POLYTECHNIC OF COIMBRA

Mass production of insects for food and feed

Rui Costa

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Poznan, Poland

Mass production of insects for food and feed

- Motivation to use insects as food and feed
- Edible insects as food and feed
- Food safety and nutrition issues
- Regulation issues
- Cultivation issues

Motivation to use insects as food and feed

- FAO prediction: 9.1 bilion people by 2050 (7.6 today)
- 2 billion people already eat it
- Cost of animal protein/EU high import of protein
- Sustainable alternative
- Can combat malnutrition
- Economical and social factors

Food conversion

Table 1.2: Examples of food conversion for some minilivestock under farming conditions

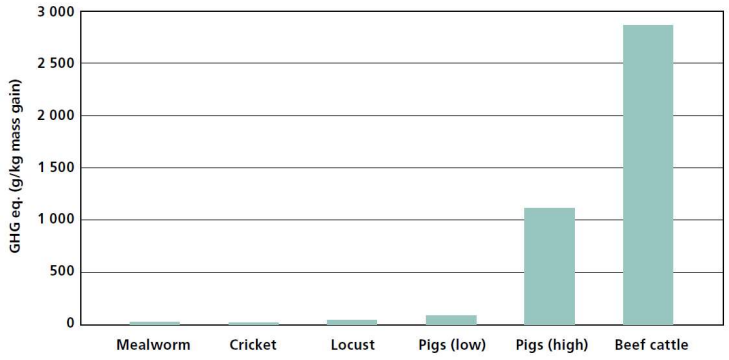
Animals		Food conversion*	Reference
Snails	(*Helix adspersa*)	1.2-2	Elmslie, 2004
Crickets	(*Acheta domesticus*)	1.7	Collavo et al., 2002
Chicken		2	Collavo et al., 2002
Pork		3.8	Collavo et al., 2002
Beef		7	Collavo et al., 2002

*Dried food required for fresh available meat.

Paoletti and Dreon (2005)

Production of greenhouse gases

FIGURE 5.4
Production of GHGs and ammonia per kg of mass gain for three insect species, pigs and beef cattle



Insects can be used to transform food waste

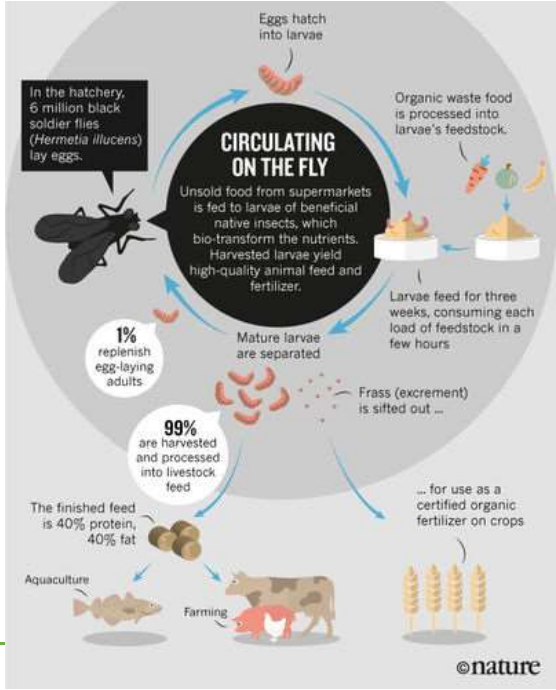


Image: Source: Enterra Feed Corporation

POLYTECHNIC OF COIMBRA

Current wide use of insects

Commercial products

- food: honey, propolis, royal jelly
- others: silk, wax (cosmetics, candles), dye (Cochineal)

Ecological roles

- pollination, food for animals, waste decomposition, and biological control.

We already eat insects in other food products!

