Agribusiness 2020

New Horizons for the UK Agri-food supply chain

Will insect protein be a viable protein substitute for UK livestock diets?

Dr Elaine Fitches
FERA
University of Durham

#agribiz2020

aic agricultural industries confederation

Will insect protein be a viable protein substitute for UK livestock ?

Agribusiness 2020 Conference
13th November 2019

Elaine Fitches; E.C.Fitches@durham.ac.uk

Durham University

fera

- Introduction: Insects and the circular economy

Viability of insects as a protein source ?

- Nutrition and safety
- Economics
- Environment

Why & Which ?

- Highly efficient in the rapid conversion of organic material into biomass
- Natural component of the diets of carnivorous fish & free-range poultry
- Protein digestibility higher than most vegetable-based proteins
- Amenable to mass rearing

Coleopteran larvae

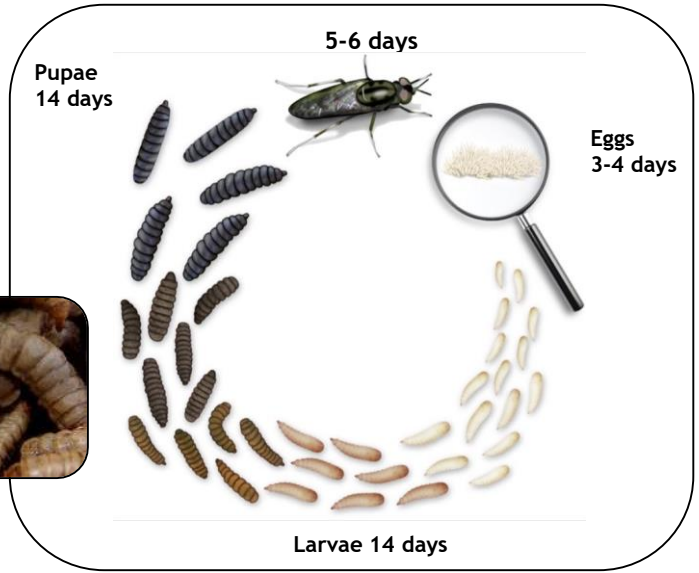
Dipteran larvae

Orthoptera

Black Soldier Fly *Hermetia illucens*

Globally preferred insect species for commercial scale production

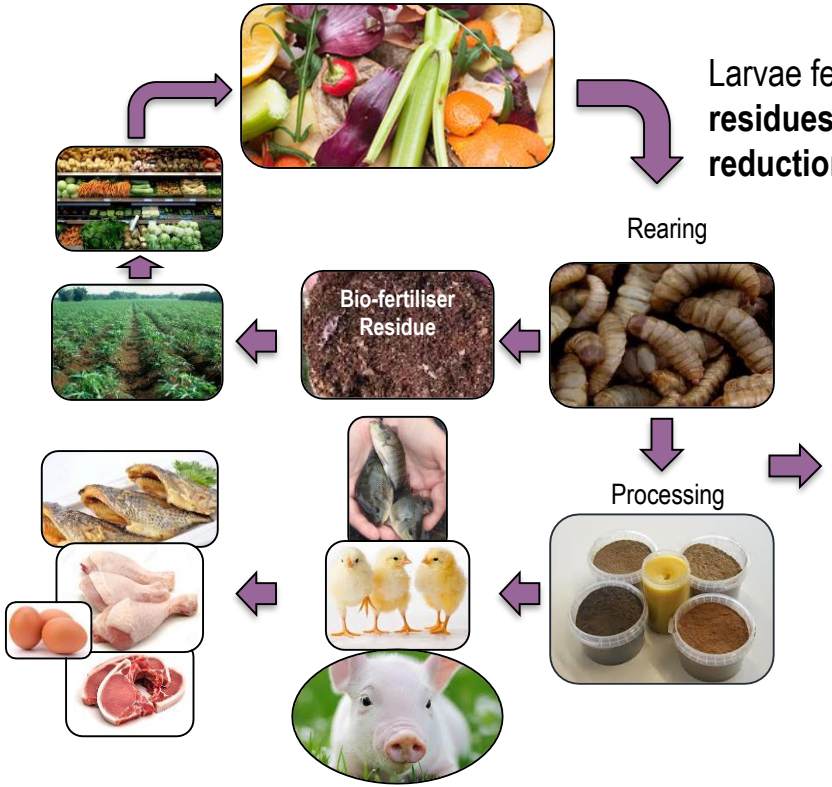
- suitable for mass rearing on organic material
- ca. 14 days from egg to mature larvae
- require ca. 27-30 °C for development
- mean wt. 0.2 g/ larvae
- Self-harvesting i.e. egress as pre-pupae
- Adults don't bite or sting!



