PROteINSECT
Work Package 5: Pro-Insect Platform in Europe

Deliverable 5.3
PROteINSECT Key Opinion Leader Round Table Meeting Report
(Expert seminar report)

PROteINSECT Key Opinion Leaders Round Table

'Safe and sustainable utilisation of protein from insects for animal feed'

14th November 2014

09:30 until 16:00

University Foundation Club,

Egmontstraat 11 rue d'Egmont, 1000 Brussels

Version: FINAL

Rhonda Smith & Edward Barnes

PROteINSECT Grant Agreement Number: 312084

Title: **Enabling the exploitation of Insects as a Sustainable Source of Protein for Animal Feed and Human Nutrition.**

Acronym: **PROteINSECT**

Grant Agreement Number: 312084

Deliverable	D5.3
Associated WP	WP5 - Pro-Insect Platform
Associated Task	Task 5.3
Due Date	31/12/2014
Date Delivered	17/12/2014
Prepared by (Lead Partner)	Minerva HCC Ltd
Partners Involved	Minerva HCC Ltd Food and Environment Research Agency Nutrition Sciences NV Katholieke Universiteit Leuven
Authors	Rhonda Smith, Edward Barnes
Dissemination Level	PU

Acknowledgement

Work reported here was funded by the Knowledge Based Bio-Economy Programme of the European Commission under the PROteINSECT Grant agreement no. FP7-KBBE-312084.

Table of contents

1. Introduction

On 14th November 2014 the PROteINSECT Round Table for Key Opinion Leaders (KOLs) 'Safe and sustainable utilisation of protein from insects for animal feed' was held at the University Foundation Club in Brussels.

The meeting was co-chaired by Emile Frison (independent, Italy) and Elaine Fitches (Food and Environment Research Agency, UK)

The event drew together key stakeholders from across Europe to discuss the use of insect protein in animal feed. The stakeholders provided representation from across the life cycle of insect protein from breeding production to final product consumption (farm to supermarket) for poultry, pigs and aquaculture.

A detailed list of the attendees and invitees can be found in Appendices Three and Five respectively. Three further organisations unable to attend have been given the opportunity to contribute by correspondence.

This report provides a high level event brief and does not cite individuals or organisations in detail. Further detailed reporting of the organisational contributions regarding the use of insect protein in animal feed will be provided in the planned PROteINSECT Consensus Business Case to be published in March 2015.

PROteINSECT would like to thank the organisations and individuals who willingly gave their time to contribute to this event. Without their valued input such an exercise would not have been possible.

2. 'Safe and sustainable utilisation of protein from insects for animal feed'

2.1 Aim

The aim of this event was to draw together key European stakeholder groups and representation from the PROteINSECT project team to facilitate a discussion on state-of-the-art insect protein production and utilisation for animal feed. This work will support the evolution of a positive and receptive platform for the utilisation of novel insect based proteins in animal feeds in Europe by engaging with, informing and understanding the views of key stakeholder groups.

2.2 Objectives

1. Provide stakeholders with an updated brief on the evidence base covering insect production, processing, quality and safety and life cycle assessment. These briefings present the latest information from PROteINSECT work packages 1 – 4.

2. With the support of the co-Chairs to hold a managed discussion to record the organisational and individual views on the use of insect protein by highlighting the current state of play

(evidence) and the key opportunities and challenges identified and acknowledged by the contributing stakeholder groups to potential utilisation of this novel source of protein.

3. Use the information gathered at the KOL event to contribute to building a Consensus Business Case in 2015.

2.3 Outcomes

There were two key desired outcomes of the KOL event:

1. A Report of the meeting reviewed and agreed by all participants (PROteINSECT Deliverable 5.3) – this document.
2. A consensus 'Business Case' document that provides the evidence base (at a point in time) for use of insect protein which will be presented to key individuals in policy and political circles, feed industry, farmers, retailers, consumer groups and publicised more widely via the media (at a time to be determined). The Business Case will be published in March 2015 (PROteINSECT Deliverable 5.2 and Task 5.3). The Consensus Business Case will also provide the 'stepping stone' to our planned White Paper to be presented to the European Parliament in 2015.

3. The process

A representative group of organisations from across Europe were invited to attend this PROteINSECT event (full list of invitees available in Appendix Three). The Agenda for the KOL event can be seen in Appendix One.

