The Insect Biomass Industry for Animal Feed – the Case for UK-based and Global Business

Members of the Insect Biomass Task & Finish Group represent key stakeholders across the Insect Biomass value chain and are committed to collaborating in order to deliver insect production at scale in the UK. The Government and its central agencies have a significant role to play in realising this innovation for UK-based and global business given its alignment with the UK Global Food Security Programme and the circular economy. All members have agreed that the following actions are key to enabling the realisation of a new insect biomass conversion industry for the UK.

Recommendations

1. The UK Government to issue a **national statement of support** for this innovative and emerging technology with significant potential impact for the UK economy and its sustainable agricultural productivity.
2. Government and industry to **support a central body** to bring all stakeholders together to achieve aligned, rapid development of the sector for the UK and render it world leading inside the requisite national infrastructure.
3. Government to collaborate with private industry **to secure dedicated funds** to help insect producers reach the market, achieve cost competitiveness, respond to the identified research and process development gaps (for example in livestock welfare) and to open up new lines of commercial opportunity (for example for soil health).
4. For the Government **to lead on delivering insect biomass legislation and regulation** in line with latest science, global market developments and which acknowledges the sustainable, natural and local credentials of insect protein for the food and feed chain and waste valorisation as a critical 'clean growth' dimension of a circular economy.
5. Government to devise and provide short term **fiscal incentives** for discounting domestically produced insect protein costs for **early adopters**/ innovators to incentivise the UK animal feed industry to introduce insect based protein as part of its feed strategies so as to help insect producers achieve cost competitiveness during the period of ramp up of scale.

There is a need for Government to act swiftly to ensure the UK does not lose further ground in this rapidly developing global market. EU-Exit provides an opportunity rather than a barrier to accelerate the development of a UK based and global business.

Report produced by Fera Science and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group

Insect Biomass Conversion and the UK

- Black Soldier Fly (BSF) is currently the primary preferred insect species for commercial scale production internationally.
- BSF larvae are suitable to be reared at scale on organic material in the UK.
- BSF does not carry human or livestock diseases and is not an invasive species risk in northern climates.
- Protein from BSF larvae is proven to be of high quality and suitable for use as a partial replacement of both fishmeal in compound fish & pig feed and soymeal in poultry & pig feed.
- Well-balanced highly digestible amino acid profiles of larvae are superior to soymeal and more comparable to fishmeal, which typically commands 4-5-fold higher prices than plant proteins in the animal feed sector.
- Residue following larval rearing on organic material has commercial & environmental value as a bio-fertiliser.
- Processing BSF larvae generates valuable additional by-products including chitin, oils and antimicrobials.

Current UK Position

The UK is lagging significantly behind mainland Europe (particularly France, The Netherlands, Belgium, Spain), the USA, Canada and South Africa in the scaleable development and delivery of insect biomass, protein plus added value by-products for animal feed and other innovative applications. Countries and companies at international and European levels are progressing swiftly to develop this sector through high level government policy statements, R&D investment and financial incentives. Rapid growth is being enabled by substantial sector investment which at c. $175 m in 2018, was 40% higher than the sum of investments received over the last 4 years (Rabobank Dec 2018 report). European insect producers represented by the International Platform for Insects as Food & Feed (IPIFF) are expecting to raise more than €2 billion in investment by 2025, generating a total of c.100 000 jobs.

UK scientists, SMEs and feed companies have, and continue, to lead and contribute significantly to research into insect biomass and novel applications including waste valorisation. However, without the support of a central strategic government policy, the UK stands to miss out on opportunities to capitalise upon existing expertise to generate a national insect biomass conversion industry. Without rapid government action and support, the UK will become ever more reliant upon protein imports (including insect protein) for feed and will fail to realise the opportunities for waste reduction and valorisation for the UK economy offered by domestic insect biomass conversion at scale.

Benefits of Implementation

Insect biomass conversion, at scale, for the production of protein for animal feed and associated by-products for UK agriculture and other industries has the potential to establish a new sustainable and 'clean' industry with total annual revenues approaching £1.0bn within 5 years and substantial additional growth from the export of new, internationally traded, commodities.

Conservative GVA evaluation, based upon the domestic market alone, forecasts over 3300 direct FTE roles over the next 5 years in the build and operation of the UK insect biomass conversion industry plus over 600 indirect FTE roles. Clearly this impact would scale upwards proportionately with ramping up for production of export volumes – where the limiting factor will become the scale of available/ suitable substrate feed permissible under current regulation.

Moreover insect biomass conversion provides an extended list of compelling economic and environmental benefits for the UK including:

- Increased agricultural productivity by creating a new UK 'clean growth' industry - evidenced by the establishment and operation of Insect Bio-Reactors (IBRs) nationwide.

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

- Provision of a new sustainable, safe, and secure supply of insect products (protein & fats) for animal feed and pet food industries.
- Reduction upon current heavy reliance upon imports (fishmeal and soy) for aquaculture and monogastric feed and, thereby, lowered risk of exposure of feed and livestock industries to price volatility and supply chain insecurities.
- Significant environment/ circular economy benefits gained from the enhanced valorisation of agri-food residues; sustainability advantages over current production and import of soy/ fishmeal.
- Potential for increased UK competitiveness through new international commodity exports.
- Prospect of better animal health and reduced reliance upon antibiotics; processed BSF fat and chitin have potential as bio-actives.
- New, sustainably sourced, insect derived products such as high value lipids and fats (partial alternatives to palm oil); antimicrobials for animal feed; and novel base materials (eg; for bio-degradable packaging).
- Biofertiliser residues from insect rearing offer potential for sustainable improvement for soil health and crop productivity; reducing both negative environmental impacts associated with inorganic fertiliser consumption and dependence upon imported nutrients.
- Valorisation and reduction in volumes of other organic wastes (sewage, slurry, food, municipal) for non-feed markets.