TABLE 14.1
Maximum permissible levels of insect contamination in food products

Product	Type of insect contamination	Maximum permissible level
Canned sweet corn	Insect larvae (corn ear worms or corn borers)	Two or more 3 mm or longer larvae, cast skins, larval or cast skin fragments, the aggregate length of insects or insect parts exceeds 12 mm in 24 pounds
Canned citrus fruit juices	Insects and insect eggs	Five or more Drosophila and other fly eggs per 250 ml or 1 or more maggots per 250 ml
Frozen broccoli	Insects and mites	Average of 60 or more aphids and/or thrips and/or mites per 100 grams
Hops	Insects	Average of more than 2 500 aphids per 10 grams
Ground thyme	Insect filth	Average of 925 or more insect fragments per 10 grams
Ground nutmeg	Insect filth	Average of 100 or more insect fragments per 10 grams

Source: USFDA, 2011.

FDA - Food Defect Action Levels

Edible insects

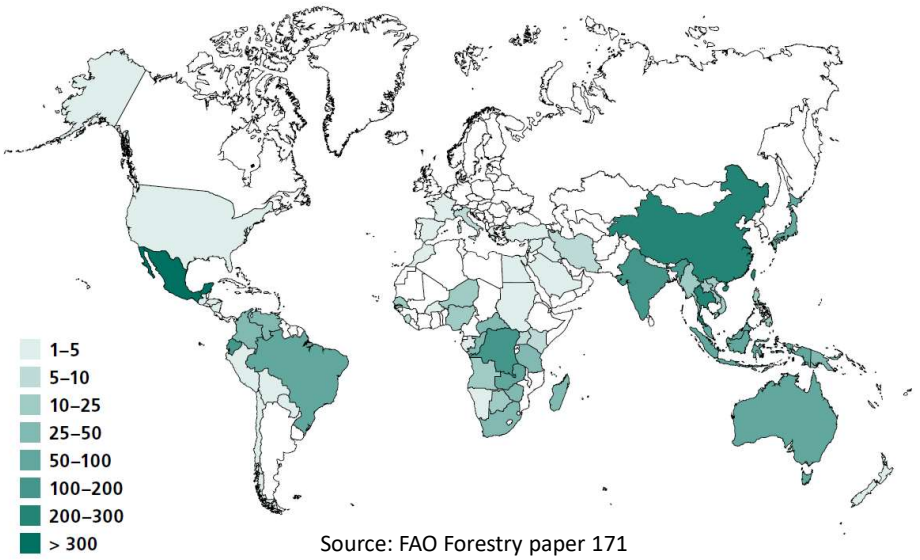
Examples of consumption by human (entomophagy)

- The primate with the most diverse entomophagy
- Most feel repulsion
- In Japan insects are eaten as part of the traditional diet
- Croatia the cheese maggot (Piophila casei L.) is regarded as a delicacy
- Sugar-rich crops of Zygaena moths (Italy)

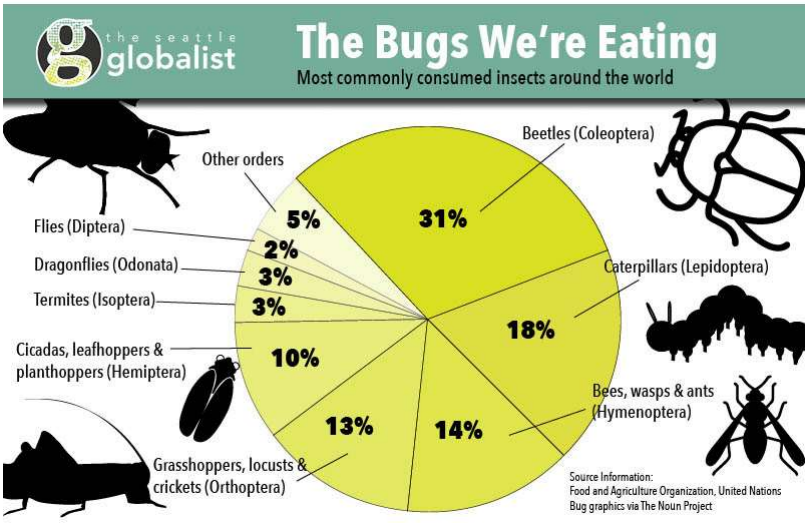
Figures

- More than 1,900 species of edible insects
- More than 2 billion people consume insects on a regular basis (DeFoliart 1989; FAO paper 171)