Attendees received detailed briefings on the current evidence base for insect use Production, Processing, Quality and Safety and the Life Cycle Assessment (LCA) work undertaken within the PROteINSECT project in advance of the meeting (Appendix Two). Attendees were requested to review these papers in advance to ensure that they were able to contribute fully on behalf of their organisations on each of these topics.

The meeting was managed in five distinct sessions, each session being introduced with a short presentation by PROteINSECT members highlighting key evidence, barriers, challenges and opportunities for the topic (Appendix Four).

- Session 1: Production - Introduced by Elaine Fitches (Food and Environment Research Agency, UK)
- Session 2: Processing - Introduced by Geert Bruggeman (Nutrition Sciences, Belgium)
- Session 3: Quality & Safety - Introduced by Adrian Charlton (Food and Environment Research Agency, UK)
- Session 4: Life Cycle Assessment - Introduced by Bart Muys (KU Leuven, Belgium)

All attendees were invited in turn to formally contribute on behalf of their organisations on each session.

The final session (Session 5: Consensus Discussion) was used to draw together the contributions from throughout the day. The co-chairs presented what they had understood to be the key themes back to the contributors to allow additional challenges and opportunities to be raised.

4. Key Themes of Discussion

There was a broad range of topics discussed throughout the meeting with six key themes emerging from the day as raised by attendees. The six themes are described below.

**Note that this document is not intended to be a detailed account of all discussions, nor a detailed representation of what each organisation / individual contributed. All contributions and issued raised will be used to develop the PROteINSECT Consensus Business Case to be published in March 2015.*

4.1 Safety Data

A broad consensus was reached regarding the need for safety data from across the regulatory spectrum (from substrate to final product). This data should include safety considerations for the workers breeding insects and processing insect protein as well as for end-consumers. The current lack of safety data is recognised by all stakeholders as a major barrier to the development of the use of insect protein. For example, current lack of safety data is holding up progress on the development and discussion of appropriate legislation within Europe.

The contributors also viewed safety data as a key element in the development of consumer perceptions via associated communications activity. An example recommendation is to develop a map of safety considerations to use as a direct communications tool. This map could be updated in line with technical developments within the PROteINSECT project and where possible utilise available proprietary data.

4.2 Quality Data

The need for additional nutritional quality data to show the potential of the use of insect protein for feed and added value products was repeatedly raised. The quality data should consider potential changes to the nutritional and taste quality of the feed and food products. Consideration should be given to the variability that may occur due to different insect rearing and processing methodologies as well as variation across a range of feed stocks where inclusion rates for insect derived protein may differ. This testing should occur both in the laboratory and with taste testing.

4.3 Animal Welfare

Two aspects of animal welfare were raised: insect processing techniques including methods of killing; and the welfare of animals being fed on the insect protein, for example the potential for allergic reaction. Additional evidence was requested on current insect killing and processing methodologies and their relative strengths and weaknesses both for the welfare of the insects and for the animals fed on insect containing feed.

An additional area of discussion regarded the acceptability of consuming meat that had been fed on insect protein; this acceptability represented both a challenge and opportunity, for example within religious group.

4.4 Communication

The importance of clear scientifically based and neutral communications was a reoccurring theme. The contributors sought communications that covered the full life cycle of insect protein from breeding and production to final product consumption. All communication needs to impartially express the current known benefits of protein from insects and be honest in the appraisal of the challenges. This work should include an understanding of the potential barriers to market uptake beyond the legislative and technical; examples cited consumer perceptions and potential for generational differences in acceptability.

The importance of carefully targeted and transparent communications was expressed by a number of contributors.

4.5 Food and feed

There was considerable discussion around the use of insects for food as well as for feed. Although there were differing opinions from across the KOL attendees, a consensus was reached that the separation of insects for food and insects as feed was both useful and suitable in this situation due in part to the differing drivers and barriers to market entry. A suggestion was that the PROteINSECT project creates communication that highlights the key differences between feed and food and includes this information within the proposed Consensus Business Case.

