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INSECTS AS A SUSTAINABLE SOURCE OF PROTEIN
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Insect Protein – International Quality and Safety findings

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INSECTS AS SUSTAINABLE SOURCES OF PROTEIN
PROteINSECT - European Commission Grant agreement no. FP7-KBBE-312084

Insect Protein Conference
Insect Protein – Feed for the Future
www.proteinsect.eu

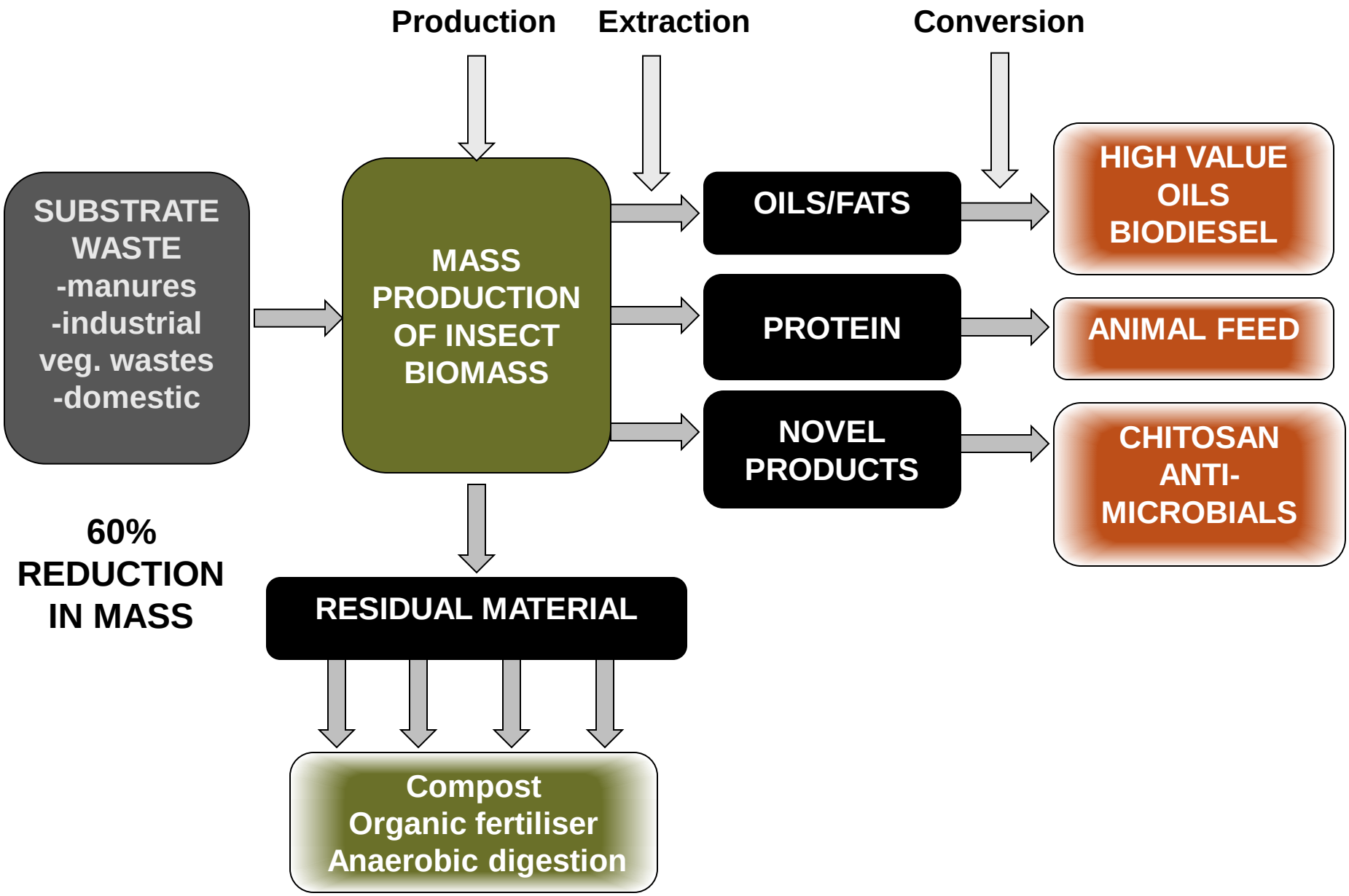
Date:
27 April 2016

Location:
Brussels

Why insects?

