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DELLE MARCHE

Dipartimento di Scienze Agrarie,
Alimentari ed Ambientali

La qualità nutrizionale di proteine da insetti edibili

Nadia Raffaelli

Bologna, 6 Aprile 2019

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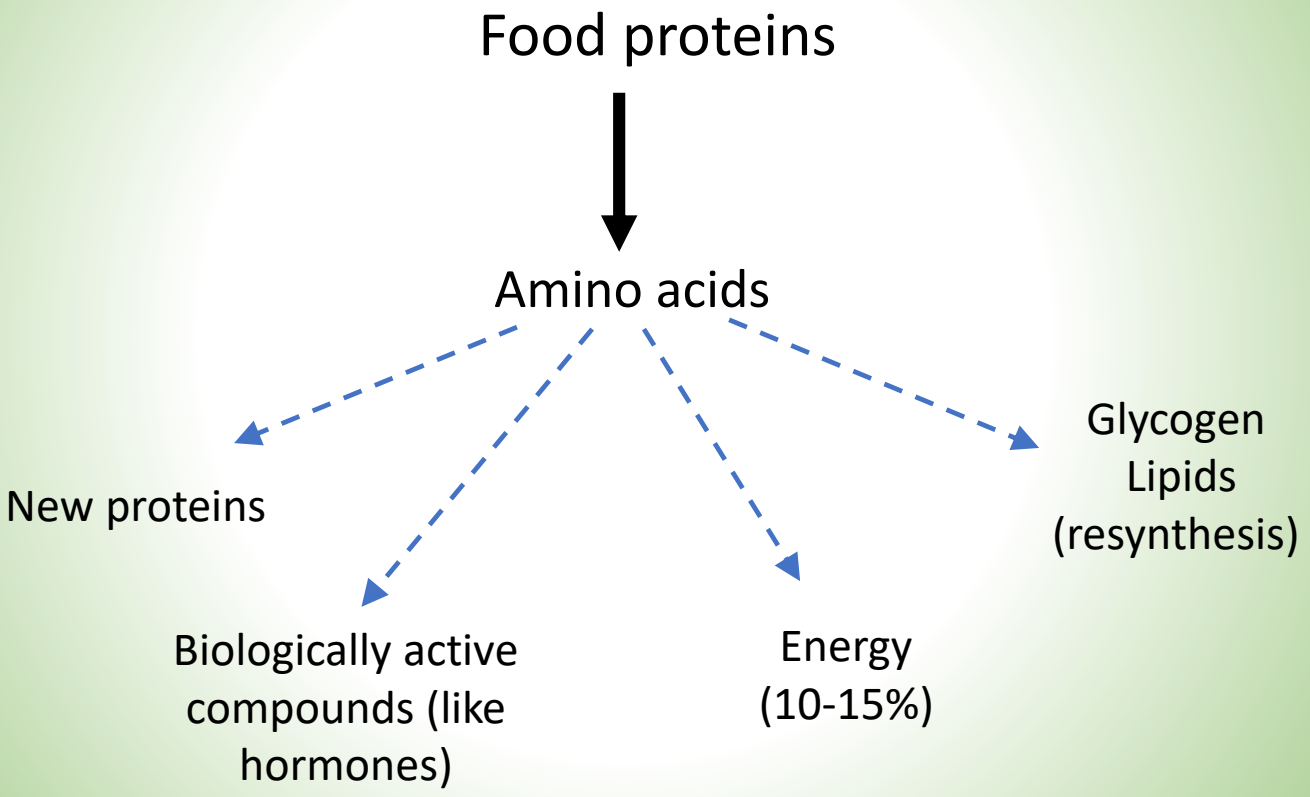
Why do we need proteins?



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Dietary protein quality

- ***Amino acid composition***

FAO/WHO requirement
EAA: 40%
EAA/NEAA: 0.6

Essential	Nonessential
Histidine	Alanine
Isoleucine	Arginine
Leucine	Asparagine
Lysine	Aspartate
Methionine	Cysteine
Phenylalanine	Glutamate
Threonine	Glutamine
Tryptophan	Glycine
Valine	Proline
	Serine
	Tyrosine

- ***Protein digestibility***

Affected by anti-nutritional factors

Indigenous

proteases' inhibitors, tannins, phytates…

Formed during heat/alkaline processing of food

Oxidized forms of sulfur AA, D-AA, Lysinoalanine (LAL-cross-linkage between polypeptides, Maillard compounds