4.6 Life Cycle Assessment

The stakeholder attendees defined Life Cycle Assessment (LCA) as a key design tool for the development of insect derived protein. LCA remains fundamental to demonstrating the full potential of insect derived protein within a variety of production systems across Europe (and the world) due to the variances in local economic, cultural and climatic conditions. The LCA needs to demonstrate the carbon, water and other environmental footprints, the energy and labour efficiency, and the socio-economic costs and benefits of each of the main established and developing production and processing techniques. The PROteINSECT project should consider the consumer acceptance of the main established and developing techniques. It was recommended that a combination of environmental and social impact assessment and life cycle costing techniques will be fundamental to providing policy makers with the decision making tools they require. It was recommended that any LCA work is bench-marked against existing data from traditional protein sources of comparable nutritional value to provide a tangible and robust comparison.

A number of stakeholders expressed the view that undertaking the LCA for a range of production systems and scenarios provided one of the greatest challenges to the PROteINSECT project.

5. Conclusions

The PROteINSECT Round Table for Key Opinion Leaders (KOLs) 'Safe and sustainable utilisation of protein from insects for animal feed' event drew together key representative stakeholders from Europe to discuss the use of insect protein in animal feed in a structured and managed environment.

These key stakeholders were provided with detailed briefings on the current evidence base for insect Production, Processing, Quality and Safety and the Life Cycle Assessment (LCA) work undertaken within the PROteINSECT project in advance and during the meeting.

The stakeholders were provided with the opportunity to contribute to the discussion on behalf of their relevant organisations. Through this discussion and challenge six key themes emerged for the development of insect protein within Europe:

1. Safety data
2. Quality data
3. Animal welfare
4. Communication
5. Food and feed
6. Life Cycle Assessment

The next step is to develop a Consensus Business Case for the use of insect protein for publication in March 2015. The contributions and representations of the KOL attendees are considered a critical contribution and will be taken into account in the development of the PROteINSECT Consensus Business Case document and where possible addressed.

PROteINSECT would like to thank the organisations and individuals who attended and contributed to the Key Opinion Leaders event and for their continued support as the project develops the PROteINSECT Consensus Business Case in 2015.

Produced by Minerva Communications UK Ltd on behalf of the PROteINSECT Consortium

Edward Barnes (edward@minervacomms.net) +44 (0)1264 326427

17/12/2014 Version FINAL

Key Opinion Leader Round Table

Appendix

Appendix One	Round Table Agenda
Appendix Two	Round Table Session One to Four Briefing Papers
Appendix Three	Round Table Attendees
Appendix Four	Round Table Session One to Four Presentations
Appendix Five	Project Partners Briefing

Appendix One
Round Table Agenda

PROteINSECT Round Table - for Key Opinion Leaders
'Safe and sustainable utilisation of protein from insects for animal feed'

Date: Friday 14th November 2014
Meeting: 09:30 (for 10:00) until 16:00
Location: University Foundation Club, rue d'Egmont, 11, Egmontstraat, 1000 Brussels
Meeting to be recorded

Meeting Chairs: **Emile Frison (independent)**
Elaine Fitches (Food and Environment Research Agency)

09:30	Arrival and coffee
10:00	Welcome from Co-Chairs - explain scope, format and objectives of the meeting
10:20	Session One: Production Introduced by Elaine Fitches - Food and Environment Research Agency
11:15	Comfort break
11:25	Session Two: Processing Introduced by Geert Bruggeman – Nutrition Sciences
12:20	Lunch
13:00	Session Three: Quality & Safety Introduced by Adrian Charlton - Food and Environment Research Agency
14:00	Session Four: Life Cycle Analysis Introduced by Bart Muys - KU Leuven
14:55	Coffee Break
15:10	Session Five: Consensus Discussion (Led by Co-Chairs)
16:00	Meeting close and next steps

Contact for queries:
Edward Barnes (edward@minervacomms.net)
Phone: +44 (0) 77185 37976

Appendix Two

Round Table Session One to Four Briefing Papers

Key Opinion Leaders Round Table

November 2014

Briefing Papers

PROteINSECT
INSECTS AS SUSTAINABLE SOURCES OF PROTEIN

PROteINSECT

'enabling the exploitation of insects as a sustainable source of protein for animal feed and human nutrition'

Food security is a global challenge. Increasing demand for food (particularly meat, fish and eggs) has led to an urgent need for new supplies of protein from sustainable sources for inclusion in animal feed. More than 40 million tonnes of crop proteins, primarily soya, are imported annually into EU countries representing 80% of the EU's crop protein consumption (Häusling, 2011). The European Parliament has adopted a resolution to address the EU's protein deficit, stating that urgent action is needed to replace imported protein crops with alternative European sources.