- Highly efficient at the rapid conversion of a range of “waste” substrates into biomass
- A natural component of animal diets including; fish, birds, reptiles and mammals
- Protein digestibility (86-89%) higher than most vegetable based proteins

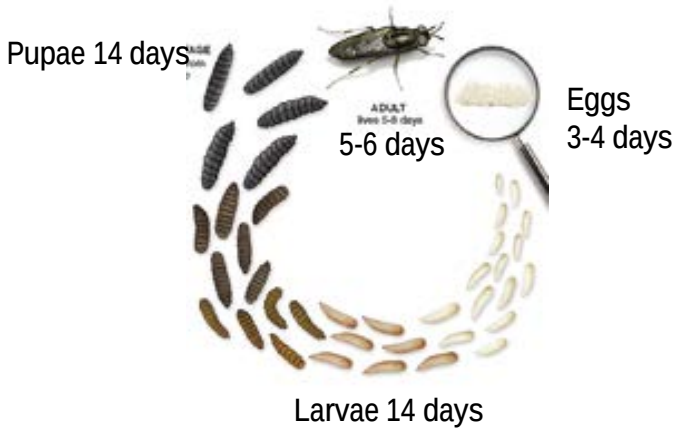
Protein content (30-80 % d.m.)
Fat content (5-60 % d.m.)
Fibre content (4-60 % d.m.)


Production
Extraction
Conversion
SUBSTRATE WASTE
-manures
-industrial veg. wastes
-domestic
MASS PRODUCTION OF INSECT BIOMASS
OILS/FATS
PROTEIN
NOVEL PRODUCTS
HIGH VALUE OILS BIODIESEL
ANIMAL FEED
CHITOSAN ANTI-MICROBIALS
60% REDUCTION IN MASS
RESIDUAL MATERIAL
Compost
Organic fertiliser
Anaerobic digestion

Flies

Complete life cycle 5-6 weeks

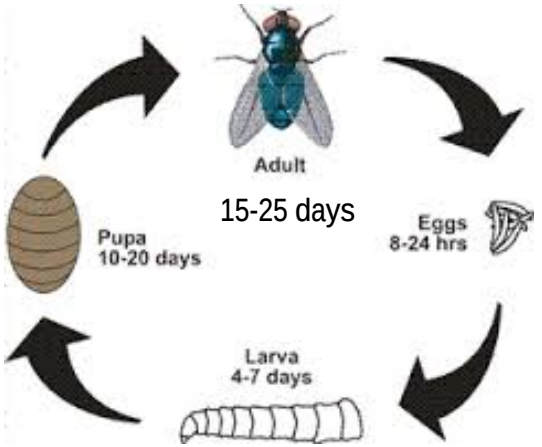
Black soldier fly: *Hermetia illuscens*



- food, swine, poultry & human waste
- min. 14 days: egg to mature larvae
- require > 30 °C for development
- mean wt. 0.2 g/ larvae
- adult breeding/egg production is challenging

Complete life cycle 3-6 weeks

House fly: *Musca domestica*



- food, swine & poultry waste
- 4-13 days: egg to mature larvae
- require > 17 ° C for development
- mean wt. 0.02 g/larvae
- 500 eggs/adult

Europe: Current legislation is a major barrier to the use of insect protein in animal feed.

Catalogue of Feed Materials (EC 68/2013)

- No entry for insect meal (listing for “whole or parts of terrestrial invertebrates”)

Directive EC 2002/32 Undesirable Substances in Animal Feed

- Insects must meet requirements (sets max levels of contaminants)

For processed insects - Regulation EC 999/2001 prohibited all Processed Animal Protein (PAP) from use in animal feed

- Now partially lifted (regulation EC 56/2013), PAP derived from non-ruminants is allowed to be fed to fish

Regulation EC 56/2013 does not apply to processed insect protein

Deliberate feeding of insect protein to farmed animals intended for food is not currently permitted under EU law