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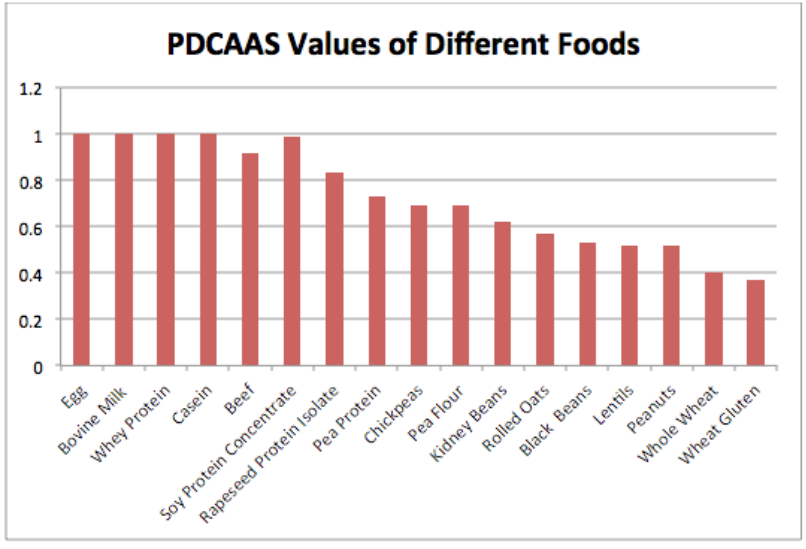
Dietary protein quality

Protein Digestibility-Corrected Amino Acid Scoring (PDCAAS)

$$PDCAAS(\%) = \frac{mg\ of\ limiting\ amino\ acid\ in\ 1\ g\ of\ test\ protein}{mg\ of\ same\ amino\ acid\ in\ 1\ g\ of\ reference\ protein} \times fecal\ true\ digestibility\ (\%) \times 100$$



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DIETARY PROTEINS SOURCES

Plant-based dietary proteins 65%

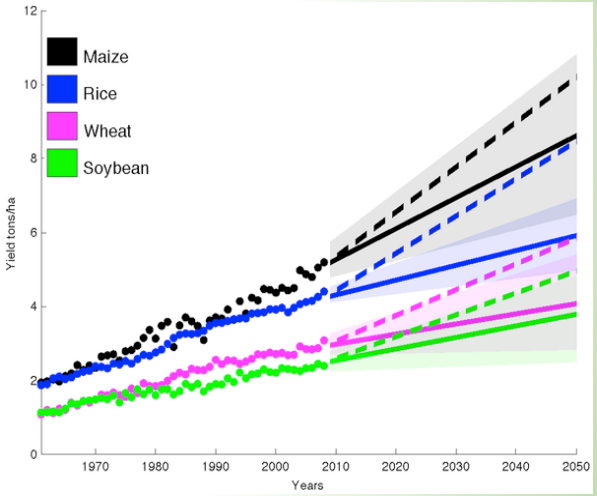
Animal-based dietary proteins 35%

Word population and meat production

year	world population (billion)	meat production (billion kg)
1950	2.7	45
2000	6.0	229
2050	9.1	465

Steinfeld et al (2006) Livestock's long shadow: Environmental issues and options. Rome, Italy: FAO.

Global projection of crop yield (tons/ha)



Demand can be met by increasing crop yield up to 2.4% per year

Ray DK et al (2013) Yield Trends Are Insufficient to Double Global Crop Production by 2050. PLoS ONE 8(6): e66428.

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INSECTS AS DIETARY PROTEIN SOURCES

- ✓ PROTEIN CONTENT
- ✓ PROTEIN QUALITY
  - ❖ AMINO ACID COMPOSITION
  - ❖ PROTEIN DIGESTIBILITY
- ✓ ANTI-NUTRITIONAL FACTORS

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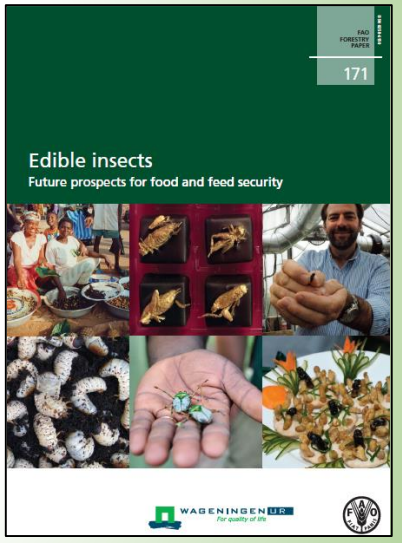
INSECTS AS DIETARY PROTEIN SOURCES

PROTEIN CONTENT

- Order and species
- Developmental stage (eggs, larvae, pupae, adults)
- Location and season of insect collection
- Diet
- Processing method



Van Huis A. et al Edible insects: Future prospects for food and feed security, 2013

