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Microbiology of insects as food and feed

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Introduction

- Feeding the world population with secure, safe, and high-quality proteins and fats is a major challenge for our future.
- (Re)discovery of alternative animal fat and protein sources apart from meat and fish

Lofty goals, noble goals…but what about the people?

Why do we waist time discussing something so trivial?

Supposedly they are good, and I think it‘s okay to sell them, but I…

Ah, *they* consume them, but *we* don‘t, of course!

Rhaaaa, we are all going to die, this is the end of our civilsation!!

Images: Wikipedia

Lebensmittelqualität und -sicherheit

Introduction

- Feeding the world population with secure, safe, and high-quality proteins and fats is a major challenge for our future.
- (Re)discovery of alternative animal fat and protein sources apart from meat and fish
- Acceptance of entomophagy (éntomon = insect, phagein = to eat) has been low so far in Germany, while being a millennial tradition in other parts of the world (e.g. Mexico, Thailand)

…dove men si sa, più si sospetta.

…the less is known, the more is suspected.

Niccolò Macchiavelli

Contents

- Productive insects
- Factors affecting the microbiome of productive insects
- Legal framework for foods containing edible insects

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Introduction

Productive insects:
insects farmed for a specific goal (food, feed, industry, agriculture, waste management, research, pets etc.)

Status	Mammals	Insects
domesticated	Dogs, domestic sheep, pigs, cattle etc.	Western honeybee, domestic and eri silkmoths
Semi-domesticated, traditional	Indian elephant, reindeer, fallow and red deer etc.	Eastern honeybees, stingless bees, cochineal, lac bugs etc.
Semi-domesticated, recent	Giant eland, moose, nutria, white-tailed deer etc.	Lesser fruit and black soldier fly, crickets, mealworms, locusts etc.
Free range	Game species	Insects gathered for food and/or ethnomedicine (> 3.000 species)

Introduction

Relevance		Examples
International	Traditional	Migratory and desert locusts, nsenene bush crickets, tropical crickets, giant water bugs, termites, mopane caterpillars, palm weevil larvae
	Recent	House, Jamaican field, and Mediterranean crickets, mealworms
National	Traditional	Dragonflies (Indonesia), chapolin grasshoppers (Mexico), bamboo borer caterpillars (Thailand), red crickets (Thailand)
	Recent	Scarabaeid beetles
Regional	Traditional	Mole crickets (Thailand), axayacatl lesser water boatmen (Mexico), azcamōlli ant eggs
Local	Traditional	Witchetty grubs (Australia), zazmushi aquatic insects (Japan), local beetle species

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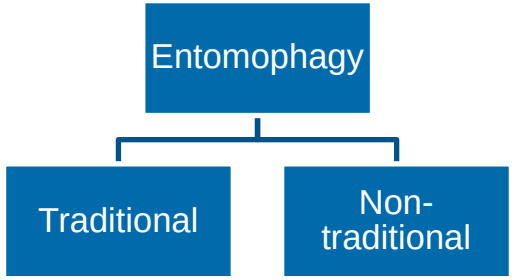
Entomophagy
Traditional
Non-traditional