Complete life cycle 5-6 weeks

- Do not carry human or livestock diseases
- Not (at present!) an invasive species risk in Northern climates

Circular Economy:
BSF Valorisation of Agri-food Residues



Larvae feed on a **wide range of residues** resulting in **significant reductions in waste volumes**

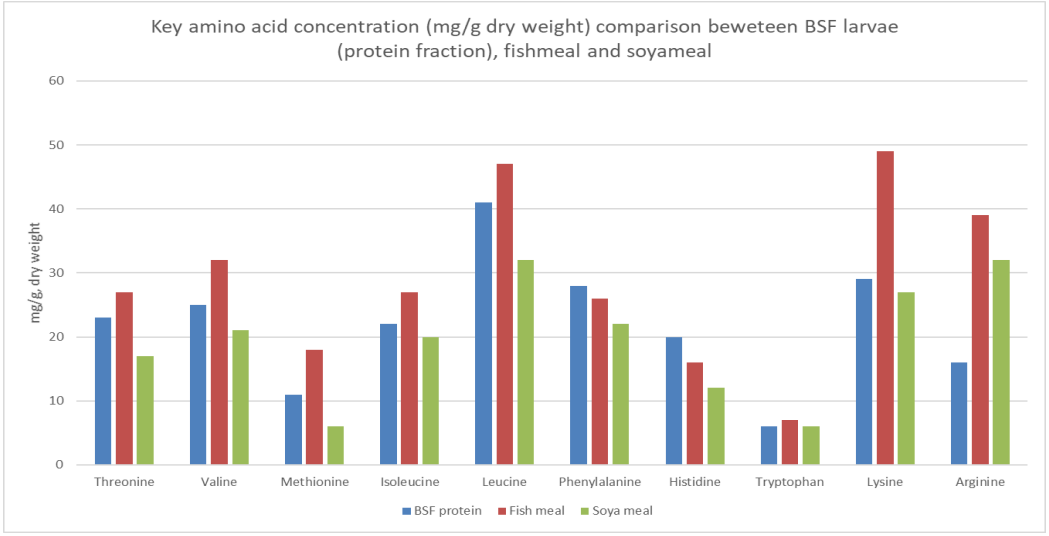
Other Added-Value Products

- Biodiesel
- Chitin
- Antimicrobials

Source of high-quality protein & fat (high in lauric acid)
Proven suitability for use in fish, poultry & pig diets

Nutritional Quality - Protein

- High quality protein (37-47 % dry wt. chitin corr.)
- Well balanced highly digestible amino acid profiles comparable to soymeal and fishmeal
- Can achieve >60% crude protein when de-fatted = superior a.a. profile to soybean meal
- Amino acid profiles consistent across different rearing substrates
- High in essential amino acids - suitable as **partial replacement** of **fishmeal** in fish & pig feed and **soymeal** in poultry & pig feed

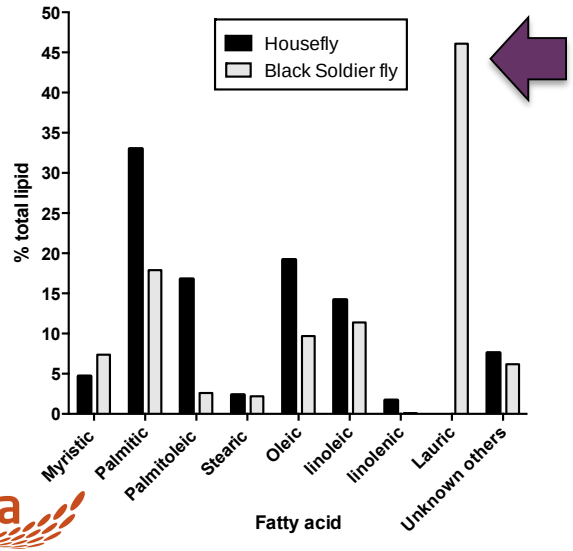


Nb. Presence of chitin can lead to overestimation of protein content
Low levels: can **positively** affect gut health: immunomodulatory, antimicrobial effects
High levels: can **negatively** affect feed intake & protein digestibility