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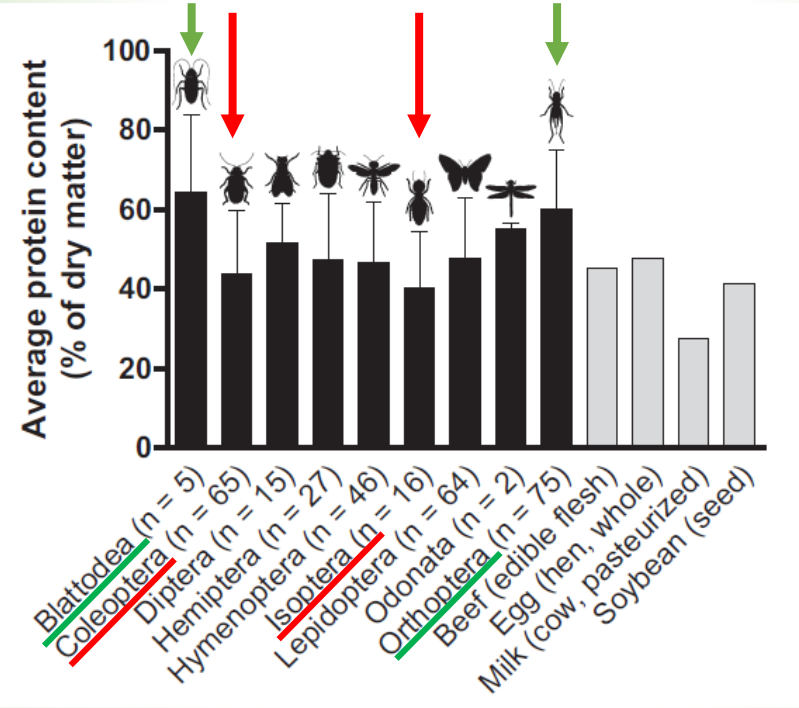
INSECTS PROTEIN CONTENT

- Order



Churchward-Venne TA et al, Nutrition Reviews, 2017

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INSECTS PROTEIN CONTENT

- Development stage

Insect order	Stage	Range (% protein)
Coleoptera	Adults and larvae	23 – 66
Lepidoptera	Pupae and larvae	14 – 68
Hemiptera	Adults and larvae	42 – 74
Homoptera	Adults, larvae and eggs	45 – 57
Hymenoptera	Adults, pupae, larvae and eggs	13 – 77
Odonata	Adults and naiad	46 – 65
Orthoptera	Adults and nymph	23 – 65

Source: Xiaoming *et al.*, 2010.

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INSECTS PROTEIN CONTENT

COMPARISON OF AVERAGE PROTEIN CONTENT AMONG INSECTS, FISH AND MAMMALS

Animal group	Species and common name	Edible product	Protein content (g/100 g fresh weight)
Insects (raw)	Locusts and grasshopppers: *Locusta migratoria, Acridium melanorhodon, Ruspolia differens*	larva	14–18
	Locusts and grasshopppers: *Locusta migratoria, Acridium melanorhodon, Ruspolia differens*	Adult	13–28
	Sphenarium purpurascens (chapulines – Mexico)	Adult	35–48
	Silkworm (*Bombyx mori*)	Caterpillar	10–17
	Palmworm beetles: *Rhynchophorus palmarum, R. phoenicis, Callipogon barbatus*	Larva	7–36
	Yellow mealworm (*Tenebrio molitor*)	Larva	14–25
	Crickets	Adult	8–25
	Termites	Adult	13–28
Cattle		Beef (raw)	19–26
Reptiles (cooked)	Turtles: *Chelodina rugosa, Chelonia depressa*	Flesh	25–27
		Intestine	18
		Liver	11
		Heart	17–23
		Liver	12-27
Fish (raw)	Finfish	Tilapia	16–19
		Mackerel	16–28
		Catfish	17–28
	Crustaceans	Lobster	17–19
		Prawn (Malaysia)	16–19
		Shrimp	13–27
	Molluscs	Cuttlefish, squid	15–18

Source: FAO, 2012f.

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INSECTS PROTEIN CONTENT

Journal of Food Composition and Analysis 62 (2017) 184–188

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Commentary

The high level of protein content reported in insects for food and feed is overestimated

Adi Jonas-Levi[a], Jean-Jacques Itzhak Martinez[b,c,*]

- ✓ Not all the N present in insect originates from proteins:

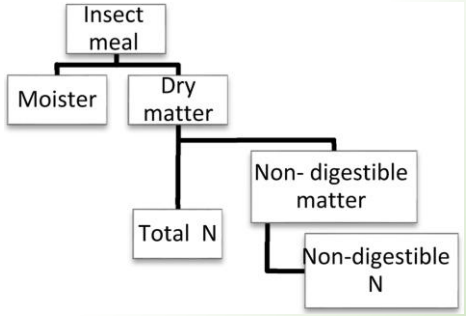
  *The exoskeleton cuticle is built primarily of **chitin**, a polysaccharide of glucosamine and N-acetylglucosamine, both containing N atoms.*