Key Actions

1. Central government strategic policy framework and statements to support a national insect biomass conversion industry and global business potential (protein production, waste valorisation, novel products).

2. Government to provide seed funding to launch an Insect Biomass Conversion Stakeholder Hub (IBCSH); co-funded by industry (such as this T&F group) and financially self-sustaining in longer term to accelerate the mission (i.e. validate and determine robust economic technical facts unique to the UK to substantiate the business opportunity) according to the requisite terms of reference and including socio-economic evaluation via funding for market intelligence and consumer perception.

3. [Industry and Govt/ Research Council Funding] to fill knowledge gaps in R&D along with the necessary infrastructure (Insect Biomass Conversion Research Centre-IBCRC) to provide the necessary assets to deliver the science framework to underpin the growth (for example, evaluating the safe use of materials currently not permitted as insect rearing substrates such as post-consumer food waste relevant for further regulatory changes, processing, engineering optimisation). (see below Gantt chart)

4. Rapid clarification of UK regulatory framework and legislation with revisions to enable the use of insect protein and associated products (eg. chitin) in commercial scale poultry and pig feeding trials to facilitate rapid regulatory changes that ensure safe use of insect products in a post-EU environment; establishment of a regulatory framework covering the use of insect residues as biofertilisers; clarity on standards and best practices to build trust and ensure safety and quality.

5. Government to review best practise amongst existing fiscal incentive schemes and deploy (eg. feed in tariff, tax relief and related schemes) to stimulate sector break through.

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

Timeline

Gantt Chart

Year-Quarter	1-1	1-2	1-3	1-4	2-1	2-2	2-3	2-4	3-1	3-2	3-3	3-4	4-1	4-2	4-3	4-4
Government Actions																
IBC sector initiative announced																
IBC sector incentivization: best practice review		Review			Formalise	Launch →										
Establish & Implement Policy framework		Establish			Implement →											
Regulatory revision to allow commercial trials																
Regulatory framework reviews/revisions														Ongoing →		
IBC Stakeholder Hub (IBCSH) Actions																
IBCSH established																
Meetings/workshops																
Report Commissioning		BR	ES	CC				CC								
Report publications				BR	ES	CC				CC						
IBCSH Annual Reporting-recommendations																
R&D Activities																
IBC R&D Centre (IBCRC) competition launch																
IBCRC award & launch																
IBCRC Operations				Ongoing →												
R&D Funding Competitions	Devise	L1				L2										
R&D/Demonstrator projects Round 1					Round 1/Demonstrator											
R&D projects Round 2										Round 2						

Key IBC=Insect Biomass Conversion
BR = bioresource/low grade heat mapping; ES = economic/social analysis; CC=consumer consultation; L=launch

Costs

Management & Leadership

Insect Biomass Conversion Stakeholder Hub (IBCSH)
3 years dedicated Lead and secretariat (including) £1m (Opex)

- Commissioned studies (3x£35k)
  (for example, socio-economic, heat mapping suitable volume wastes and residues etc)
- Community development - meetings/workshops
  incl industry 'in-kind' support (time, hosting etc)

Infrastructure

- Insect Biomass Conversion Research Centre-IBCRC £3m Capex;
- R&D Council and Innovate UK (Govt/ industry) projects £6m
  (10 projects of 6 months-> 3 years; £1m management/ admin)
- Government fiscal incentive ('feeding tariff') £ tb calculated

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

Appendix 1

The Evidence - Insect production and waste valorisation potential for the UK

The need

- There are compelling environmental and economic drivers to enhance valorisation of agri-food residues and other waste streams in the UK, many of which may be suitable substrates for rearing BSF (e.g. food waste has the potential to generate c. 90% more economic value per tonne than anaerobic digestion (AD)).
- There is a national strategic driver to reduce the UK's current heavy reliance on current protein imports (fishmeal and soya) for animal feed from the current level of £1.9 billion p.a. (2015) in order to lower the on-going risk of exposure to economic and supply chain insecurities. Insect protein from BSF presents a potential sustainable alternative to expanding land use for protein crops or plant breeding to markedly increase protein sources for animal feed.
- The UK compound feed sector is interested and willing to utilise viable, new and more sustainable sources of protein (365 feed mills; annual production of 15.7 million tonnes at a value of £3.63 billion) including insects/BSF which may also bring added benefits for animal health.
- The UK Pet Food Sector needs new sustainable and innovative sources of protein.
- Locally produced insect protein, if economically viable, will help shield feed and farming sectors from volatile protein prices; Scotland's salmon farming sector is the third largest in the world and produces and consumes c.300 kt feed annually and currently pays the highest feed costs of the top 4 salmon farming nations worldwide owing to relatively high diet inclusion levels of marine fish meal and fish oil. Fishmeal prices have increased substantially over the past decade and are projected to rise further.
- UK BSF farming could further reduce the aquaculture industry's reliance on fishmeal as a protein source, along with the existing use of plant-based alternatives (fishmeal currently represents c. 20% of salmon diet composition); research has shown that insect/BSF meal can replace 50% or more of fishmeal in farmed fish diets.
- Bio-fertilisers (global market >$2 billion USD) derived from rearing insects/ BSF on organic substrates can support soil quality, reducing negative environmental impacts associated with inorganic fertiliser production and deployment. New EU laws announced in November 2018 will promote the increased use of recycled materials for producing fertilisers, thus helping to develop the circular economy, while reducing dependence on imported nutrients.