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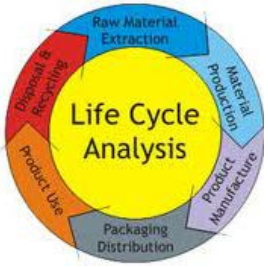
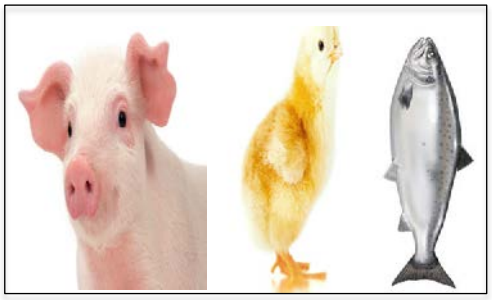
- Substrates- animal manures
- Low value wastes
- Insect rearing systems (China, Africa, UK)



- Nutritional value & quality
- Safety (Chemical & Biological)
- By-product evaluation

- Processing- crude vs refined protein

- Regulation
- Consumer perception



- Animal trials
- inclusion rates
- meat quality

Quality and Safety

- Little published data about the risks of using insects in feed and how these can be managed.
- Robust nutritional data also sporadic.
- Performance traits of animals fed on insects need to be established.
- Analysis of meat from insect reared animals to be undertaken (e.g. taints).
- Potential for high value by-products such as fats and oils.

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Safety testing (DIRECTIVE 2002/32/EC)

- Heavy metals (As, Pb, Hg)
- Pesticides
- Dioxins and PCBs
- Veterinary medicines
- Mycotoxins
- Salmonella

Chemical Safety

- Risks will be dependant on feedstock and processing.
- Different feedstocks and insect combinations = different risks

Examples might include:

- **Bioaccumulation** of metals and environmental contaminants.
- **Concentration** of natural contaminants such as mycotoxins.
- **Transfer** of toxic residues e.g. pesticides

Metals

- Toxic (e.g. cadmium, mercury, arsenic, lead)
- Nutritional but toxic at low levels (e.g. selenium, zinc)
- Nutritional but toxic at high levels (e.g. iron, potassium).

<u>EU regulations in feed range from 0.5 to 5 ppm.</u>

Initial tests show levels in some insects higher than permissible EU limits for feed

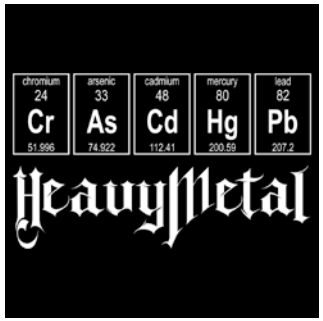


Image courtesy of www.angrygirlwear.com

Pesticides

- Multi residue screen. Total 416 compounds.
- Covers non-permitted pesticides (e.g. DDT) and permitted (e.g. dimethoate).
- EU regulations in feed range from 5 to 200 ppb

What is ppb?

One ppb is 10^{-9} the equivalent to finding one person in the population of India or adding one grain of salt to a 10 ton bag of crisps.

Dioxins, PCBs and PAHs

70 compounds:

- 28 Polycyclic aromatic hydrocarbons (PAHs)
- 25 Polychlorinated biphenyls (PCBs)
- 17 Dioxins

Persistent organic pollutants enter food chain through incineration (e.g. forest fires, use of fuels for drying).

Known to **bioaccumulate** in fat.

Highly toxic.

EU limits in feed range from 0.75 to 10 **ppt**

What is ppt?

One ppt is 10^{-12} so adding one grain of salt to a 10,000 ton bag of crisps!

Veterinary Medicines

68 EU regulated compounds:

- 17 Sulphonamides
- 7 Tetracyclines
- 8 Penicillins
- 8 Cephalosporins
- 10 Quinolones
- 13 Macrolides
- 5 “Others”, e.g. Chloramphenicol