The availability of food for human consumption at the global level is heavily impinged upon by the demands that livestock production places on land and water use. It has been estimated that around three quarters of the world's agricultural area is devoted to producing livestock either directly or indirectly (Foley at al., 2011). Production of feed crops represents 24% of global crop production by mass (Cassidy et al., 2013). Animal protein production is estimated to require 5-20 times more water than that required for the production of cereal protein on a per kilogram basis (Chapagain and Hoekstra, 2003), but when the water required for forage and grain production is included in the equation this figure approaches 100 times (Pimentel and Pimentel, 2003) and this places considerable stress upon the sustainability of the global water supply.

Invertebrates already contribute to the natural diet of wild fish and "free range" monogastric livestock across the world offering the potential to be used effectively as alternatives to other animal and soya based proteins in animal feed. Insects thrive on waste products from various sources including those which have no other use; they efficiently convert nitrogenous compounds into valuable protein whilst requiring fewer valuable resources such as land and water per unit protein than protein crops (van Huis, 2013).

The production of insects specifically with the intention of being fed to domestic animals has been the subject of evaluations for several decades (e.g. Bondari and Sheppard, 1987; Newton et al., 2005; Hem et al., 2008), but has not yet reached a stage that has led to any significant replacement of traditional protein used for livestock production with insect based protein. Importantly, much of the work to date has made little or no attempt to process insect protein into amenable products or to assess safety, social and acceptability issues.

PROteINSECT is focusing on five key areas in order to evaluate insects as a novel source of protein for animal feed and to ensure that methodologies are sustainable and economically viable.

1. The development and optimisation of fly larvae production methods for use in both developed and developing countries at small and large scale.
2. Determination of safety and quality criteria for insect protein products.

3. Evaluation of processing methodologies and the evaluation of crude and refined insect protein extracts in fish, chicken and pig feeding trials.
4. The determination of the optimal design of insect-based animal feed production systems utilising the results of a comprehensive life cycle analysis.
5. To build a pro-insect platform in Europe to encourage adoption of sustainable production technologies to include examination of the regulatory framework.

Additional PROteINSECT introductory information can be found on our website:

Insect Production
Quality and Safety
Insect protein technologies and feeding trials
Life Cycle Sustainability Assessment

Session One: Insect Production Briefing

Introduced by Elaine Fitches - Food and Environment Research Agency

Introduction

Most animals require proteins to compensate for their inability to synthesise certain amino acids. Insects are rich in protein and are a natural component of the diets of carnivorous fish and free-range poultry. Insect species considered most suitable for feed production include silkworms, mealworms, black soldier flies and the common house-fly. As fly larvae can be reared on a wide range of wastes they also offer a potential solution to the need to utilise increasing quantities of organic wastes produced by agriculture and food industries. Furthermore, the residual material remaining after larval digestion has economic value as a fertiliser or soil conditioner. Historically insects have been used in many parts of the world as a direct source of human food as well as a complementary food source for animals and fish. As such, extensive expertise in the rearing of insects is evident in non-European countries, particularly Asia and Africa. In Europe commercial insect rearing is limited to the production of insects such as crickets and mealworms for pet food, and fly larvae for recreational fishing. Mealworms are already raised on an industrial scale for the pet feed industry. For example in China, HaoCheng Mealworm Inc. exports 200 tonnes of dried mealworms annually to Australia, Europe, North America and South Asia. Growing recognition of the potential value of insects, along with the drive to find new sources of protein for animal feed, has resulted in a growing number of new commercial enterprises over the past decade.

Agriprotein, a South African company established in 2009, is considered the world leader in the mass production of fly larvae. The company is focussed on nutrient recycling using organic wastes to produce insect based protein feed, extruded oil, and fertilisers. Its first industrial scale factory was established in 2014 and has a current capacity of 800 kgs wet larvae per day. The goal is to produce 7 tonnes of insect meal, 3 tonnes of oil and 20 tonnes of fertiliser per day and the company aims to establish 10 similar sites by 2020. House-fly, blow fly and black soldier fly larvae are all “farmed” in a factory that uses a combination of automated and labour intensive processes.