The applications

Current: Insects are currently permitted for use in pet food and aquaculture in the EU and worldwide. European and UK pet food companies are utilising insect meal but not from UK insect producers. Live insects can be fed to poultry but delivery on a practical scale has yet to be realised in the UK.

- Following authorisation in 2017 the aquafeed market has consumed approx. 500 tonnes of European produced insect meal and this is expected to rise (IPIFF; Vision Paper 2018). None of this is currently produced in the UK.
- Insects are primarily used in niche, exotic pet food markets, such as live feed for reptiles (crickets, locusts and mealworms). Monkfield Nutrition (UK market leader) produces ~700kg dried insects per week. Several European pet food companies already incorporate insects in their feed to diversify their product range e.g. aquarium fish feeds, hypoallergenic products.
- Wild bird feed mixes and suet blocks incorporate insects and are almost always imported from overseas/ China.

Scale and Route to Market

The potential scale of insect production based upon the use of agri-food waste for the UK is difficult to determine. In principle with >9 mt of food waste available (WRAP, Estimates of Food Surplus & Waste Arisings in the UK, 2017 Report), c. 20% conversion this gives an estimate of 1.8 million tonnes insect meal per annum (or c. 1800 kt protein;

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

1200 kt oils and fats). A single commercial insect farm has a potential (and further scaleable) annual output of 5.600 kt of meal, 2.8 million litres of oils and fats and 21 kt tonnes of soil conditioner.

- The potential scale of annual UK demand; aquaculture feed is c.70 kt protein (at an inclusion rate of 23%); c. 200 kt of dried meal for poultry feed (at 5% inclusion rate); > 100 kt for pig feed (at 5% inclusion rate)
- The potential scale for pet food in the UK can be estimated as 20 kt protein per annum (based on a conservative estimate by the Pet Food Manufacturing Association of 5% of the current market size).
- Route to scalable market for insect protein for compound feed is via accredited feedmills able to test, confirm quality, build reputation and trust; direct to farm potential for large pig/poultry producers able to manufacture own feed.
- UK potential to build/ establish 12 'plants' in the short term (3-5 years) and 24 in the medium term (5-10 years); capacity is dependent upon a consistent supply of rearing substrate at appropriate scale.

UK Work and Action to Date

Research & Development: Innovation & Investment

Chicken and pigs fed on insect protein are currently not allowed into the food chain in the EU and feed with insect protein cannot be made in feed-mills, currently limiting R&D to small scale studies.

- PROteINSECT EU Framework 7 supported project led by Fera Science Ltd. UK (partners across Europe, China & Africa) established the feasibility of obtaining high quality & safe insect meal and protein for animal feed from fly larvae reared on organic wastes.
- ABAgri & Fera Science Ltd (Innovate UK supported) investigated use of fly larvae reared on chicken manure in poultry feed, demonstrating larval meal has comparable amino acid digestibility to commercial fishmeal.
- Current research Innovate UK projects are supporting SME and University based research into insect-based food waste valorisation (InsPro Ltd., Nottingham & Liverpool Universities), insect breeding and processing, but are not currently directly supporting production scale-up; other research includes development of a new antibiotic (seraticin) derived from common green bottle fly by Swansea University.
- SME Beta Bugs combines biotechnological & breeding approaches to create new breeds of high-performance insects. UK Innovate funded breeding programme will incorporate quantity and quality traits for both insect protein users and insect farms.
- SME Entomics is developing technologies for the emerging insect bioconversion industry, including: (1) advanced bioprocessing solutions that can optimise/ tailor insect-derived feeds for specific market applications (Innovate UK, EIT, LEP support) (2) modular insect rearing solutions for localised production (IUK support) in collaboration with Cambridge, Stirling, Sheffield, Reading Universities & Rothamsted Research..
- SME Entocycle have developed and built a 2nd generation, semi-automated BSF facility in London (HQ), with scale-up rollout planned in late 2019 and has attracted $2.8m of private investment and $1.2m in UK & EU grant funding.
- SME MultiBox is in the conceptual engineering, design phase; construction and commissioning of a first insect farm with intent for a capacity for 22,500 tonnes meal per annum is anticipated in 2021.
- Retailers are encouraging meat and fish suppliers to support research and innovation into animal feed, including insect protein.
- Tesco are willing to support further insect trials and support collaborations, providing regulations allow.
- McDonald's is supporting research into the use of insects in poultry feed.
- Zero Waste Scotland (ZWS) held a 1-day workshop in Feb 2019 to gather together key stakeholders from across the insect protein value chain. They offer Circular Economy Business Support and Investment Fund Programmes to develop innovative projects in Scotland, which could include insect farming.

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

- Scottish Aquaculture Innovation Centre (SAIC) has received expressions of interest relating to insect proteins in salmon feeds, but no studies funded to date (SAIC's investments in aquaculture feed development are centred around health benefits to fish, rather than ingredient substitution *per se*.)
- AgriProtein the largest insect based nutrient recycler moved its global head office to the UK in 2018; attracted $105m of investment; if legislation permits and substrate allowances are broadened it will add UK to its factory roll out plans.