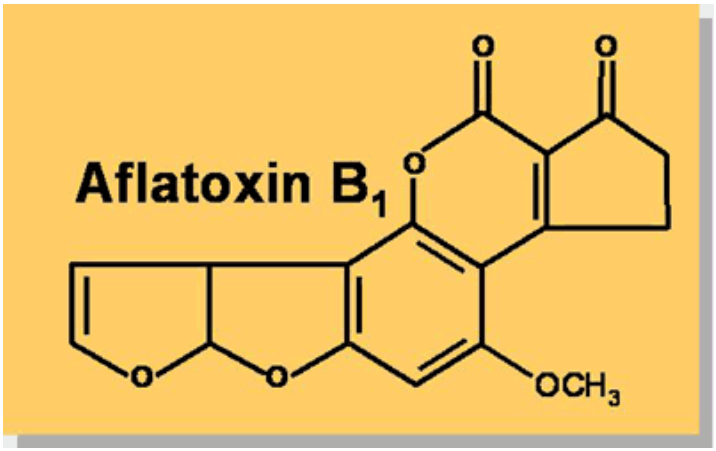
Exit animals through faeces. Antibiotic resistance risk if transferred.

Also screening to detect the presence of 492 compounds including those known to be used worldwide.

Limits in range 0.2 – 150 ppb

Mycotoxins

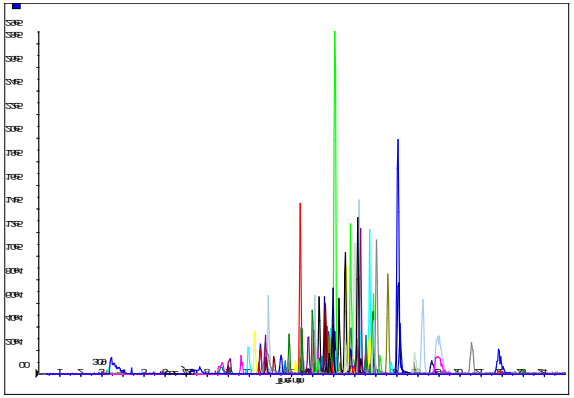
- Natural plant toxins – risk if rearing on food waste as produced by fungus.
- Aflatoxin B1 has 5 ppb regulatory limit 2002/32/EC.
- Fumonisins, deoxynivalenol, T2 toxins, Ochratoxin A and Zearalenone. all with recommended limits between 50 and 5000 ppb.



Non-targeted Profiling

- Broad non-selective analytical approach.
- Data scrutinised against a database of currently 5,500 compounds including; shellfish toxins, plant toxins and pharmaceuticals.

Risks we may not detect at the moment:
Some inorganic compounds (e.g. nitrite).
Proteins (e.g. prions).
Insect toxins.
Others (e.g. Brominated flame retardants).



<u>Shellfish toxins cause paralysis at very low levels of exposure</u>

Production systems

Chemical safety

Screen for 492 agrochemicals

68 Veterinary medicines

393 Pesticides

69 Mycotoxins

28 Polychlorinated biphenols (PCBs)

48 Heavy metals/trace elements

42 Dioxins/Polychlorinated hydrocarbons (PAHs)

Exploring the chemical safety of fly larvae as a source of protein for animal feed

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Contaminants below recommended max. concentrations (EC, WHO, & Codex)

- Cadmium high in 3 samples

Microbiological Safety

- Feedstock and insect species dependant
- Potentially managed through processing e.g. heat, pressure.

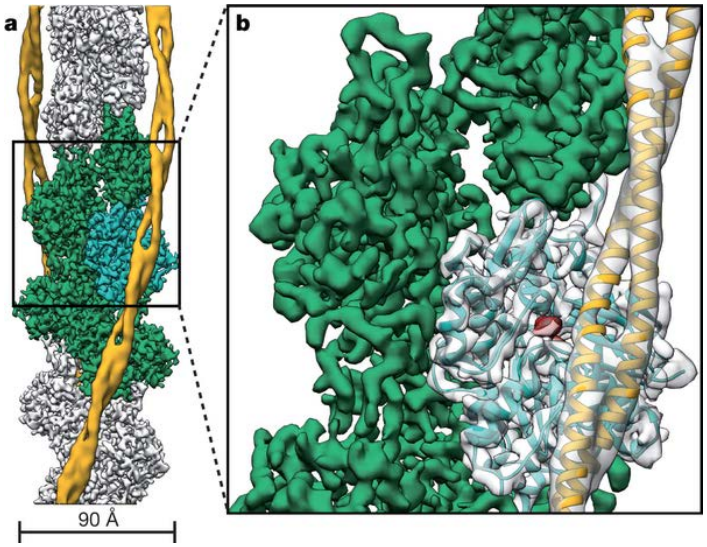
- Anticipated persistent risks may include; Salmonella spp, and Hepatitus E.