Sprangers et al., (2017), DOI 10.1002/jsfa.8081; DiGiacomo & Leury (2019) doi:10.1017/S1751731119001873; Jozefiak et al., (2016) DOI: 10.1515/aoas-2016-0010; Moula & Detielleux (2019) doi:10.3390/ani9050201; Tran et al.,(2015) doi:10.2527/af.2015-0018; Hall et al., (2018) dx.doi.org/10.3382/ps/pex433

Nutritional Quality - 2

- Minerals: high in Ca, P levels suitable for pig/poultry- unaffected by rearing substrate
- High in energy (BSF 25.7 MJ/kg; soya beanmeal 13-17 MJ/kg)
- Lipid content (26-35 % dry wt.) varies with rearing substrate; high in C12:0 lauric acid
- Ash content (ca. average 12% DM) varies with rearing substrate



Nutraceutical potential /alternatives to antibiotics ?

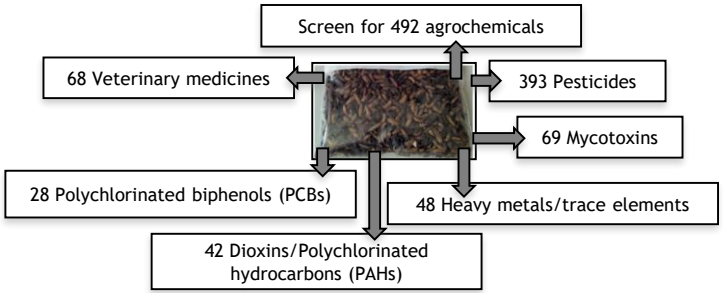
High C12:0 - potential for beneficial microbiota effects

Rich source of **AMP**s: activity against bacteria, fungi, parasites & viruses; may boost innate immune responses

https://www.feedtables.com/content/black-soldier-fly-larvae-fat-20-dried-0; Jozefiak & Engberg, 2017 DOI: 10.22358/jafs/69998/2017; Sprangers et al., (2017), DOI 10.1002/jsfa.8081; DiGiacomo & Leury (2019) doi:10.1017/S1751731119001873; Jozefiak et al., (2016) DOI: 10.1515/aoas-2016-0010; Moula & Detielleux (2019) doi:10.3390/ani9050201; Tran et al.,(2015)

Chemical & Biological Safety

Ensuring insect products can be **safely** included in the feed chain is paramount



- Contaminants below recommended max. concentrations in feed (EC, WHO, & Codex)
  BUT Cadmium high in 3 samples (further evidence for BSF cadmium bioaccumulation reported[1,2])
- BSFL do not appear to accumulate PCBs, PAHs, selected pesticides, pharmaceuticals or Mycotoxins [3,4,5]
- Microbiological risks (eg. Enterobacteriaceae, Salmonella) mitigated by processing (drying, heat treatment; methods based on method 7, ABP regulations shown to be suitable for drying larval material[6,7])

Substrate analyses and traceability of supply is essential to ensure safe use

[1]Biancarosa, et al., (2018) Apr;98(6):2176-2183. J. Sci Food Agric. doi: 10.1002/jsfa.8702. Epub 2017 Oct 27;[2]Cai, et al. Environ Sci Pollut Res (2018) 25: 1559.; [3]Bosch et al., 2017 Toxins 2017, 9(6), 185; [4] Lalander et al., (2016) Sci.Total Env.Vol. 565, 279-286; [5]Purschke et al., (2017) Food Addit. Contam. Part A Chem. Anal. Control. Expo. Risk Assess. 34, 1410–1420; [6]Fitches, et al., (2018) JIFF https://doi.org/10.3920/JIFF2017.0061; [7]Hall et al., (2018) Poultry Science 0:1–8 http://dx.doi.org/10.3382/ps/pex433

Insect Protein: Quality & Safety

- Insect meals: excellent sources of nutrition, highly suited for incorporation in fish & monogastric feeds
- Viable as **partial** alternatives to soybean and/or fishmeal: likely that protein value will be enhanced by de-fatting
- Potential sources of alternatives to antibiotics
- No evidence for negative sensory effects on meat/fish fed on insect containing diets
- Consumer acceptance unlikely to be a barrier towards development of industry
- Safe use of insect products requires use of appropriate processing methods AND traceability of substrate and insect products

Is insect protein economically viable as protein substitute for UK livestock ?