Consumer Perception/ Acceptance

- Stakeholders' perception is that consumers know little about pet food and livestock feed generally, and thus are largely unaware of the potential use of insects, but given that insects are a natural component of diets the concept is likely to be well received; large-scale UK based consumer perception surveys are required to build confidence in the supply chain.
- Smaller surveys indicate a potential positive acceptance and that insects in feed is far less contentious than insects as food. PROteINSECT's information gathering exercises involving > 2000 consumers found a high level of support and an expressed desire for more information. Survey 1(of 1302 participants) = 73% were willing to eat fish, chicken or pork from animals fed on diets containing insects; Survey 2 (of 1150 participants) = 70% said it was totally acceptable to feed insect protein to farmed animals including fish.
- Tesco and the Pet Food Manufacturers Association have stated they are willing to conduct consumer perception studies in collaboration with others with expectation of low resistance
- One major European supermarket (Albert Heijn) is already marketing eggs from animals fed on live insects with very little resistance and positive feedback from the public. Sainsburys has just launched a range of edible insects for human consumption. In France Auchan launched sales of farmed trout reared on insect protein in December 2018.
- Educating key opinion makers (e.g. trade/ B2B media and intermediaries) have a role to play in the cascade of information on safety throughout the chain as favourable environmental credentials, part of traditional/ natural diet where particular care is required in messaging for vegetarians especially in relation to the egg market.

Policies/ Regulation/ Standards/ Quality Assurance

As insects were never envisaged to be used in pet food or livestock feed, the regulatory authorities' approach has been to modify existing regulations rather than create an insect policy framework. This has resulted in a lack of clarity concerning what 'is' and 'is not' permitted. With global business in mind, this presents a great opportunity for the UK to lead in the establishment of insect biomass specific legislation (protein production, waste valorisation, novel products).

Production: Insects are classed as livestock under Article 3(6) of Regulation (EC) No 1069/2009, and therefore rearing and breeding should be covered under welfare acts in respect to farmed animals. Adherence to the Farm Animal Welfare Council´s internationally accepted Five Freedoms is being promoted by European and UK insect producers.

Processing: The production of feed and feed materials is currently governed by European legislation and seeks to ensure that all animal feed and ingredients are safe for animal consumption, fit for purpose and do not represent a danger to human health. Feed hygiene is covered under regulation EC No 183/2005 and covers basic manufacturing guidelines. Processing of insect protein for pet food is covered under section F of the revision (EU 2017/893 to (EC) No 999/2001) and now covers insect protein and declares '*In several Member States, the rearing of insects for the production of processed animal protein derived from them and other insect derivatives destined for petfood has started. This production is carried out under the national control schemes of the competent authorities of the Member States. Studies have shown that farmed insects could represent an alternative and sustainable solution to conventional sources*

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

of animal proteins destined for feed for non-ruminant farmed animals'. It also confirms that the process must be fit for purpose and to the audited by a competent authority according to the processed animal proteins (PAP) guidelines (Method 7) which sets out the regulatory standards required for the production of insect protein.

- The current legislative landscape limits development of the insect farming business model; Regulation No 2017/893, adopted by the EC, May 2017 authorised the use of insect proteins (PAP) originating from seven insect species (including BSF) in feed for aquaculture animals. Only feedstuffs currently approved for animal feed are permitted for insect rearing i.e. pre-consumer agri-food residues known as 'former food products', including out of specification food, potato chips or breakfast cereals; leftover dough and liquid chocolate, surplus bread collected from retailers and bakeries. IPIFF are currently requesting scientific evaluation on the safe use of former feedstuffs and catering waste for insect production in order to assist EFSA in formulating the necessary risk assessments.
- Significant concern remains re: intra-species feeding of animal proteins (due to historic UK BSE outbreak) but an EU concept paper for the use of insects in animal feed was agreed in 2016 and work is progressing on detection and agreement of thresholds of PAPs in feed that could allow pig PAP in poultry feed and *vice versa*. The industry expects insect proteins will be authorised for use in pig and poultry feed by mid-2019 (Rabobank report 2018).
- Insect derived fat/ oil is covered under the feed materials catalogue ((EU) 2017/1017 and as such can legally be used in any livestock feed,but retailers restrict the use of tallow, fat and lard. There is a lack of legislation and regulatory alignment.
- Insect derived chitin/ chitosan is not currently covered under either the feed materials catalogue ((EU) 2017/1017 amending Regulation (EU) No 68/2013) or the feed additives register (EC No 1831/2003). According to Regulation 767/2009 these products must be notified in the EU Feed Materials Register; both chitin and chitosan are listed in this register, although not from insect sources. Entering feed materials on the Register is a relatively simple process and would allow such products to be fed to farmed animals.
- UK position post EU Exit offers a potential opportunity to progress enabling legislation at a faster rate than at the EU level. FSA is engaging with UK companies and organisations to progress where APHA/ Defra are the Responsible Bodies.
- There is currently no UK specific Quality Assurance scheme for insect production; IPIFF is preparing a manual of best practices for insect rearing for feed and food to include current regulatory requirements. Insect producers will need to ensure they meet both regulatory and assurance requirements and processors should also ensure they are registered with local Trading Standards and approved under ABP regulations by APHA for sale of insect products.
- Stakeholder consensus is that insect products for feed must be safe, of consistent quality, traceable, and price competitive.
- Bio-fertilisers derived from insect rearing; with AVLA approval would fall within the existing framework permitting land spreading of compost, AD and sewage sludge.

What are Other Countries Doing to Progress … How/ why are they Stealing a March?

- South Africa: Permissive legislation change in last 10 years, central funds to support local business, local governments working on waste management solutions. Agriprotein established in 2009 was possibly the first company to highlight the potential use of insect production at scale for animal feed (outside of Asia and Africa); recycles permissible organic waste streams and processes into insect meal, protein, fat, and residual soil conditioner. UK holding company reported record raise of US$105 million (backed by TerraSan) to fund construction of insect factories (3 in M. East, 2 in Asia, 1 in S. Africa each to take 250 tonnes waste per day). Agriprotein is now a division of the Insect Technology Group which acquired the Belgian BSF company Millibeter in 2018 and has plans to build factories in Europe in the next 2 years.