Allergenicity in Humans

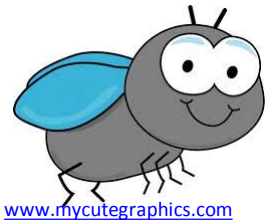
- Very little information available about insect allergens
- Low probability of insect proteins being contained in meat/egg/fish produced from insect-fed animals.
- Higher risk from insects as food.
- Potentially allergenic proteins include tropomyosin

Tropomyosin

- main allergen in shellfish
- protein sequence very similar in insects
- some insect tropomyosins known to be allergenic



Tropomyosin sequence alignment



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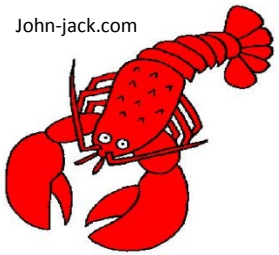

John-jack.com

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Musca domestica      MDAIKKKMQGMKIDKDAALERAATCEQQARDANLRAEKAEEEARQLQKKIQTVENELDQT
Coakroach            MDAIKKKMQAMKLEKDNAMDRALLCEQQARDANLRAEKAEEEARSLQKKTQQIENDLDQT
Lobster              MDAIKKKMQAMKLEKDNAMDRADTLEQQNKEANIRAEKTEEEIRITHKKMQQVENELDQV
North Sea shrimp     MDAIKKKMQAMKLEKDNAMDRADTLEQQNKEANNRAEKSEEEVFSLQKRMQQLENDLDSV
                     *********.**:** *::**   *** ::** ****:***    :*: * :**:**..

Musca domestica      QEALTLVTGKLEEKNKALQNAESEVAALNRRIQLLEEDLERSEERLGSATAKLSEASQAA
Coakroach            MEQLMQVNAKLDEKDKALQNAESEVAALNRRIQLLEEDLERSEERLATATAKLAEASQAD
Lobster              QEQLSLANTKLEEKEKALQNAEGEVAALNRRIQLLEEDLERSEERLNTATTKLAEASQAA
North Sea shrimp     QEALLKANAHLEEKDKALSNAEGEVAALNRRIQLLEEDLERSEERLNTATTKLAEASQAA
                      * *  .. :*:**:***.***.************************ :**:**:*****

Musca domestica      DESERARKILENRALADEERMDALENQLKEARFLAGEADRKYDEVARKLAMVEADLERAE
Coakroach            DESERARKILESKGLADEERMDALENQLKEARFMAEEADKKYDEVARKLAMVEADLERAE
Lobster              DESERMRKVLENRSLSDEERMDALENQLKEARFLAEEADRKYDEVARKLAMVEADLERAE
North Sea shrimp     DESERMRKVLENRSLSDEERMDALENQLKEARFLAEEADRKYDEVARKLAMVEADLERAE
                     ***** **:**.:.*:******************:* ***:**********************

Musca domestica      ERAEQGENKIVELEEELRVVGNNLKSLEVSEEKANQREEEYKNQIKTLNTRLKEAEARAE
Coakroach            ERAESGESKIVELEEELRVVGNNLKSLEVSEEKANLREEEYKQQIKTLTTRLKEAEARAE
Lobster              ERAETGESKIVELEEELRVVGNNLKSLEVSEEKANQREEAYKEQIKTLANKLKAAEARAE
North Sea shrimp     ERAETGESKIVELEEELRVVGNNLKSLEVSEEKANQREEAYKEQIKTLTNKLKAAEARAE
                     **** **.**************************** *** **:***** .:** ******

Musca domestica      FAERSVQKLQKEVDRLEDEYIIEKERYCLVGDSLDEAFMDLIPGLEPFYTPRNPKPPTPK
Coakroach            FAERSVQKLQKEVDRLEDELVHEKEKYKFICDDLDMTFTELVGY----------------
Lobster              FAERSVQKLQKEVDRLEDELVNEKEKYKSITDELDQTFSELSGY----------------
North Sea shrimp     FAERSVQKLQKEVDRLEDELVNEKEKYKSITDELDQTFSELSGY----------------
                     ******************** : ***:*  : *.** :* :*
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Allergen detection

- LC-MS/MS enables the identification of known allergens including tropomycin, arginine kinase and myosin light chain.
- Bioinformatics search for orthologues of allergens where insect genomes are available – high homology may indicate allergenic potential.