UK Insect Biomass
Task & Finish Working Group
aic agricultural industries confederation
UKFFPA UK FORMER FOODSTUFFS PROCESSORS ASSOCIATION (AN AIC AFFILIATE)
CIEL Centre for Innovation Excellence in Livestock
Scottish Aquaculture Innovation Centre
ZERO WASTE SCOTLAND
Durham University
ENTERPRISE PARTNERSHIP York / North Yorkshire / East Riding
Business Inspired Growth
fera
Sainsbury's
entomics
TESCO
ENTOCYCLE
MULTIBOX
npa national pig association
AgriProtein Repairing the Future
NFU
pfma a member of
Red Tractor Assurance
BRITISH POULTRY COUNCIL The voice of the British poultry meat sector
aic agricultural industries confederation
wrap
Food Standards Agency food.gov.uk
HUMPHREY FEEDS & PULLETS
Anparia
Minerva

What the T&F group is evaluating

- Global developments & Government/industry action, levels of investment
- Current levels of production, UK potential scale of production & demand, applications across different feed sectors
- UK drivers
- UK R&D Expertise & Gap Analysis
- Barriers & Challenges

Consensus documents

1. **Case for UK-based Insect Biomass Industry (April 2019)**
2. **Review of Environmental Impact of Insect Bioconversion Processes (August 2019)**

Economic viability - Commercial scale BSFL Production

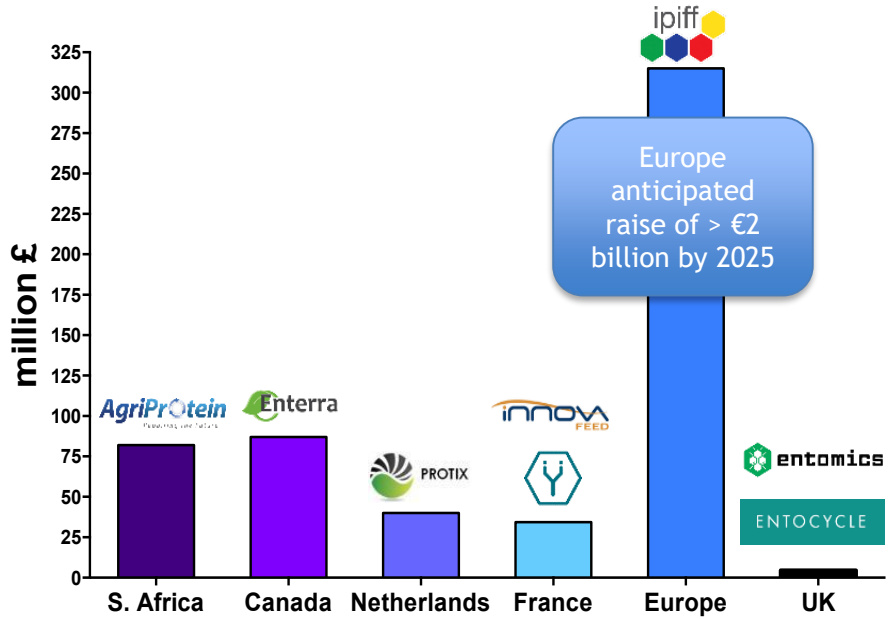
Increasing levels of automation for production at scale are being realized

- Adult and larval rearing can be conducted on the same site
- Also potential for satellite egg production sites to distribute to local insect farmers
- Likely that scale of production is heavily influenced by the logistics of rearing substrate supply

Global Developments: Investment in Insect Industry

Several countries developing alternative protein roadmaps- driven by the need to
Improve waste management & reduce reliance upon imports for animal feed

- Current Scale of production difficult to determine (nb. this is an emerging sector)
- Recent National stimulus/support: several companies now transitioning from pilot to commercial scale
- As such production capacity is typically confidential



UK SMEs: Expertise BUT None currently producing insects at commercial scale

MULTIBOX
entomics
AgriSect
ENTOCYCLE
INSPRO LTD

Feed Strategy Magazine (Jan 2019); globally 6 000 tonnes insects produced in 2018 across 15 different countries; in Europe 95% production was BSF and yellow meal worm.