- Netherlands: Government & Venik (Dutch Association of Insect Producers) signed Green Deal B92, a joint effort in lobbying and designing a framework for market approval for insect production at scale for feed & food

applications. Protix (original member of IPIFF in 2015) working with Buhler (market leader in supply of animal feed manufacturing installations) and the breeding corporate Hendrix Genetics; 2017 announced 45M Euro funding for scale-up through Aqua-Spark, & other private investors. Market penetration being established through permitted niche products such as insect lipid for piglet feed, proteins for hypoallergenic pet food and live larvae for egg producing chickens (OERei eggs sold by Netherlands supermarket giant, Albert Heijn).

- France: aims to become leading world supplier of protein by 2030 with an agreement signed between government and industry in 2016. Protein France industry consortium boosting investment into research, innovation and scale up on animal and vegetable and 'future' proteins such as microalgae and insects. Ynsect leading French company in insect protein original member of IPIFF in 2015; 46 members, 15 different countries, 355 million euros invested in member companies, 6,000 tonnes insect produced so far in 2018. Ynsect has raised a total of $175 m since 2011, and has secured $70m for 2019-2023; construction of first full-scale production site in Amiens in 2019 will produce 20 000 tonnes of insect protein for fish feed annually. French supermarket Auchan launched insect-fed trout in 52 of its supermarkets in northern France (December 2018).

- USA: Legislative bodies (state and national levels) are changing legislation quickly in favour of insect meal and substrate use. Low government funding but high government attention to enabling legislation (FDA approval for insects in salmonid feed in 2016; recommendation for inclusion in poultry feed in 2018). Enviroflight (JV between Intrexon and Darling Ingredients) has moved from a pilot facility to new commercial facility (December 2018).

- Canada: Enterra Feed produces BSF (whole dried larvae, protein meal, fat and soil conditioner) on pre-consumer waste for pet food, salmonids, and poultry. Legally approved as for use in salmonid and poultry feed in 2016, encouraged by 2015 ban on disposal of food as landfill. 2018 Investment raise puts company valuation at 100 million US dollars, 3 new factories planned in Canada and US (2019-21) will increase production capability 90x.

Current Barriers and Challenges

1. Lack of central strategic policy to provide financial incentives and enable a cohesive holistic approach to develop a national alternative proteins sector. This presents particular challenge and disadvantage to UK competitiveness as other 'competing' industries such as AD have government subsidies and feed-in tariffs, making it tough for the emerging insect bioconversion industry to access suitable food waste streams on a level playing field.

2. Regulatory restrictions around the use of insects in animal feeds is hindering private investment for scale-up in the UK; investors are concerned that the precarious regulatory environment may never allow the alternative nutrient industry to fully take off and achieve expected revenues. Lack of alignment of regulations and trading standard authorities is currently preventing the use of insect fat in livestock feed.

3. Lack of commercial scale production facilities is preventing uptake of insect biomass in pet food and aquaculture and a bottleneck to conducting large scale trials necessary for commercial feed mills to validate pilot scale studies.

4. Restrictions on permissible substrates for rearing insects for feed. Insects can currently be reared on substrates suitable for use in animal feed; large volumes of these products are already used in feed or as feedstocks for AD (driven by renewable energy regulations and green electricity Feed in Tariffs), thus there is a need to consider expanding the range of permissible substrates.

5. Research & innovation. There has been no funding call specifically targeted for the UK insect biomass sector to date under UKRI or the Industrial Strategy Challenge Fund (Clean Growth Economy).

6. Meeting feed industry requirements i.e. feed safety, stability, homogeneity, palatability and consistency of supply. The industry will only consider the use of protein from assured suppliers, requiring rigorous control of feed

material production, testing for contaminants and other anti-nutritional factors, the absence of ruminant DNA etc, particularly dependent on the substrate used which must be traceable and there is concern over the risk of disease carry over.

7. Cost. Insect product prices (currently benchmarked against fishmeal) must compare favourably with other protein sources to be commercially viable; this can only be achieved at scale. Insect products will become more competitive as fishmeal prices continue to rise and as the entry barrier to investment is lowered for UK organizations to build at production scale (in the manner demonstrated by the French or Dutch, for example).

8. Consumer perception/ market acceptance is not considered a major challenge but requires a careful, joined up, approach across the supply chain. There are some concerns over compromising demand for products (e.g. free-range eggs from hens fed on vegetarian diets), if derived from insect fed poultry and this may affect the market for vegetarians. Halal and kosher requirements also need to be taken into account, however, religious councils of S E Asia have issued a fatwah (2018) declaring insect protein as Halal.

What Gaps Need to be Filled?

Market intelligence, translational research, consumer perception

Market analysis & intelligence to elucidate the potential value of an insect sector in the UK for national and global business.

Substrate supply to understand how insect production in the UK might fit/ complement current supply chains. Current major valorisation of agri-food residues is via AD (>2.5 mt food waste annually) or animal feed (650 kt of carbohydrate rich agri-food residues annually valorised back into animal feed UKFFPA). There is a requirement to to determine volumes, and access to, substrates for insect farming to understand the potential scale of production and deliver confidence to the supply chain. Ricardo Energy & Environment (REE) have identified, quantified and mapped bioresource arisings across Scotland; the Mapping tool provides the total volume/ amount of the resources, their geographical arisings and, importantly, their biochemical composition is split across 14 different biochemical characteristics (e.g carbohydrate, proteins etc). The tool also considers the bioresources availability taking into account: accessibility (distance), seasonality, price (if it has an existing market value/ cost/ landfill gate-fee). The tool enables users to search on any given biochemical, e.g. protein, and the results will provide the quantity of protein in a given area across Scotland. REE are currently developing a similar dataset for the whole of the UK but specifically identifying bioresources suitable for biorefining (such as forestry and agricultural residues) to provide the biochemicals required for producing compostable packaging. There is a need build upon these studies and to superimpose Bioresource arisings across the UK with a low-grade, heat source mapping to identify hotspots suitable for the establishment of insect production sites and improved net carbon savings.