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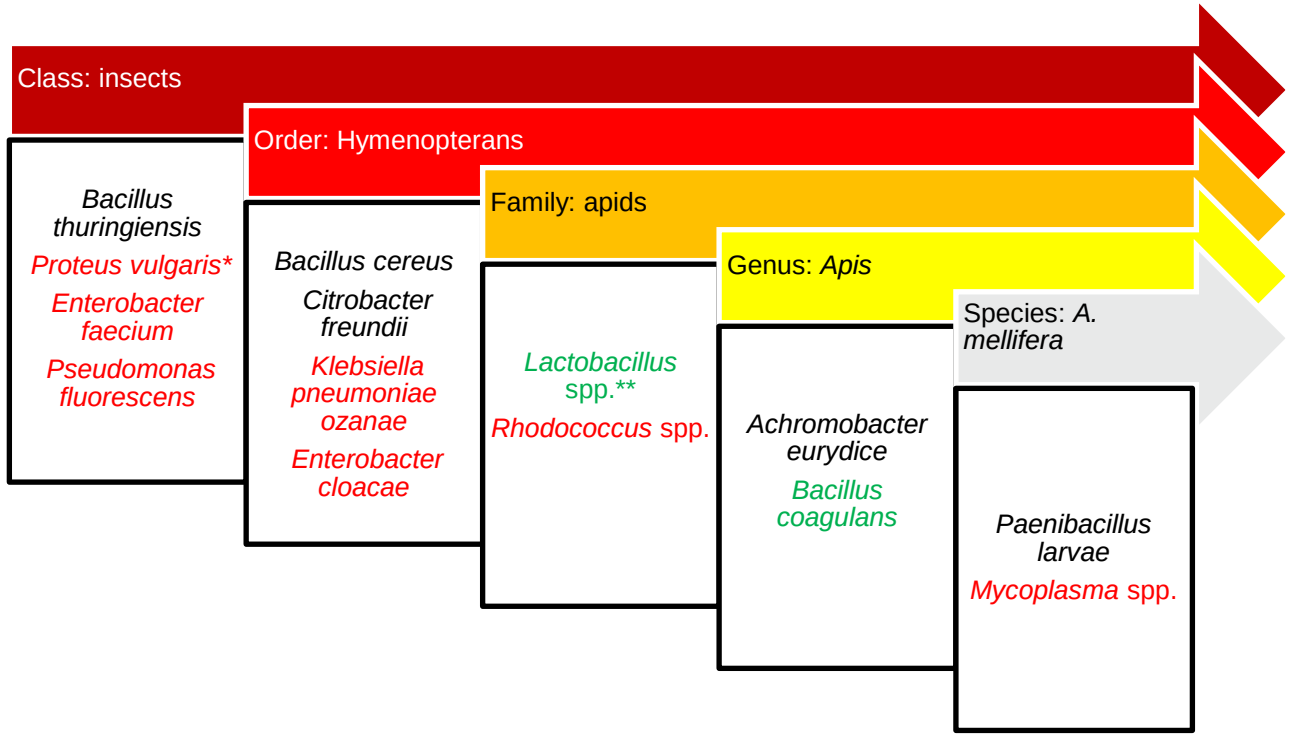
Micro and mycobiome of insects: Taxonomy

Taxonomy seems to be an important factor in insect microbiomes. There is a basic set of microorganisms common (probably) all insects, and taxon-related subsets (order, family, genus, species, etc.)

Images: Wikipedia

Micro and mycobiome of insects: Taxonomy



*Nosocomial and/or potentially zoonotic
**Probiotic

Micro and mycobiome of insects: Metamorphosis

Hemimetabolous:
locusts, grasshoppers,
crickets, termites, bugs

Holometabolous:
beetles, butterflies, flies,
bees, wasps, ants

Micro and mycobiome of insects: Physiology

The kind of digestive tract, its morphology and the feed habits of the insect, affects the microbiome.

Micro and mycobiome of insects: Environment

Insect inhabit a great variety of biotopes, filling specific ecological niches. Social insects also create their own environmentx, e.g. bee hives or termite nests, allowing the growth of certain microorganisms. Feed is another important factor, both for herbivores, predatores, and detritovores.