IPIFF (2019) predicts insect meal production will reach 200 000 tonnes in 2020 & 1.2 million tonnes in 2025

Table 1 *Trading price of different protein sources intended for farm animal nutrition and per unit of protein expressed as times relative to soy meal 45% (=1) (adapted from All About Feed, 2016)*

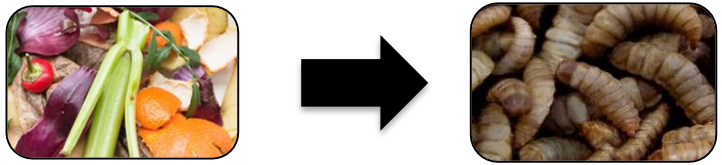
	Protein % dry matter (defatted) meal	Trading price, times relative to soy meal (=1)	Trading price for 100 g of protein, times relative to soy meal (=1)
Soy meal, 45% CP	45%	1	1
Fish meal	65%	3	2
High-quality soy meal extract (soybean meal hi-pro)	62%	7	5
Small mealworms	86%	12	6
BSF larvae	63%	12	9
Crickets	60%	285	213

CP = crude protein; BSF = black soldier fly (*Hermetia illucens*).

Pinotti et al., (2019) doi:10.1017/S1751731118003622

Opportunities for enhancing productivity

Efficiency of Substrate conversion to Insect Biomass



Feed Conversion Ratios (FCR)

Amount of Feed required (kg) to obtain 1kg increase in wt.

Can be expressed as wet wt. or dry wt.

- Variable & highly dependent upon rearing substrate!
- Unlike conventional livestock insects develop **within** their feed
- Assumed all feed is consumed
- High efficiency requires optimal diets to be established: trade-off between efficiency and value of rearing residues

Livestock	FCR (wet wt.)[1]
BSF	1.4-2.6
Poultry	2.3
Pork	4
Cereal Beef	8.8

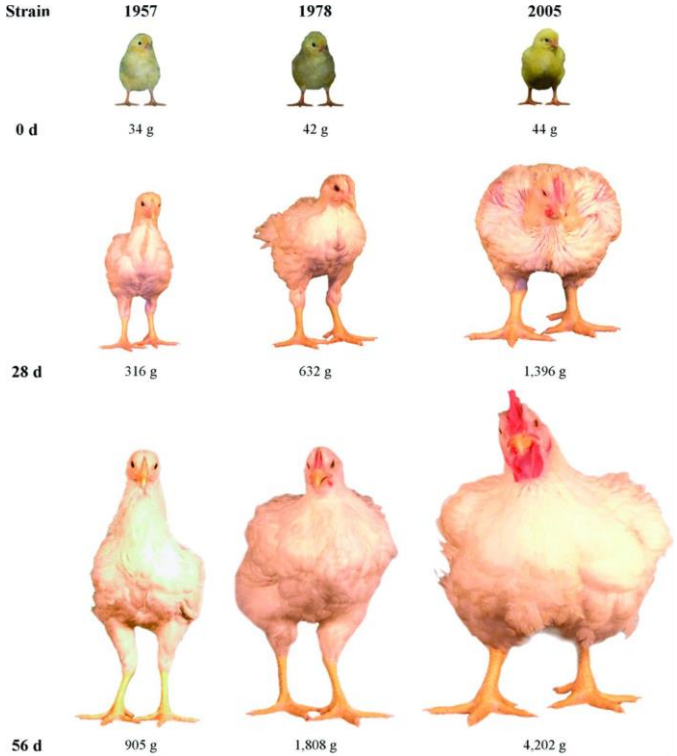
1. Oonincx et al., (2015) PLoS One 10(12):e0144601. https://doi.org/10.1371/journal.pone. 0144601

Progress in Poultry Production

Broiler growth (1957-2005) increased by > 400%, alongside a 50% reduction in FCR

- Genetic selection
- Nutritional knowledge
- Development of dietary enzymes

Opportunities for improving BSF productivity ?



Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005[1]

[1]Poult Sci. 2014;93(12):2970-2982. doi:10.3382/ps.2014-04291

Is insect protein environmentally viable as a protein substitute for UK livestock ?

Environmental Impact

LIVESTOCK FEED

Soya

Fishmeal

Insects

Globally
Livestock production = 14.5% of all carbon emissions (FAO)

Feed production = **45% of livestock production carbon footprint** (FAO)

Envtal. impact of insect production lower than livestock production[1]

- Less land & water
- GHG emissions lower
- High feed conversion efficiencies
- transform low-value organic by-products

LIVESTOCK PRODUCTION

How does it compare with soya or fishmeal ?