Journal of Insects as Food and Feed, 2015 online

ARTICLE IN PRESS

Wageningen Academic Publishers

Sequence homology of the fly proteins tropomyosin, arginine kinase and myosin light chain with known allergens in invertebrates

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High potential of allergenic response to eating insects if sensitive to shellfish

Also risk of occupational exposure

European Food Safety Authority

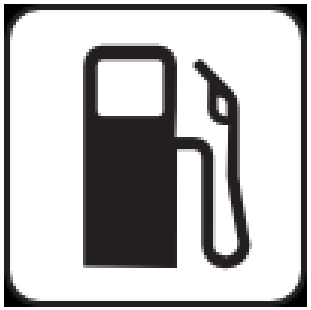
- European Commission gave EFSA a mandate to provide an opinion on the safe use of insects as food/feed.
- EFSA working group formed in late 2014 and provided final opinion in October 2015
- PROteINSECT members and data helped to inform opinion

Refined protein

Animal Feed

By-products

Nutrition & Quality



Oils & Fuels

Cosmetics & pigments

Bioactives

Larvae nutrition

- *Musca Domestica* larvae (dry matter)

Protein: 45 – 60 %

Isoleucine: 20 - 25 mg/g
Valine: 20 – 30 mg/g
Lysine: 35 – 50 mg/g
Methionine: 10 – 20 mg/g
Tryptophan: 3.5 – 5.5 mg/g

Fat: 20 – 35 %

Palmitic acid: 65 – 100 mg/g
Oleic acid: 40 – 60 mg/g
Linoleic acid: 25 – 50 mg/g

Minerals

Ca: 2 – 9 mg/g
P: 9 – 15 mg/g
Na: 2 – 5 mg/g
K: 9 – 11 mg/g
Mg: 2 – 5 mg/g
Zn: 0.15 - 0.25 mg/g
Mn: 0.2 – 0.35 mg/g
Fe: 0.3 – 0.5 mg/g

Feeding trials

Larvae producer – fly species (country)	**Nutrition tests by (country of testing):**	**Animal**
Grantbait – *Musca domestica* (UK)	Nuscience (Belgium)	Poultry and pig
Grantbait – Musca domestica (UK)	Stirling (UK)	Atlantic salmon post-smolt
FfA and Stirling – *Hermetia illucens* (Ghana)	Stirling (Ghana)	Tilapia fingerlings
IER – *Musca domestica* (Mali)	IER (Mali)	Layers
IER – *Musca domestica* (Mali)	IER (Mali)	Broilers
IER – *Musca domestica* (Mali)	IER (Mali)	Catfish
HZAU – *Musca domestica* (China)	HZAU (China)	Poultry
HZAU – *Musca domestica* (China)	HZAU (China)	Tilapia
GEI – *Musca domestica* (China)	GEI (China)	Huxu Broilers
GEI – Musca domestica (China)	GEI (China)	shrimps
GEI – Musca domestica (China)	Nuscience (Belgium)	Poultry and pig

Animal trials

- 3 highly quality assured animal trials undertaken in late 2015 / early 2016 to European feed industry standards
- Control diets contained fishmeal and/or soybean meal. This was substituted at a range of relevant inclusion levels with insect meal derived from *Musca domestica*

UNIVERSITY of STIRLING

1. Salmon fingerlings (up to 40% protein replacement)

2. Broiler chickens (up to 25% protein replacement)

3. Weaning piglets (up to 20% protein replacement)

nuscience
safe & innovative nutrition

Main aim was to understand performance of animals fed on an insect fortified diet and to provide meat/fish for safety and organoleptic testing