- ✓ Not all the proteins in insects are digestible:

  During the sclerotization stage of development, numerous and diverse cuticular proteins harden the cuticle by linking the chitin fibers

Kieldhal method

- determines the total nitrogen concentration
- a conversion factor is needed to convert the measured nitrogen concentration to a protein concentration.
- For meat/insects a conversion factor of **6.25** is used
  - *all the N present is in the form of protein*
  - *100 g meat/insects proteins contain about 16 g N*



Whole larvae	Conversion factor
T. molitor	4.75
A.diaperinus	4.86
H.illucens	4.67

Janssen RH et al, J Agr Food Chem, 2017

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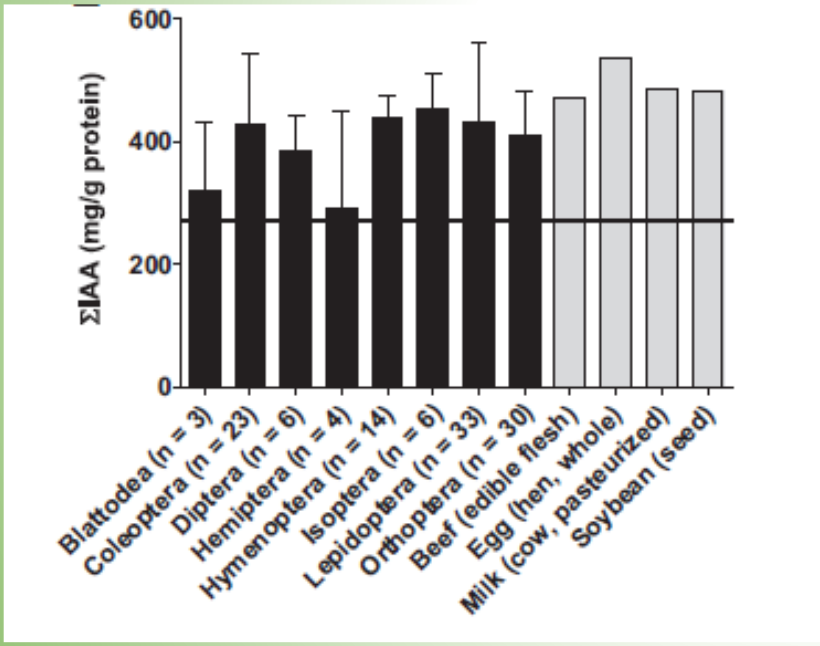
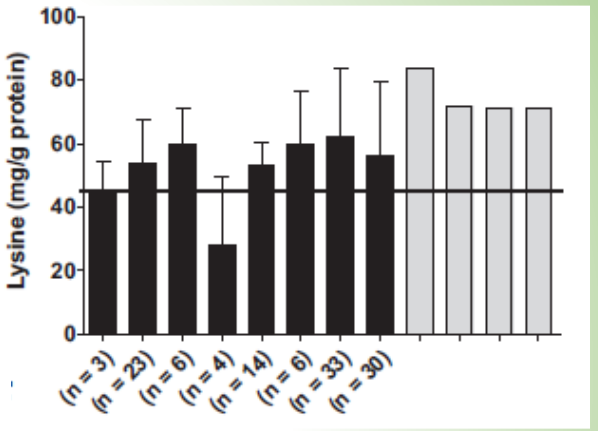
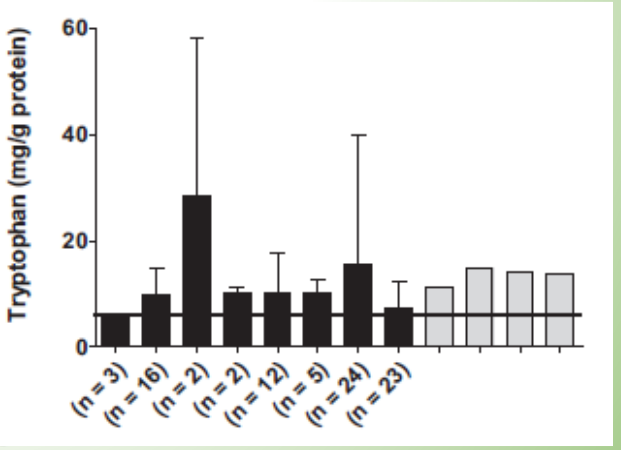
INSECTS PROTEIN QUALITY