Images: Wikipedia

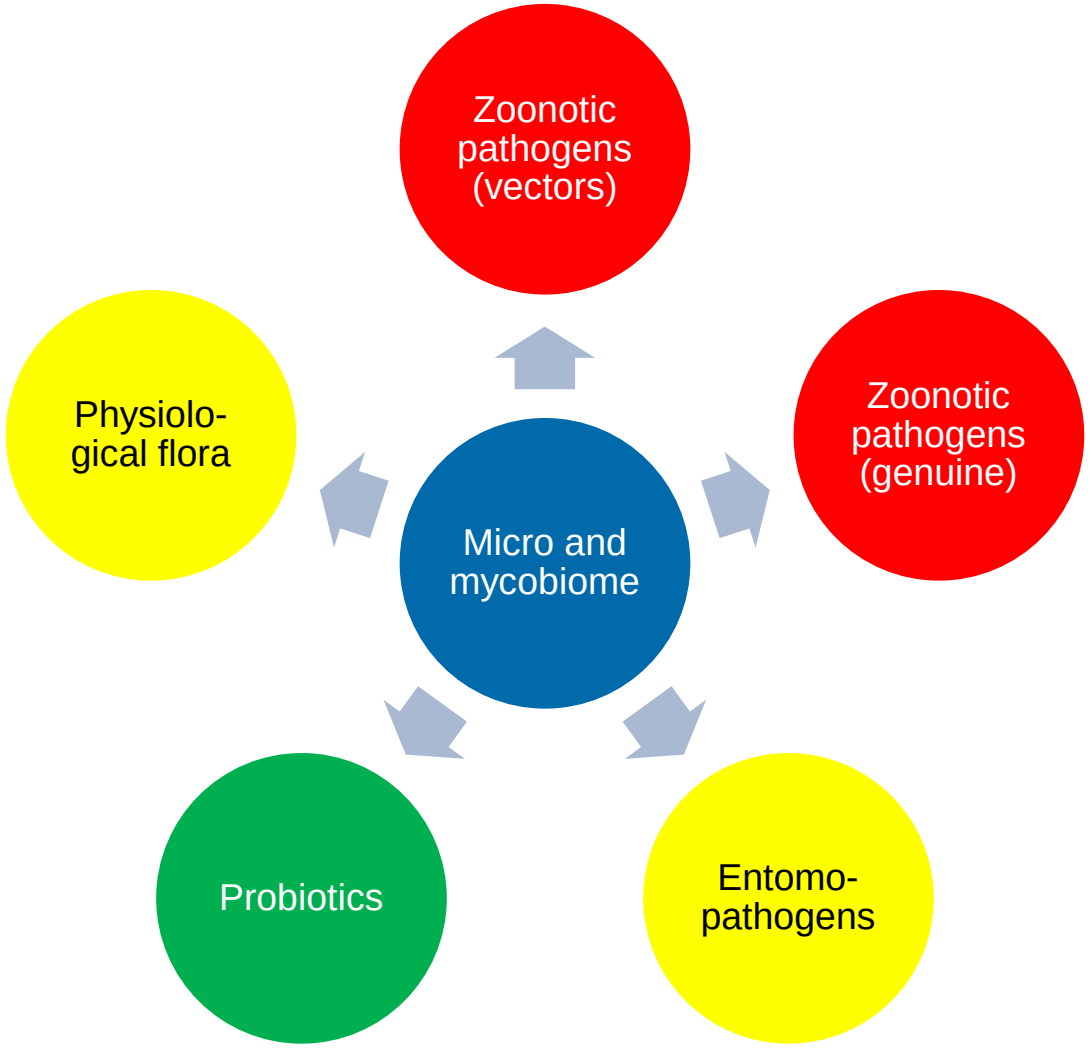
Micro and mycobiome of insects: Farming Techniques

Xiroculture (dry)	Hygroculture (humid)	Aquaculture (wet)	Xyloculture (wood)
Crickets, locusts, mealworms	Flies, particularly young instars	Water bugs, water beetles, salt flies	Palm weevils, bamboo borers

Micro and mycobiome of insects: Farm Environment

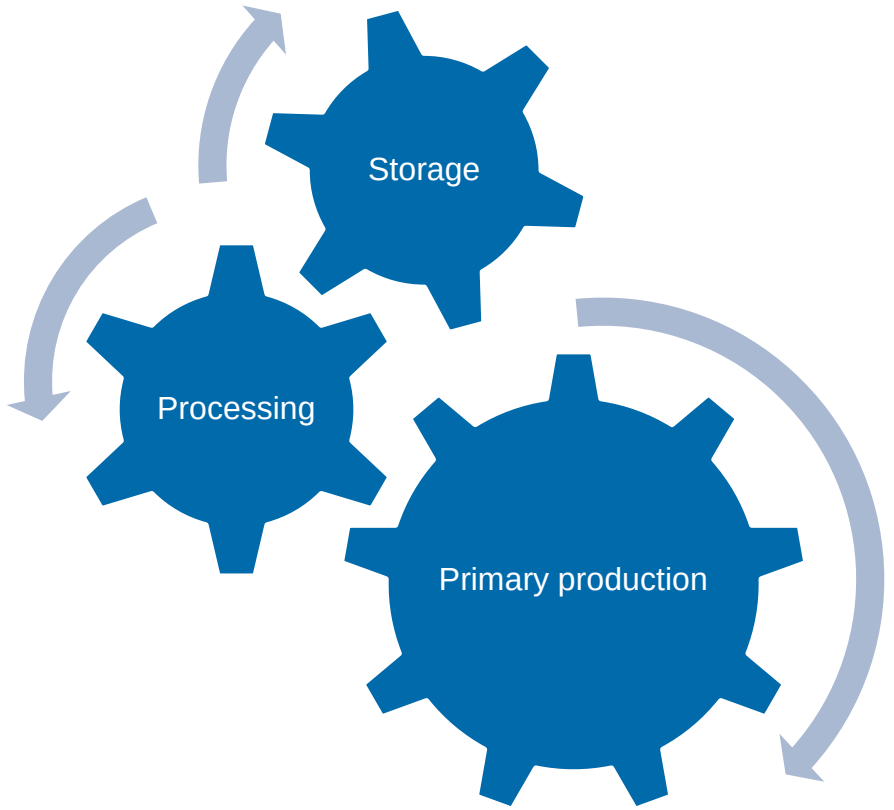
There are different kinds of farmes used for insects, from open systems like former vertebrate livestock housings and greenhouses to closed systems like former production builings used for black soldier flies or mealworms. Entry, control and colonisation of these facilities by microorganisms vary, in addition to the flora entering the system via the feed or the water.