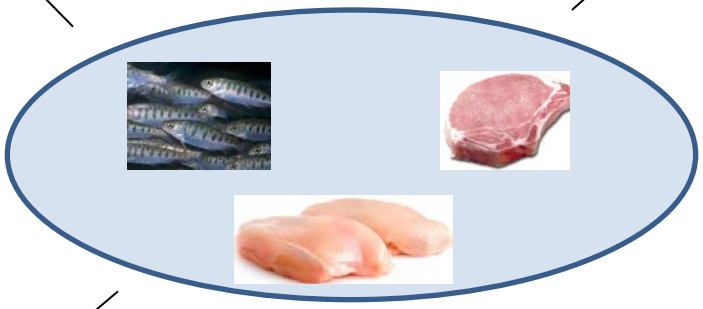
Animal trials – Safety analyses

69 Veterinary medicines

416 Pesticides

69 Mycotoxins

Salmonella
E. Coli (e.g. O157)
Listeria monocytogenes



28 Polycyclic aromatic hydrocarbons

Approx 8100 cpds in screening method. Includes pesticides, dyes, pharmaceuticals, (plant) toxins and associated metabolites

48 Metals

16 Dioxins

25 Polychlorinated biphenyls

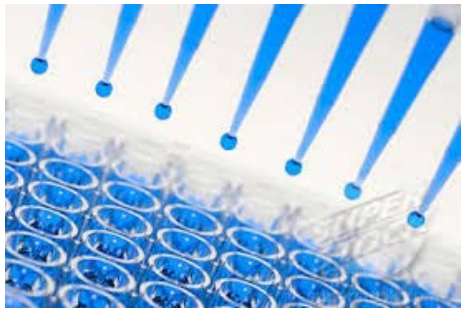
Allergenicity

- Assessment of allergenicity in animals during feeding trials:

Wikimedia.org

– Monitor symptoms,
- e.g., scratching, watery eyes

– Measure IgE levels: antibodies produced upon exposure to allergen.



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Animal trials –Results

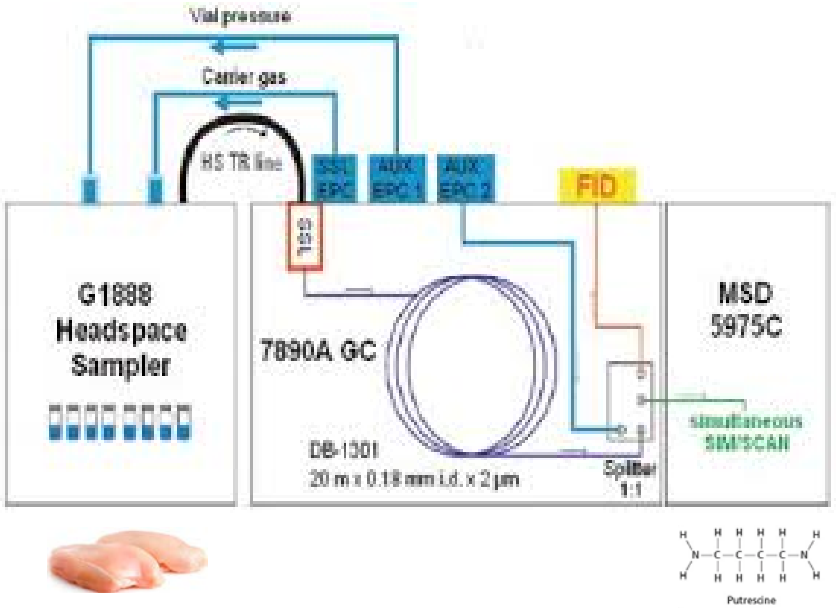
- Performance of all animals were broadly in line with controls. Higher inclusion rates may reduce weight gain

- No safety concerns have been noted in fish, chicken and pork samples from analytical / microbiological results. Residue / contaminant levels < current EU regulatory limits

- All safety analyses should be undertaken on edible insects if standards are applied evenly

Animal trials: Meat / fish quality

- Nutritional profiles of meat/fish
- Product quality parameters: e.g. taints from biogenic amines



- No undesirable taints discovered
- Nutritional profile normal in final food product

Summary

- There is huge potential for using insect protein as a source of animal feed.
- There is a lot of work to do to understand and manage safety risks for both food and feed.
- Legislation in Europe for the nutritional use of insects is currently prohibitive.
- This is entirely correct until we have ensured that a robust international safety framework for insects in the food chain can be adopted.

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Thanks for your attention!