❖ AMINO ACID COMPOSITION







Macrotermes bellicosus

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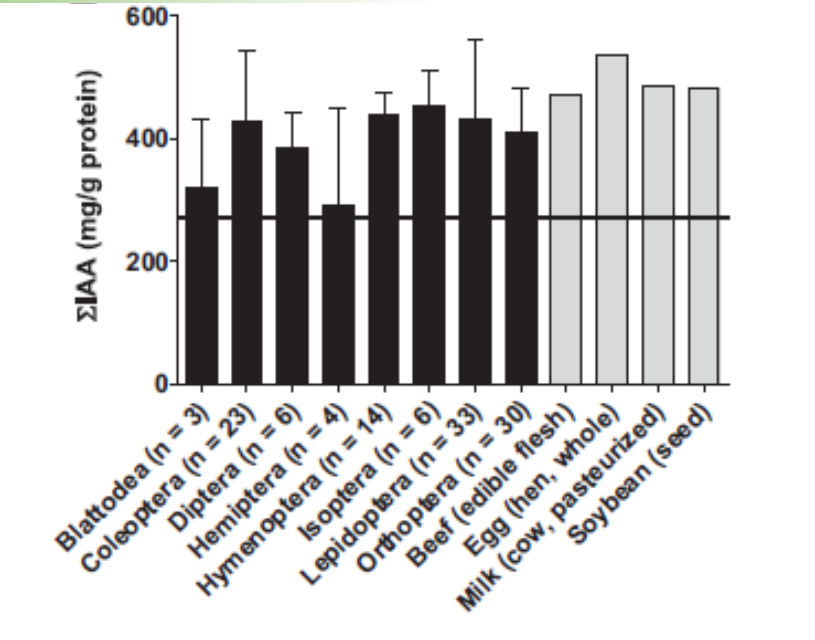
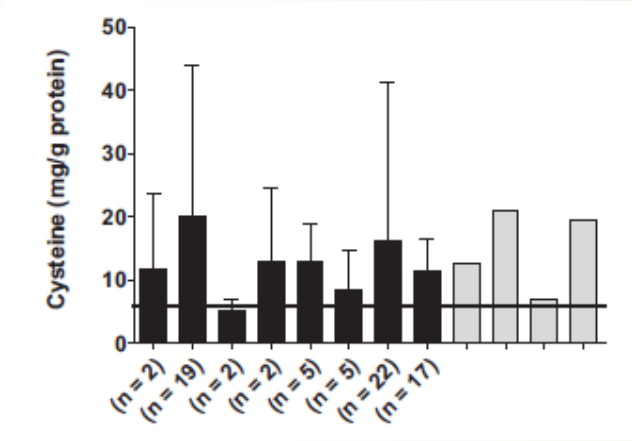
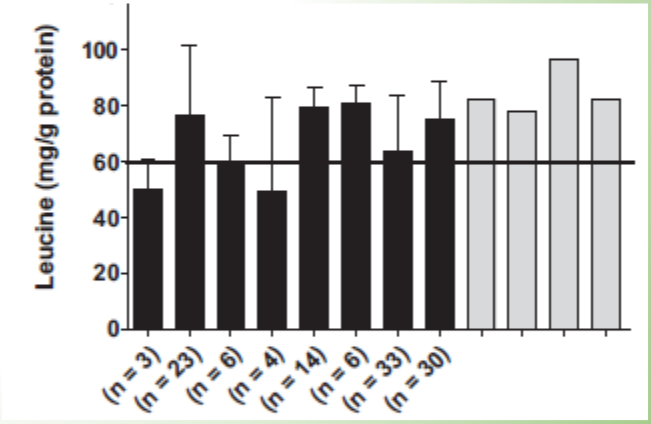
INSECTS PROTEIN QUALITY

❖ AMINO ACID COMPOSITION







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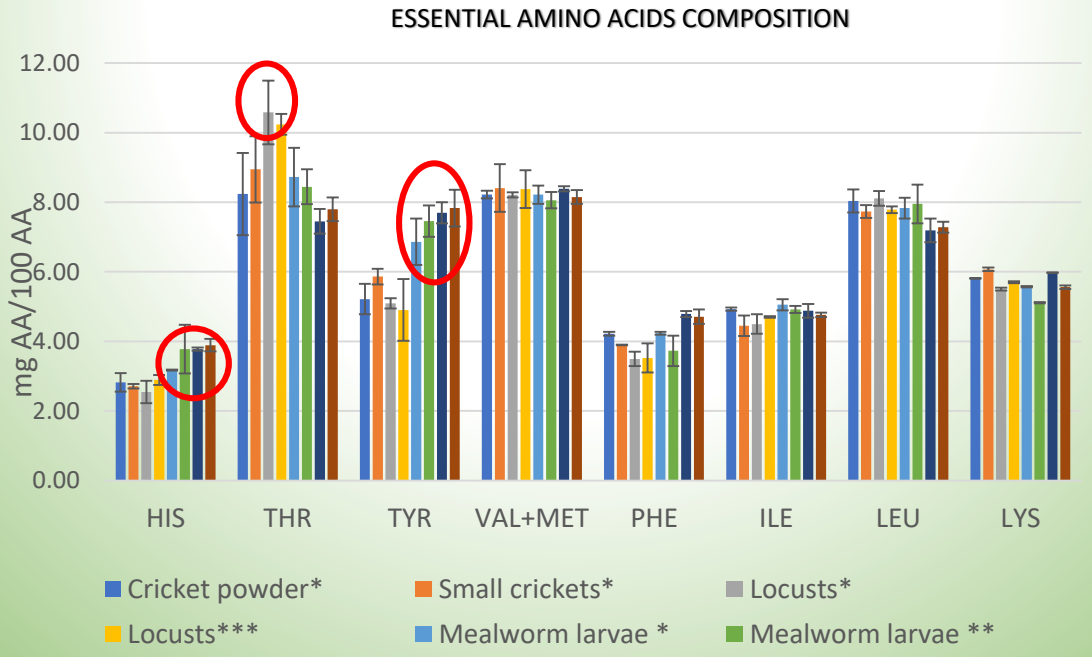
PROTEIN QUALITY OF EDIBLE INSECTS MARKETED IN EU

