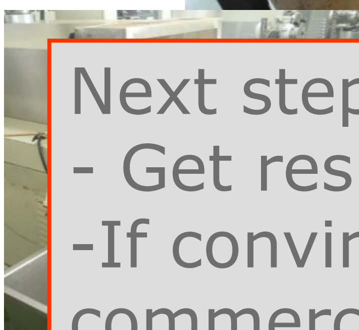
Intervention study Cambodia:

- 420 children randomised to 4 food groups
- Daily feeding for 9 months from age 6 to 15 months (May 2011 – Feb 2012)
- Assessed for: growth, body composition, micronutrient status, morbidity, motor development, physical activity
- Parallel study in Kenya, starting now

WinFoods – Fe and Zn contribution from spiders

	WinFood	WinFood 'Lite'	Corn-Soya-Blend (CSB++)	Corn-Soya-Blend (CSB+)
Cereal/legume, g/100g	76,2	80,8	78,0	83,3
Animal source food g/100g	**14,3 Fish +spider**	**10,0 Fish**	**8,0 Milk**	**0**
Oil, sugar, total g/100 g	9,6	9,6	12,0	16,6
Energy, kcal/100 g	433	408	420	425
Total protein, g/100 g	17,6	15,2	16,0	11,7
Animal protein, g/100 g	11,1	8,4	2,9	0,0
Minerals/100 g				
Fe, total mg	5,0	7,9	6,5	5,4
Fe from fish (%)	31%	17%		
Fe from spider (%)	**5%**			
Zn, total mg	4,5	4,9	5,0	4,2
Zn from fish (%)	35%	32%		
Zn from spider (%)	**22%**	-	-	-

WinFood production for human intervention



Next step:
- Get results from interventions!
-If convincing, scaling up WinFood Lite for commercial production

- Scaling up WinFood on standby due to lack of food standards for spiders, and uncertaincy about sustainability of supply

Discussion points/next steps

I. How can insects contribute to improve global nutrition?

- Insects are an underutilised food resource for improving dietary quality in developing countries. Systematic screenings of contents of micronutrients, fatty acid profiles and protein quality are needed to identify the most nutritious species
- Identifying geographical and cultural 'hot spots' suitable for scaling-up local insect production/consumption
- Moving insects from the informal and traditional food systems to formalised food systems (to give access to public and private investments in research and innovation in breeding and management, and to control for sustainable and safe production). Edible insects recorded in FAOSTAT national food supply statistics

II. Research needs in human nutrition:

- How much can insects improve protein quality of plant-based diets? (protein digestibility-corrected amino-acid scores (PDCAAS) values needed)
- How much n-3 and n-6 fatty acids do insects contribute? How and where can they contribute more?
- Bioavailability of micronutrients from insects needs to be investigated - especially of iron and determining the 'meat-factor' effect on non-heme iron
- Effect of insect protein compared to milk/meat/fish proteins on child growth and development (during '1000 days')
- Allergy – specific insects allergies, and testing og the 'hygiene-hypothesis'