Micro and mycobiome of insects: Type of Microorganism



There are two main sources for microorganisms: the cuticula and the GIT. In bothe case, there are two barriers normally preventing the entry of bacteria and fungi into the coelomic cavity, the cuticula as such and the peritrophal membrane (GIT).

Micro and mycobiome of insects: Processing



Tendency: bacterial counts ↑/→/↓

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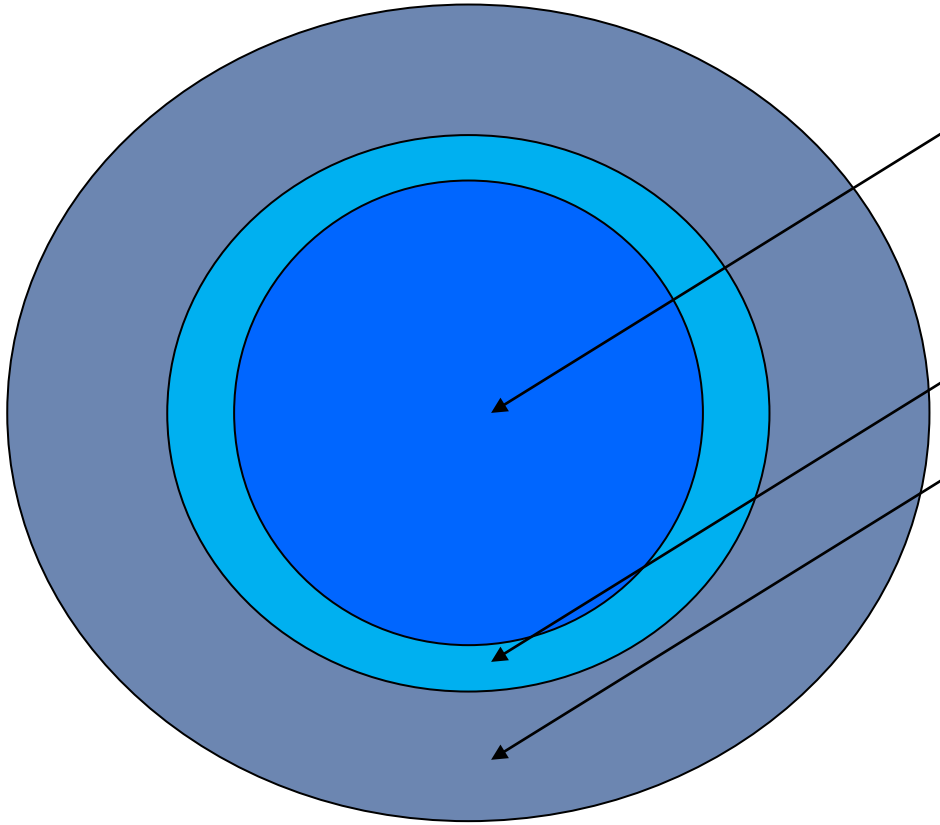
Legal framework: Productive Insects are Livestock