FIGURE 2.1
Recorded number of edible insect species, by country



Source: FAO Forestry paper 171

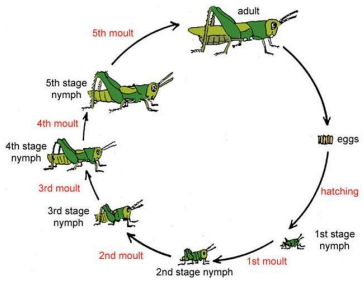


http://www.seattleglobalist.com/2013/09/20/seattles-bug-chef-promotes-insect-diet/16587

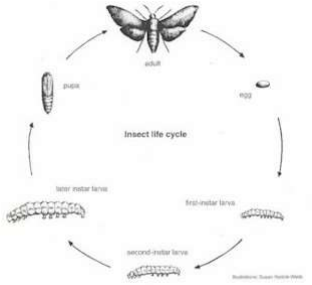
Feedipedia

- Black soldier fly larvae (Hermetia illucens)
- Housefly maggot meal
- Locust meal, locusts, grasshoppers and crickets
- Mealworm (Tenebrio molitor)
- Silkworm pupae meal

Consumed in any period of their biological cycle: eggs, larvae, pupae and adult



https://pt.pinterest.com/pin/311381761709030706/



http://www.co.stevens.wa.us/weedboard/htm_bio/insect_life_cycle.htm

Nutrition

Essential amino acids

Unit (mg/g crude protein)	A. diaperinus	T. molitor	Z. morio	A. domesticus	B. dubia	Casein	Soybean	1985 FAO/WHO /UNU
Methionine + Cysteine	26	26	24	25	23	35	24	22
Valine	58	61	63	55	52	63	49	39
Isoleucine	43	43	46	36	31	54	47	30
Leucine	66	73	71	66	56	95	85	59
Phenyl-alanine + tyrosine	120	100	111	92	93	111	97	38
Histidine	34	29	31	21	23	32	25	15
Lysine	61	54	54	53	43	85	63	45
Threonine	39	39	40	35	32	42	38	23
Tryptophan	12	12	14	9	8	14	11	6
Sum of EAA	459	437	454	392	361	531	439	277

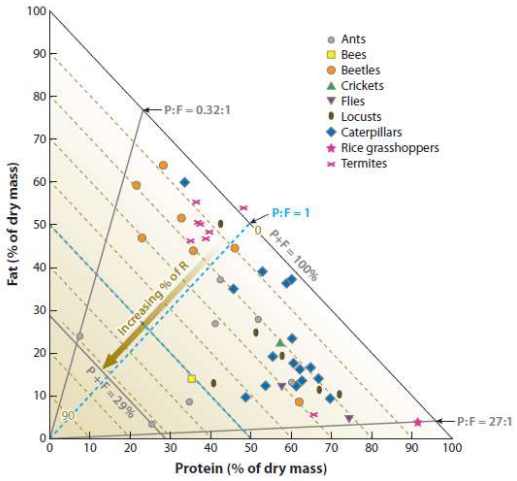
Fatty acids

Table 14.5: Proportion of fatty acids (%) of diverse organisms for obtention of animal protein (Adapted from National Research Council, 1988)

Organisms	Saturated acid	Monounsaturated acid	Polyunsaturated acid
Cattle	52.0 (28.1)	44.2	3.2
Pig	44.1 (24.3)	44.3	11.6
Poultry	35.5 (20.2)	40.8	22.7
Fish	29.6 (22.6)	39.6	30.8
Insects	11.0–43.4 (0.1–9.1)	55.9	57–100

For cattle, average of 27 cuts; pig 16; poultry 8; fish 3 types with 2 products of each type (e.g. Halibut, Tuna); insects maximum and minimum values from 27 analyzed species (percentage of stearic acid given in parentheses). Modified from DeFoliart G., 1991.