1. Oonincx et al., 2010 PLoS One 5(12):e14445. https://doi.org/10. 1371/journal.pone.0014445

Environmental Impacts – T & F Group Review of Published data

Key findings:

Consensus - environmental impacts of **nascent pilot scale insect production systems** are **lower** for land use (LU) but **higher** for **energy use** (EU) and **GWP** compared to **mature soymeal or fishmeal production**

- **No directly comparable LCA data**; systems compare different functional units, bioconversion rates, scales etc. GWP- limited by the lack of data
- **Production efficiency improvements** offer potential to **substantially reduce environmental impacts**
- **Substrate source** is a **key determinant** of **environmental impact**. Enabling a wider variety of substrates (especially those not already utilised in the feed chain) would help to lower GWP
- **BSFL do not** appear to **emit methane** or **generate significant levels of ammonia or nitrous oxide** although **emissions arising from substrates requires further study**.
- Insect biomass conversion has the **potential to play an integral and complementary role in the reduction of GHG emissions arising from conventional waste valorisation strategies** (e.g. AD, composting).
- Currently **no published data** available in relation to **GHG emissions** arising following the **application of insect residues/biofertiliser to agricultural land.**

Land Use

Protein crops (e.g. soya)
2-3 t/ha./year; 90 % dry wt & 40 % crude protein = ca.**1.1 t protein**

Fly larvae potential (non-optimized - not vertical!)
25 t/ha./8-10 days = 1000 t/ha./year; 25 % dry wt & 60 % protein = **150 t protein**

> 120 fold reduction in land use

Insect production at scale could reduce demands upon land for feed protein crops

BUT: land-use dependent upon **rearing substrate (LCA analysis)**

eg. Mealworm production facility associated with 0.2% of total land use BUT feed (mixed grain/carrots) associated with 99% of the land use![1]

Soya yields: International Benchmarks for Soybean Production 2016; 1. Oonincx DGAB, De Boer IJM (2012) PLoS One 7(12):e51145. https://doi.org/10.1371/journal.pone.0051145

Fitting in with current UK waste valorization strategies

Black Soldier Fly – A Circular Economy Solution for Scotland

By Anton Riera (MSc, University of Edinburgh) and Michael Lenaghan (Zero Waste Scotland)

Scottish specific LCA study comparing BSF farming (on pre-consumer waste) with AD

- BSF farming potential to generate 90% more economic value per tonne input than AD
- BSF and AD treatment of food waste BOTH result in net carbon savings BUT BSF generates ~10% additional carbon benefit (displacement of soy accounted for)
- EU and source of energy key factors for emissions

Table 1. Value generated per tonne food waste input

BSF	Gate Fee	Fat/ Oil	Protein	Frass	Total
	£29	£26	£56	£1	**£113**
AD	Gate Fee	Electricity	Digestate	Liquor	Total
	£29	£33	-£1	-£1	**£60**

Co-location of BSF farming & AD plants ?
AD generated heat to warm BSF rearing system, use of insect residues to improve quality of AD output ?

WRAP Report, 2019: UK ca.**1.6 mt** farm gate food waste is generated every year: either microbially decomposed (AD or composting), incinerated, applied to land/landfill, or destined for waste water treatment.

Rearing Substrates - Regulatory constraints

Substrates- key determinant of **environmental impact**. Enabling a wider variety of substrates would help to lower GWP

Legally permitted (as a source of protein for fish feed)

- Plant based (eg. Brewery residues, potato)
- Unprocessed former foodstuffs (no meat)
- Agricultural residues (eg. Pea waste)

Suitable substrates include:

- Food waste (containing meat)
- Catering waste
- Animal manures
- Slaughterhouse products

IPIFF requesting scientific evaluation on the safe use of **former feedstuffs** and **catering waste** for insect production to assist EFSA in formulating the necessary risk assessments.

Insect Protein: Economical and Environmental viability ?

Economically viable ?

- Price not yet competitive with conventional feed proteins –but industry IS transitioning from pilot to commercial scale - potential for production efficiency improvements in the short term
- Without significant stimulus for sector development in the UK insect protein is likely to be an imported product

Environmentally viable ?

- Environmental impacts lower for land use but currently higher for EU & GWP (pilot scale systems)
- Scale, production efficiency improvements will reduce EU and GWP in the short term
- Integration with current waste valorization strategies offers huge potential for reducing EU and GWP
- Expansion of permitted rearing substrates may be key providing lower impacts as compared to soyameal or fishmeal but ensuring safe use is paramount!

Many thanks for your time !

Agribusiness 2020

New Horizons for the UK Agri-food supply chain

#agribiz2020

aic agricultural industries confederation