Osimani et al, Eur Food Res Technol 2016

Orthoptera EAA: 47%
EAA/NEAA: 0.9

Coleoptera EAA: 50%
EAA/NEAA: 1.0

FAO/WHO requirements
EAA: 40%
EAA/NEAA: 0.6



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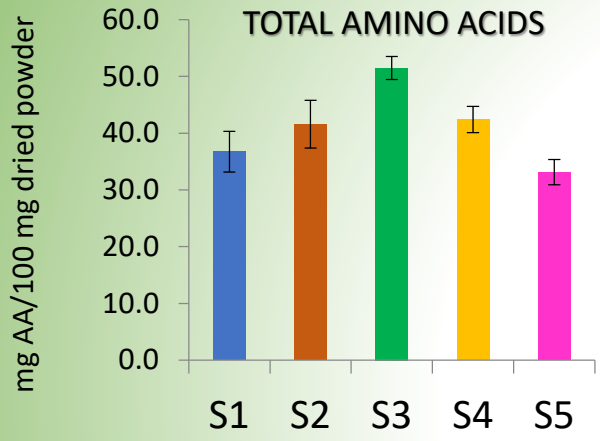
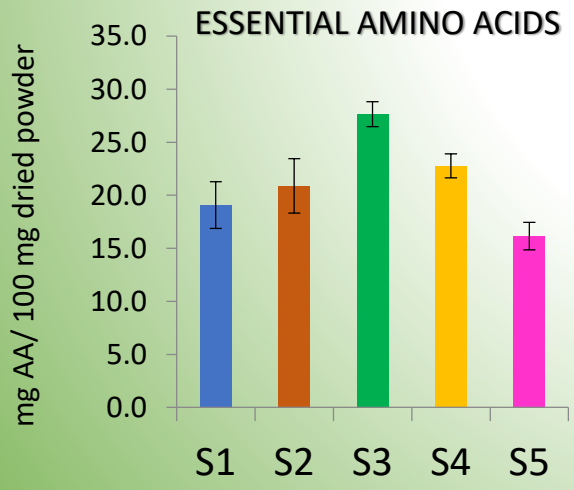
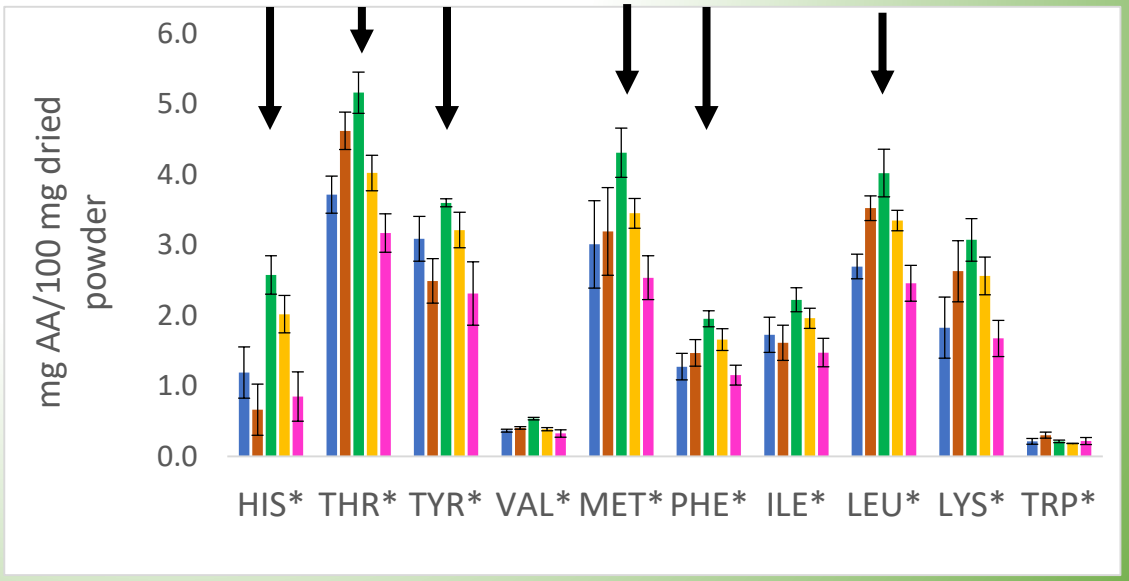
PROTEIN QUALITY OF *T. MOLITOR* REARED ON ALTERNATIVE SUBSTRATES