Protein vs Fat



Other components

- Minerals
- Antinutritional factors
- Chitin

Food safety

Hazardous substances

- heavy metals
- mycotoxins
- pesticide residues
- pathogens
- natural toxins
- allergens
- processing contaminates
- veterinary residues

Microbial safety

In general, insect pathogens are taxonomically separate from vertebrate pathogens and can be regarded as harmless to humans.

mopane caterpillar: presence of aflatoxins from 0–50 µg per kg of product; the maximum safe level set by FAO is 20 µg per kg

study with 5 insects (Giaccone, 2005)

- 10^5-10^6 CFU/g total; gram(-); high fecal coliform
- Neither Salmonella nor *Listeria monocytogenes* were identified
- Unlikely that these insects attract microbial flora that pose risks to humans

Toxicity

In the Democratic Republic of the Congo, Bouvier (1945) observed that consuming grasshoppers and locusts **without removing the legs caused intestinal constipation** because the large spines on the tibia (shinbone) would catch in the gut.

The tessaratomid *Encosternum delegorguei* in Zimbabwe and South Africa excretes a **pungent fluid** (Faure, 1944; Bodenheimer, 1951) **that can cause severe pain and even temporary blindness** if it comes into contact with the eyes (Scholtz, 1984).

Allergic reactions

- *Acheta domesticus*
- *Zophobas morio*
- *Alphitobius diaperinus*
- *Locusta migratória*
- *Schistocerca americana*
- *Schistocerca gregaria*
- *...*

EFSA
Risk profile related to production and consumption of insects as food and feed
EFSA J., 13 (2015), p. 4257

May be needed to use gloves and eye protection

Regulation

BELGIUM

Agence Fédérale pour la Sécurité de la Chaîne Alimentaire
21-05-2014

PCCB/S3/ENE/KBE/1158552 Insectes, denrées à base d'insectes, consommation humaine, aliments pour animaux

1. *Acheta domesticus*
2. *Locusta migratoria migratorioides*
3. *Zophobas atratus morio*
4. *Tenebrio molitor*
5. *Alphitobius diaperinus*
6. *Galleria mellonella*
7. *Schistocerca americana gregaria*
8. *Gryllodes sigillatus*
9. *Achroia grisella*
10. *Bombyx mori*

EU regulations
178/2002 food chain operators
852/2004 farmers, processors distributors
183/2005 animal feed
…

REG (EU) 2017/893 of 24 May 2017
farmed insects for aquaculture and fur animals

- Black Soldier Fly (Hermetia illucens) and Common Housefly (Musca domestica),
- Yellow Mealworm (Tenebrio molitor) and Lesser Mealworm (Alphitobius diaperinus)
- House cricket (Acheta domesticus), Banded cricket (Gryllodes sigillatus) and Field Cricket (Gryllus assimilis);

EU regulation limits to use insects as Food and Feed

Annex III of 767/2009 prohibited materials	feces, urine, wood treated with preservatives, waste from sewage, municipal solid waste, packaging and parts of packaging, etc.
1069/2009	The kitchen waste, leftover food and unprocessed animal by-products can not be used in the diet of insects.

EU regulation limits to use insects as Food

Reg (EU) 2283/2015

- 'novel food' means any food that was **not used for human consumption to a significant degree within the Union** before 15 May 1997, irrespective of the dates of accession of Member States to the Union, and that falls under at least one of the following categories
- Includes whole insects and their parts

Cultivation

Current industrial examples

Ornamental insects	• Japan and Taiwan have strong beetle-farming communities (mainly for Lucanidae, Cetoniidae and Dynastidae)
Combat of pests	• screw-worm fly (Cochliomyia hominivorax) in North America • medfly (Ceratitis capitata) in Central America
Pet food and fish bait	• *Tenebrio molitor* to feed spiders • Drosophila larvae for fish bait

AgriProtein (South Africa)

Black Soldier Fly larvae

https://agriprotein.com/our-products/

MagMeal™

"Unsurprisingly, the animal and digestibility trials were superb. After all, it is the feed they would naturally forage for."
Dr. Elsje Pieterse, Department of Animal Science, Stellenbosch University

A 55% protein feed ingredient with a powerful blend of essential amino acids, with high digestibility across all our agricultural and aquaculture trials. No surprise, it is a natural feed for birds and fish in the wild. Pets also appreciate the natural protein and oils which have been proven as ingredients in chew treat trials for dogs.

MagMeal™ is as an early life stage 'super feed'. We target the early life stages of poultry development, as we do fingerlings in aquaculture and the first shrimp growth periods. This is the time when the basic building blocks of animal development are put in place.