Environmental impact: There are no published studies that provide a detailed LCA for a commercial operation producing insect protein for animal feed. Preliminary reports suggest insect production at scale would have reduced environmental impacts (land and water use, GHG emissions, energy consumption) compared to conventional livestock production although the impact derived from the generation of rearing substrates and residues are important factors in determining sustainability metrics. A recent Scottish-specific LCA study comparing BSF farming (on pre-consumer waste) with AD found both systems resulted in net carbon savings but BSF generated c. 10% additional carbon benefit and that if heat requirements for BSF production could be met by existing low-grade waste heat, net carbon savings of BSF farming could double to -153.4 $kgCO_2e$/tonne input. Further studies to evaluate emissions (particularly ammonia) along with energy requirements and possibilities to source low grade energy should be investigated.

Insect diet formulation to optimise productivity at scale, product consistency and quality. Agri-food residues may be ideal substrates for insect rearing from a circular economy perspective but are highly variable across space and time.

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

Value in animal feed: Publications report that inclusion of insect meal (or processed protein /fats) in the diets of fish, pig and poultry does not reduce and can improve performance. However, there is a need to determine suitable inclusion levels for livestock feeds given to different animals at various growth stages and at commercial scale. Similarly, the potential use of processed products such as chitin as feed additives to enhance gut health and alleviate reliance upon conventional antibiotics requires further research.

Productivity and safety evaluation, risk assessment of insects reared on non-permissible agri-food to evaluate overall safety and potential risks across the whole chain and covering a variety of substrates e.g. post-consumer, restaurant waste (i.e. containing meat and fish), to provide regulatory bodies with the evidence base for legislative change.

Further gaps in research include; (1) benefits for animal health of antimicrobial peptides (AMPs) produced by insects; (2) understanding the potential value of the residues derived from insect rearing as bio-fertiliser to enhance crop yields and disease immunity; (3) the full potential for by-product exploitation (lipids, chitin) in high value markets such as healthcare; (4) consumer perception studies as discussed above.

Recommendations

1. The UK Government to issue a **national statement of support** for this innovative and emerging technology with significant potential impact for the UK economy and its sustainable agricultural productivity.

2. Government and industry to **support a central body** to bring all stakeholders together to achieve aligned, rapid development of the sector for the UK and render it world leading inside the requisite national infrastructure.

3. Government to collaborate with private industry **to secure dedicated funds** to help insect producers reach the market, achieve cost competitiveness, respond to the identified research and process development gaps (for example in livestock welfare) and to open up new lines of commercial opportunity (for example for soil health).

4. For the Government **to lead on delivering insect biomass legislation and regulation** in line with latest science, global market developments and which acknowledges the sustainable, natural and local credentials of insect protein for the food and feed chain and waste valorisation as a critical 'clean growth' dimension of a circular economy.

5. Government to devise and provide short term **fiscal incentives** for discounting domestically produced insect protein costs for **early adopters**/ innovators to incentivise the UK animal feed industry to introduce insect based protein as part of its feed strategies so as to help insect producers achieve cost competitiveness during the period of ramp up of scale.

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

Appendix 2

Gross Value Added

Gross value added (GVA) is the measure of the value of goods and services produced in an area, industry or sector of an economy. Simplistically GVA is equivalent to a market sector or an individual firm's net profit.

Output per hour

Output per hour is defined as GVA/employee hours. The UK's Office of National Statistics (ONS) publish quarterly tables of Output per Hour for different market sectors (Current Prices, Seasonally Adjusted). See references.

Black Soldier Fly Larvae Farming GVA

Multibox has costed a number of different size Black Soldier Fly Larvae Farms (described by the tonnes of insect protein produced per annum) and the levels of automation. We have also looked at different sales strategies, product prices, capital and operating costs.

	Farm 500 (Low Auto) Oils to Bio Diesel	Farm 500 (Low Auto) Oils to Animal Feed	Farm 500 (High Auto)	Farm 4,200 (High Auto)	Farm 17,000 (High Auto)	Farm 17,000 (Dry Insects)
Gross Revenues						
Whole Dry Insects						16,875,000
Protein	399,840	399,840	399,840	2,700,000	12,150,000	
MCFA		364,854	364,854	2,463,750	8,505,000	
MCFA + LCFA	128,651					
Total	**528,491**	**764,694**	**764,694**	**5,163,750**	**20,655,000**	**16,875,000**
Tonnes of dry insect per annum	833	833	833	5,625	22,500	22,500
Revenue per tonne of dry insect	£ 634	£ 918	£ 918	£ 918	£ 918	£ 750
Cost of Sales						
Depreciation (10 year straight line)	100,000	100,000	150,000	1,576,721	4,240,380	3,000,000
Annual Operating Costs	909,581	759,581	609,581	3,764,675	10,570,373	10,320,373
General and Administration Costs	200,000	200,000	200,000	329,756	2,148,782	2,189,217
Total Cost of Sales	**1,209,581**	**1,059,581**	**959,581**	**5,671,152**	**16,959,535**	**15,509,590**
Cost per tonne of dry insect	£ 1,452	£ 1,272	£ 1,152	£ 1,008	£ 754	£ 689
Gross Margin per tonne	-£ 818	-£ 354	-£ 234	-£ 90	£ 164	£ 61
Net Profit	- 681,090	- 294,887	- 194,887	- 507,402	3,695,465	1,365,410
Net Profit Margin						
Number of Staff	15	15	10	34	55	55
Staff Output per Hour	-£ 26	-£ 11	-£ 11	-£ 8	£ 38	£ 14