Tenebrio molitor larvae

S1 flour
S2 wheat meal
S3 75% S2, 25% olive pomace
S4 50% S2, 50% olive pomace
S5 25% S2, 75% olive pomace



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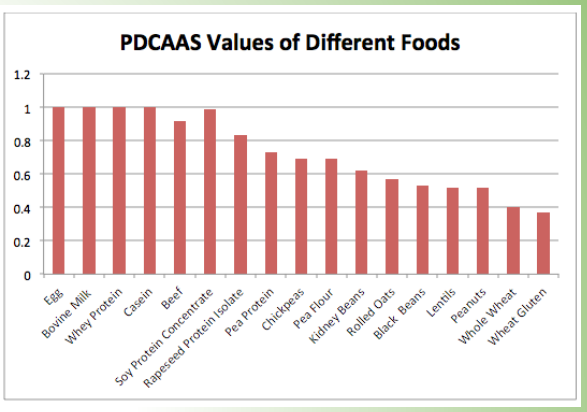
INSECTS PROTEIN QUALITY

PDCAAS of edible insects commonly used as food (in Nigeria and China)

Cricket (Gryllus assimilis)	Moth (Cirina forda)	Grasshopper (Melanoplus foedus)	Termite (Macrotermes nigeriensis)	Holotrichia parallela
0.73	0.42	0.46	0.42	0.68

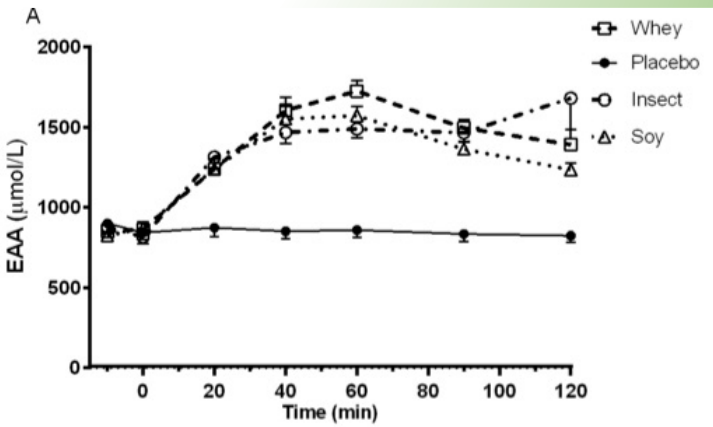
Oibiokpa F et al, Food Science and Human Wellness, 2018; Yang Q et al, J Insect Science, 2014



Nutrients **2018**, *10*, 1357; doi:10.3390/nu10101357

Ingestion of Insect Protein Isolate Enhances Blood Amino Acid Concentrations Similar to Soy Protein in A Human Trial

Mathias T. Vangsoe [1,*], Rebekka Thogersen [2], Hanne C. Bertram [2], Lars-Henrik L. Heckmann [3] and Mette Hansen [1]



Alphitobius diaperinus

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INSECTS ANTI-NUTRITIONAL FACTORS

trace amounts of

phytates
tannins

Yam beetle (*Heteroligus meles*)
palm weevil (*Rhynchophorus phoenicis*)

Adesina AJ, Elixir Food Science, 2012

chymotrypsin inhibitors

Mealworm (*Tenebrio molitor*)

T. molitor
$1.7 \times 10^{-3} \pm 0.7$

g protease inhibited per Kg larvae

soybean	Kidney bean	Lupin seed
12.0 ± 1.8	9.2 ± 0.9	1.4 ± 0.8

Grant G et al Br. J. Nutr. 1995, 73, 17-19

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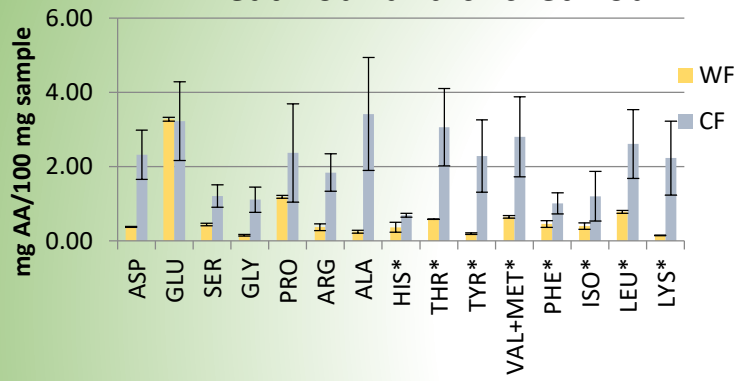
PROTEIN QUALITY OF INSECTS' ENRICHED BREAD