Our product helps develop good bone structure and exoskeletons and promotes organ

AgriProtein (South Africa)

Black Soldier Fly larvae

https://agriprotein.com/our-products/

MagOil™

"It takes a minimum of 1.5kg of fishmeal to make 1kg of farmed fish, a scandalous plundering of the ocean's limited resources that threatens the entire marine ecosystem."

Paul Vantomme, United Nations Food & Agriculture Organisation

MagOil™ is a nutty smelling, meaty tasting oil extracted from our larvae. It is very similar in make up to linseed oil and contains natural lauric acid. It is ideal for inclusion in layer chicken diets, fish pellet mixes and for all kinds of pet foods.

At room temperature, it is almost solid and makes a wonderful tallow. We are investigating its use in cosmetics with a Fortune 500 business and expect to be able to share preliminary results in August 2017.

Considering industrial facilities

(Schneider, 2009)

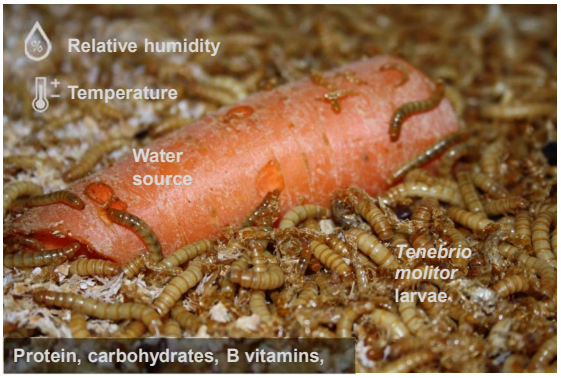
- facility design
- facility management (including health and safety)
- environmental biology
- management of microbial contamination
- nutrition and diet
- population genetics
- quality control

Quality control (Leppla, 2010)

- Quantity- number of pupae or adults
- Size- weight of pupae
- Fecundity- oviposition and egg hatch
- Rate of development
- Adult behavior-flight, longevity
- Field performance- achieve purpose

Studies needed (Morales-Ramos et al.,2013)

- Crowding (density of populations)
- Design of oviposition substrates and rearing enclosures
- Temperature and production (life tables)
- Quality control and production

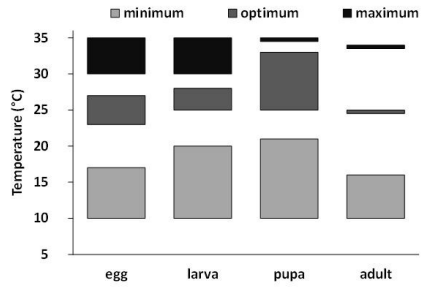


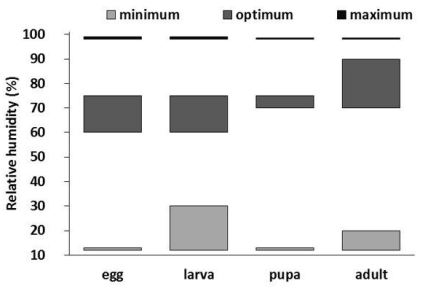
Tenebrio molitor

Nuno Ribeiro, Manuela Abelho, Rui Costa (2018)

A Review of the Scientific Literature for Optimal Conditions for Mass Rearing Tenebrio molitor (Coleoptera: Tenebrionidae).

Journal of Entomological Science (accepted for publication)





Tenebrio molitor

Tenebrio molitor

optimal diet

1. 5% to 10% of yeast (Martin and Hare 1942);
2. less than 1% fat (Fraenkel 1950);
3. 80-85% carbohydrates (Fraenkel 1950);
4. Vitamins of the B complex (Martin and Hare 1942; Leclercq 1948).