Legal requirements for livestock for human consumption

Legal requirements for edible insects

Own judgement when lacking regulatory base

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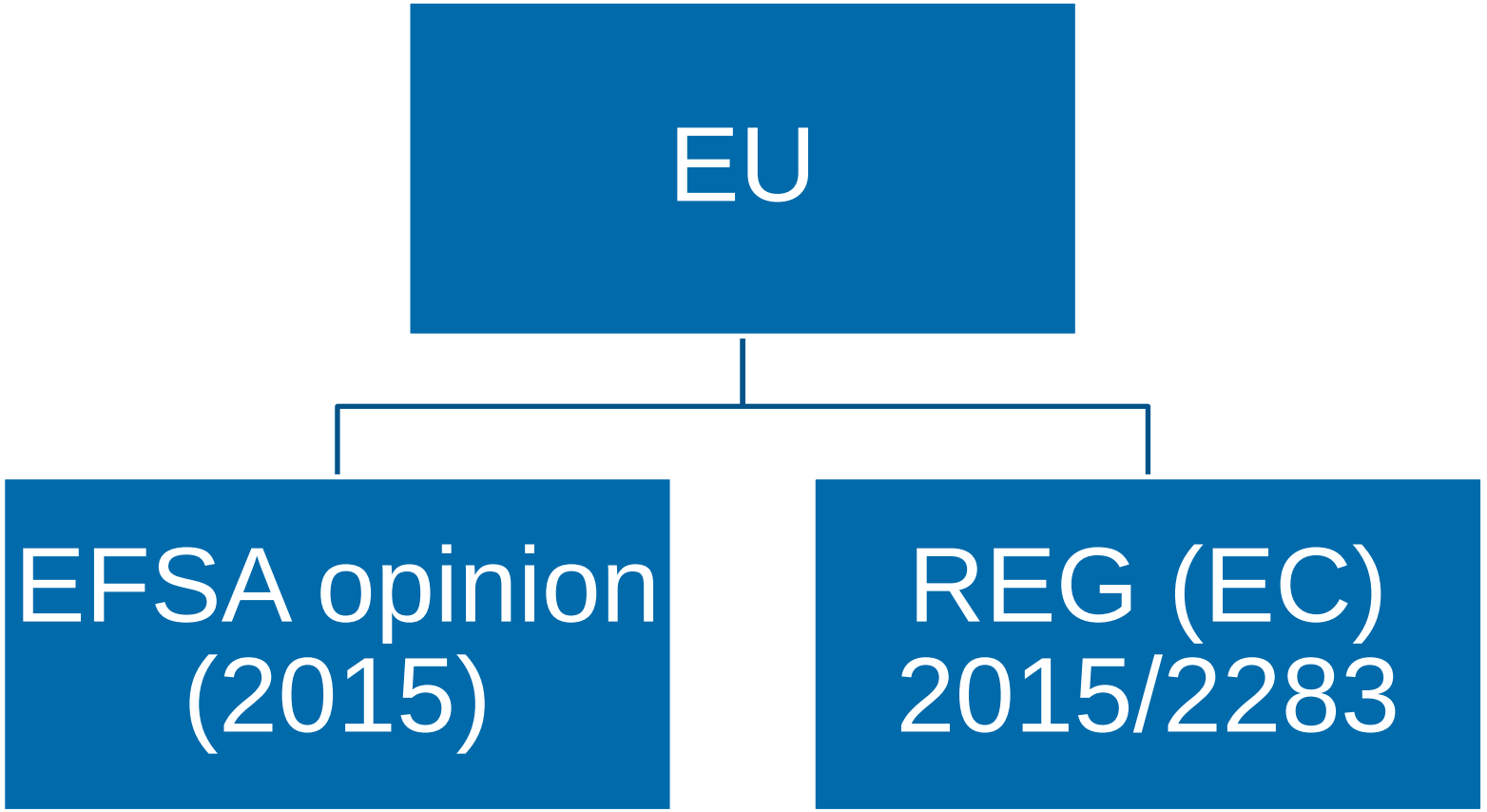
Legal framework



Legal framework: EFSA Opinion

EFSA (2015): Risk profile related to production and consumption of insects as food and feed

1. Introduction
2. Material an methods
3. Breeding and processing (species, substrates, breeding systems, production chain, processing, consumption)
4. Risk profile (microbiology, chemistry, allergens, processing, storage, environment)
5. Conclusion
6. Uncertainties
7. Recommendations

Legal framework: EFSA Opinion

Type	Risk	4. Profile	5. Conclusion	6. Uncertainty
Microbiology	**Prions**	**Species barrier, vector?**	**≤, when not containihg risk material**	**Inconclusive data**
	Viruses	**Species barrier?**	**≤, when using certified feedstuffs and applying corresponding heating methods**	**Viral metabolites?**
	Bacteria	**Entomopathogenic and physiological flora**		**Inconclusive data**
	Fungi	**s. Other livestock**		
	Parasites	**Farmed insects?**		
Chemistry	Heavy metals	Substrate-dependant	**?**	
	Toxins			
	Veterinary drugs	Substrate, treatment		
	Others	Substrate-dependant		
Allergens	Tropomyosin	Cross-reaction	**+**; labelling!	
Processing	Bacterial counts	Spoliage	**+**; no raw consumption	
Environment	Breeding	s. Other livestock	**≤**; manure control	

Legal framework: Novel Foods – Caveat!