AMINO ACID COMPOSITION

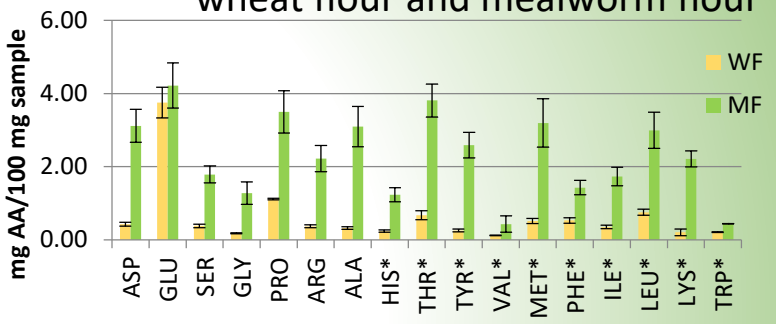
Osimani et al, Innovative Food Science and Emerging Technology, 2018

wheat flour and cricket flour

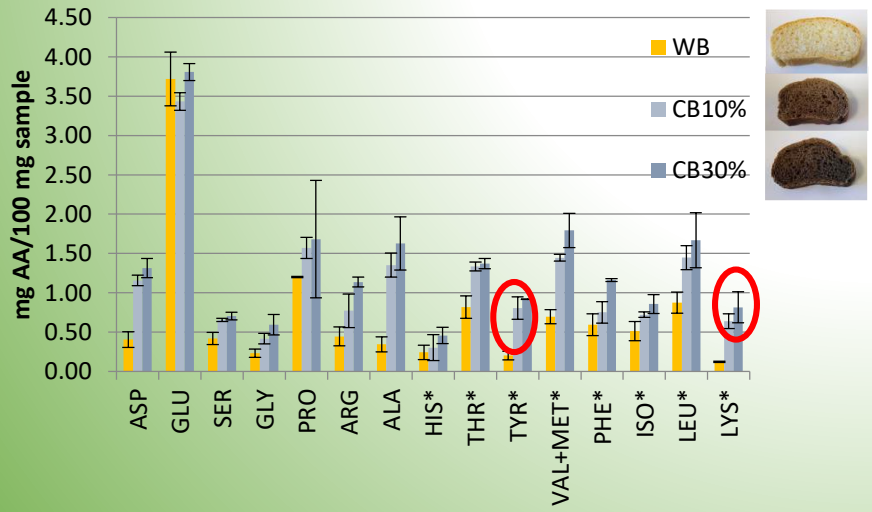


Roncolini et al, PLoSone, 2019

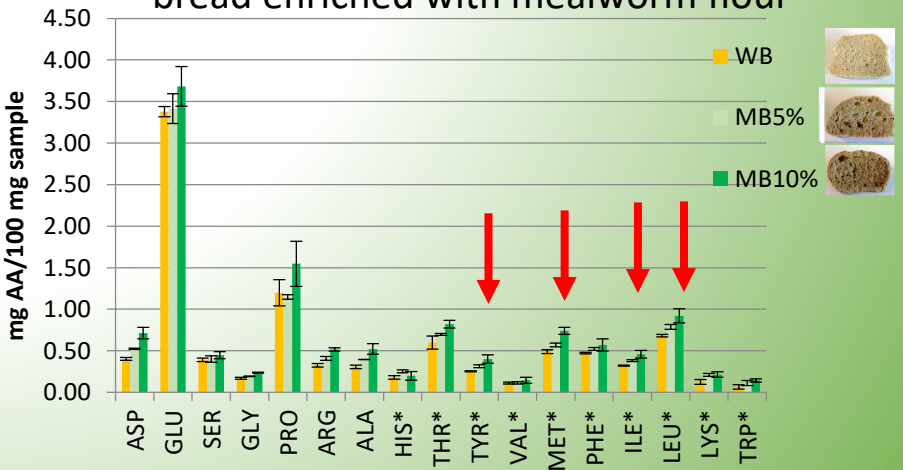
wheat flour and mealworm flour



bread enriched with cricket flour



bread enriched with mealworm flour



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CONCLUSIONS

- ✓ Insects meet the dietary requirement in term of both protein content and protein quality
- ✓ Insect's rearing on waste substrates can improve proteins quality
- ✓ Insects-enriched foods may have a higher nutritional value