Cortes Ortiz et al. (2016). Insect Mass Production Technologies

FIGURE 6.7 **Large scale mealworm rearing in paper containers (China).** *(Pictures from Liu Yusheng, Shandong Agricultural University)*

Acheta domesticus

Collavo et al. (2005) House cricket small farming

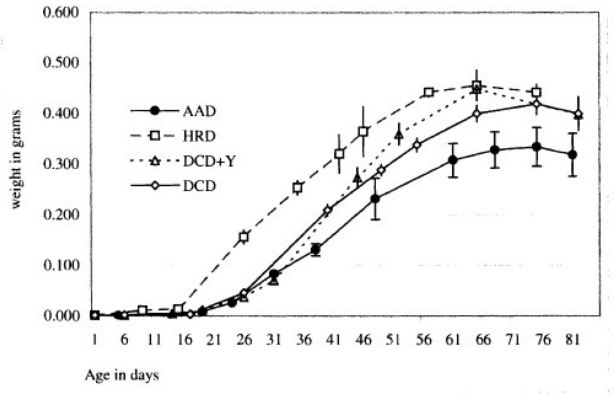


Fig. 27.1: *Acheta domesticus*, average weight gained using different diets (AAD—Aromatic-Arboreal Diet; DCD+Y—Dairy Cow Diet with Yeast; HRD—Human Refuse Diet; DCD—Dairy Cow Diet.

Acheta domesticus

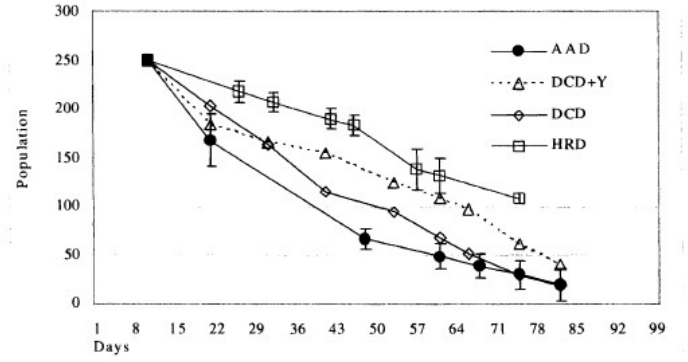


Fig. 27.2: *Acheta domesticus*, average mortalities in rearing colonies given different diets (AAD—Aromatic-Arboreal diet; HRD—Human Refuse Diet; DCD+Y—dairy Cow diet with Yeast; DCD—Dairy Cow Diet).

Acheta domesticus

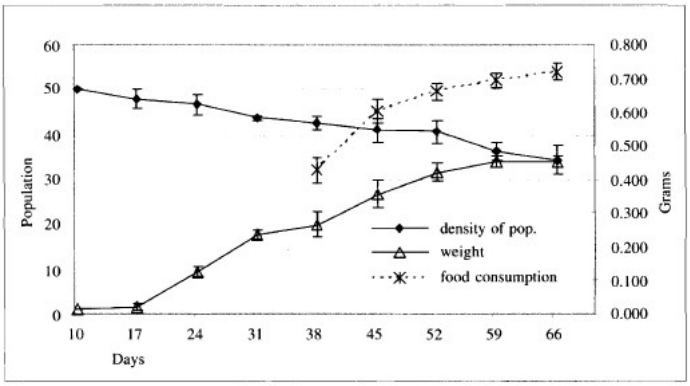


Fig. 27.3: Average density of population, weight, and feed consumption in colonies raised on Human Refuse Diet.

Acheta domesticus

Table 27.9: Annual production of different crops per hectare (ha); 1 q = 100 kg (pers. comm. G. Cozzi, 2002)

Lucern (*Medicago sativa*), hay	130 q/ha;
Corn flour (*Zea mays*)	120 q/ha;
Silage corn (*Zea mays*)	800 q/ha;
Soybean flour (*Glycine max*)	40 q/ha;
Wheat (*Triticum durum*)	70 q/ha;
Sugar beet (*Beta vulgaris* var. *esculenta*)	650 q/ha.

Table 27.10: Resources and cultivable surface needed to produce 1 ton of *Acheta domesticus* with dairy cow diet (DCD)

	Soybean flour	Lucern	Corn	Wheat	Sugar beet	Silage corn	Total
Resources needed	6.4 q	5.5 q	4.6 q	4.1 q	3.6 q	3.5 q	27.8 q
Surface needed	1596 m²	425 m²	382 m²	593 m²	56 m²	44 m²	3096 m²

Research needs on the cultivation of insects

- Nutrition
- Environmental impact
- Rearing data
- Developing diets

dziękuję za uwagę

ruicosta@esac.pt