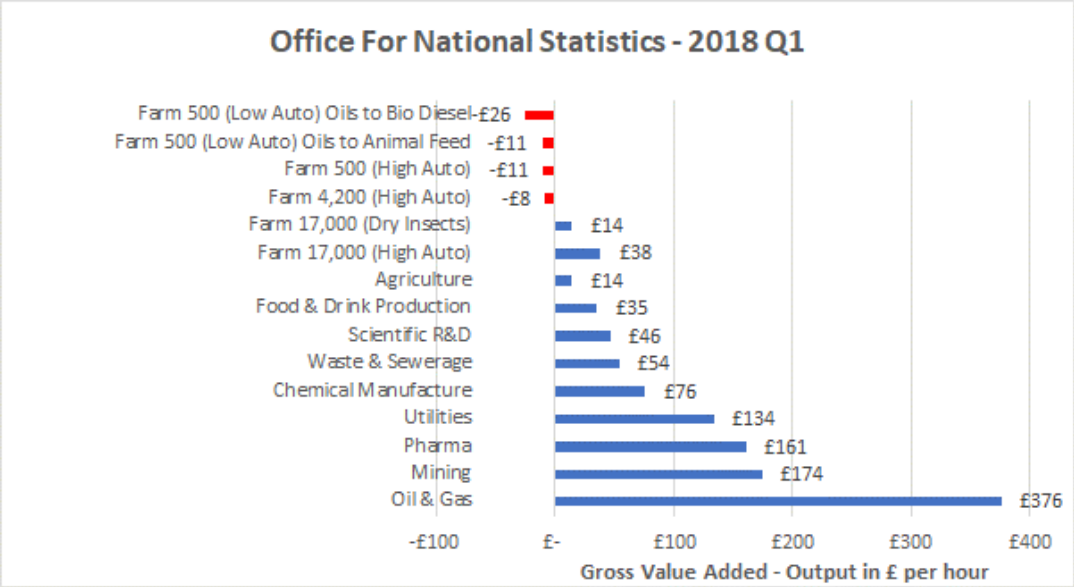
The staff output per hour was calculated by taking the farm business net profits and dividing by the total number of staff assuming 220 working days per annum and an 8 hour day.

It is clear that BSFL Farm labour output per hour rises with increasing size and automation of the farm. Comparing the various BSFL farm options with ONS measures of output per hour for Q1 2018 the following observations can be made:

- For this industry to be commercially variable farming will need to be conducted at scale.
- Plants producing in excess of 20,000 tonnes per annum of dry insect matter, similar in scale to the plants envisaged by global leading insect farmers, will generate an output per hour in-line with the agricultural and food production industries.

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

- Enhanced GVA output rates could be achieved through the development of novel products such as Chitin



BSFL farming at scale has the opportunity to make a significant contribution to UK GVA and Gross National Product through establishing an export business parented in the UK.

Job Creation

Job creation in this industry goes beyond the day to day running of the IBR facility. Given the building requirements and extensive supply chain needs (substrate, consumables, machinery etc), a significant number of direct and indirect jobs will likely be created.

The table below, outlines the estimated number of jobs this industry will create. This assumes the build of 40 IBR sites within the UK. This would generate insect protein output of ~360,000 tonnes per annum, which is in-line with the estimated level of insect protein demand within the UK.

It should be noted that there are potential export possibilities of any final product which an insect farming industry produces, leading to further expansion of this industry within the UK.

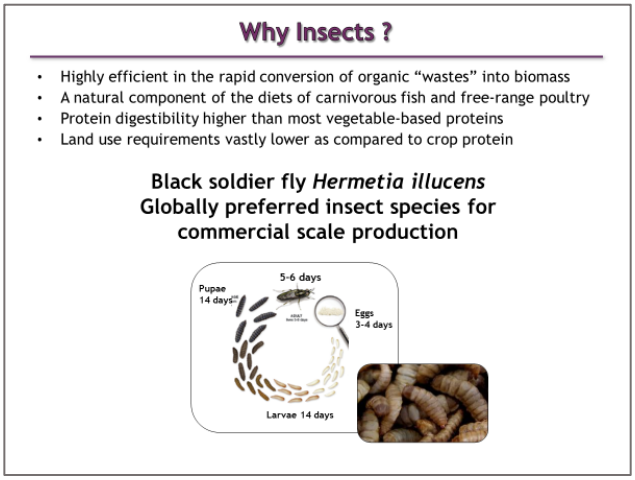
Job Type	No. Roles	Comments
Site roles	2,200	55 Jobs @ 40 sites
Building jobs	400	Based on previous projects, build is estimated
Supply chain	770	Assumed at 35% of site roles
Indirect jobs created	670	Assumed at 20% of direct jobs created
Total	**4,040**	