Caveat 1: Not all processing forms are allowed by the EU

Species	Product	Company's headquarters	REG (EC)
Lesser mealworm (*Alphitobius diaperinus*)	frozen, paste, dried and powder	France	2023/58
Yellow mealworm (*Tenebrio molitor*)	dried, entire or as powder	Id.	2021/882
	frozen, entire or as powder	Netherlands	2022/169
	UV-treated powder of whole larvae	France	2025/89
Migratory locust (*Locusta migratoria*)	frozen, entire or as powder	Netherlands	2021/1975
House cricket (*Acheta domesticus*)	Id.	Id.	2022/188
	partially defatted powder	Vietnam	2023/5

Legal framework: Novel Foods – Caveat!

Caveat 2: Not all processing forms are allowed in all foods!

Product	Yellow mealworm		Migratory locust	House cricket
	F	NL	NL	NL
Alcoholic beverages	.	+	+	+
Bakery products	+	+	+	+
Protein products	+	.	.	.
Protein products without meat analoga	.	.	.	+
Meat analoga	.	+	+	+
Meat preparations	.	+	.	+
Vegetable products	+	+	.	.
Canned vegetables	.		+	.
Cereal bars	.	+	.	.
Potato products	.	+	.	.
Snacks	.	+	.	+
Confittery, chocolate	.	+	+	+
Dairy products	.	+	+	+
Whey powder	.	+	.	.
Nuts, oil seeds, and chickpeas	.	+	+	+
Pasta and pasta dishes	+	+	+	+
Pizza	.	+	.	.
Salads	.	+	+	.
Sauces	.	+	.	.
Soups	.	+	+	+

Legal framework: Novel Foods – Caveat!

Caveat 3: Microbiological criteria may vary according to the insect product!

Type	Parameter	House cricket			Buffalo worm		Locust			Mealworm		
		Frozen	Dried/powder	Part. defatted	Dried/paste	Dried/powder	Frozen	Dried	Powder	Frozen	Dried	Dried/powder
Chemical composition	Humidity, ashes, crude protein, crude fat, crude fibre, chitin, peroxide number	+	+	+	+	+	+	+	+	+	+	+
	Cyanide	.	.	+	.	.	.	.	.	.	.	.
	Saturated fatty acids	+	+	.	.	.	+	+	+	+	+	+
	Mangan	.	.	+	.	.	.	.	.	.	.	.
	Digestible carbohydrates	+	+	.	+	+	+	+	+	+	+	+
Contaminants	Pb, C, aflatoxins (sum of B1, B2, G1, and G2), desoxylivaneol, ochratoxin A	+	+	+	+	+	+	+	+	+	+	+
	Aflatoxin B1	+	+	.	+	+	+	+	+	+	+	+
	Dioxin and (dioxin-like) PCP	+	+	+	.	.	.	.	.	+	.	+
	Sum of dioxins and dioxin-like PCB	+	+	+	.	.	+	+	+	+	.	+
Microbiological criteria	**Listeriae, salmonellae, aerobic mesophilic counts, *Bacillus cereus* (presumptive), *E. coli*, Enterobakteriaceae, yeasts and mould, coagulase-negative staphylococci**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**
	Sulphite-reducing anerobials	**+**	**+**	**.**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**

Shelf control – determining insect freshness

- Each species tastes differently!
- Cooked insects use to be rather neutral smell (due exceptions: Mediterranean crickets and super worms)
- Spoiled insects smell of putrefaction
- Darkening, from the body centre, spreading to the extremes (caveat: species with dark bodies)
- Fungal growth

Conclusion

- Consuming insects is nothing else but living resp. reviving and/or modifying traditional food habits
- Many factors influencing the micro and mycobiome → species and farm-specific composition
- Food insects in the EU: clasical microbiological criteria, caveat when evaluating samples for the lab (→ Union list)

Thank you for your attention!

Have you hugged your vet today?

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