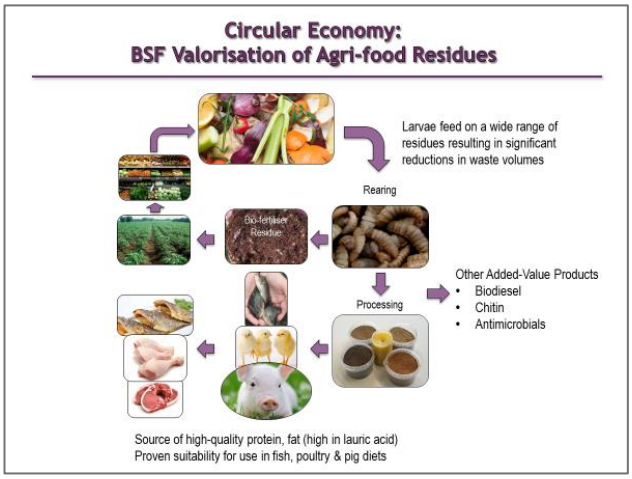
References

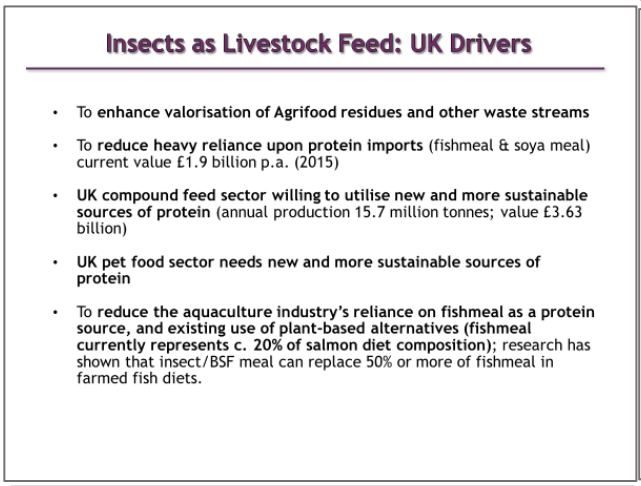
Office for National Statistics
Version: Labour Productivity: Q1 2018// Date of Publication: 06 July 2018
Contents
- Productivity Hours (Seasonally Adjusted)
- Output per Hour (Chained Volume Measure, Seasonally Adjusted)
- Output per Hour (Current Prices, Seasonally Adjusted)

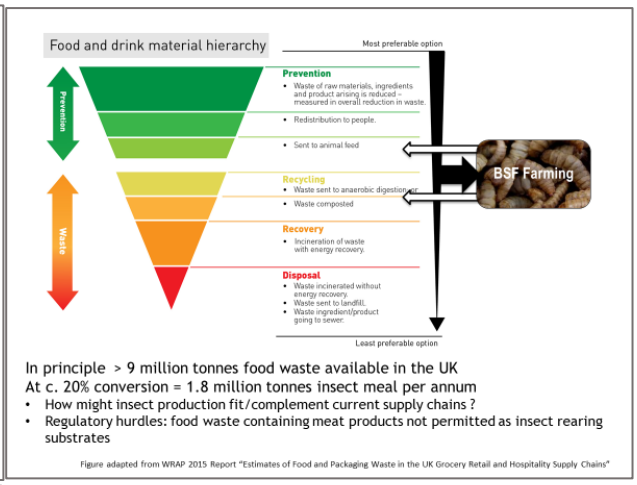
Contact details
productivity@ons.gsi.gov.uk
+ 44(0)1633 455086
Useful links
https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures

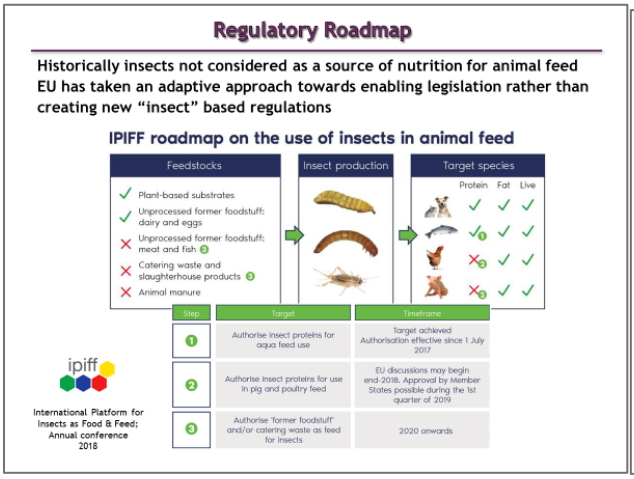
Appendix 3: Visuals

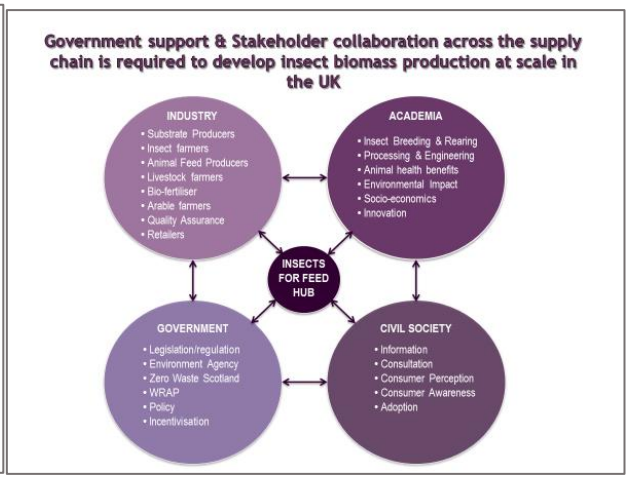












Contacts:

Dr Elaine Fitches, Fera Science Ltd/Durham University E.C.Fitches@durham.ac.uk +44 (0)7592-870967; +44(0)191 334 1253
Rhonda Smith, Minerva UK Ltd, rhonda@minervacomms.net +44 (0)7887-714957; +44(0)1264-326427

Produced by Fera Science Ltd and Minerva Communications UK Ltd on behalf of the Insect Biomass Task & Finish Group #6
for the Agricultural Productivity Working Group of the Food Sector Deal as part of the UK's "Clean Growth" Industrial Strategy.

fera Original thinking... applied

Minerva