In Canada the Enterra Feed Corporation utilises food processing and distributor wastes to rear black soldier fly. The company produces protein and oil products for aquaculture feed, animal feed and pet food. Like Agriprotein, the digestate from the larvae is processed and sold as a natural fertilizer product. In the US, Enviroflight is using low-value co-products from breweries, ethanol production, and pre-consumer wastes to rear black soldier fly larvae. The larvae are processed into meal and sold as feed for carnivorous fish such as rainbow trout, perch and bass. Digested feedstock is sold principally as a feed for omnivorous fish, such as Tilapia and catfish as well as freshwater prawns.

A growing number of companies with similar ambitions is being established in Europe. However, markets are limited by the current legislative landscape that does not permit the use of insects in livestock feed. For example "Protix Biosystems BV" in the Netherlands has developed scaleable insect production systems using "end-of-life streams" to produce insect meal and purified oil, as well as chitin as a basis for derivatives like chitosan. The Spanish spin-out, "Bioflytech" specialises in rearing a range of dipteran species producing biomass for animal feed with additional focus on the use of insects in the development of technologies for waste valorisation. Other biological control companies, such as Koppert in the Netherlands, and Hermetia in Germany, are ideally placed to enter the market owing to their significant expertise in rearing pollinators (including flies) and beneficial insects.

PROteINSECT

The principal objective of PROteINSECT is to facilitate the exploitation of insects as an alternative source of protein for animal and human nutrition. The programme is focussed on evaluation of the potential for incorporation of insect protein into the human food chain via utilisation as a component of animal feed, although possibilities for the inclusion of processed insect protein in food are also considered. The development of sustainable and economically viable insect production methodologies is clearly essential for wide-scale adoption of this approach to be achieved. PROteINSECT is focussed on the exploitation of flies (house-fly *Musca domestica*; black soldier fly *Hermetia illuscens*) reared on organic wastes (principally manures) as a sustainable source of protein for animal feed and as a means of reducing and valorising waste.

The PROteINSECT consortium brings together academic partners from China and Mali, and a UK maggot farmer, all of whom have considerable experience in the rearing of flies. One of the principal aims of the project is the co-ordinated development and optimisation of fly production methods for animal feed. As such an entire work package entitled "Sustainable insect production" has been tasked with the following objectives:

- Define the characteristics of the existing fly rearing systems presently used by the partners
- Optimise/improve existing and newly set up rearing systems
- Set up new fly rearing systems at partner organisations using other partners expertise
- Provide fly larvae for assessments of quality and safety and potential for processing crude samples and data to enable life cycle assessments to be conducted.

Our aim is not to develop large-scale automated production systems but rather to establish, evaluate and optimise local to pilot scale production systems in different parts of the world. A critical aspect of the project is that it has enabled, for the first time, analyses of larval samples derived from five distinct locations to be conducted. In all cases larvae have been harvested at the same time (late larvae/pre-pupal stage) and prepared (harvested and dried) in a similar manner. Comprehensive analysis of the safety and quality of samples, together with feeding trials, will provide information of relevance to the assessment of the suitability of larvae as a source of protein in feed and the use of organic substrates as feedstocks. Four distinct fly rearing systems in place at the beginning of the project have been precisely characterised and formed the starting point from which further systems were developed. These are as follows:

- Grantbait (UK): *Calliphora vomitoria* (blowfly) produced for fish bait
- IER (Mali): *Musca domestica* produced for poultry feed
- GEI (China): *Musca domestica* produced for poultry feed
- HZAU (China): *Musca domestica* produced for various purposes

All rearing systems follow the general scheme depicted in Figure 1.1 whereby a separate adult culture is maintained to enable the provision of eggs for larval rearing on organic waste substrates.

Using other partner's expertise, new rearing systems for house fly or black soldier fly have been set up, or modified from the systems available at the beginning of the project. In China a rearing system for the blowfly species *Chyrsomya megacephala,* able to grow when temperatures are too high for house-fly larvae, has also been established. Larvae are reared in trays or in concrete beds and in all cases larvae are separated from the rearing substrate and left for several hours to clear their guts before harvesting and drying. The pre-pupal stage has been selected for two reasons; firstly, to minimise the risk of contamination from rearing substrates and, secondly, to ensure that the samples have a relatively low chitin content. High levels of chitin present in fly pupae may result in anti-nutritive effects in animal feeding trials as it is difficult to digest. Larvae are slaughtered by placement in hot water and dried. A brief summary of the systems that have been developed outlining major differences and bottlenecks to production is described below.

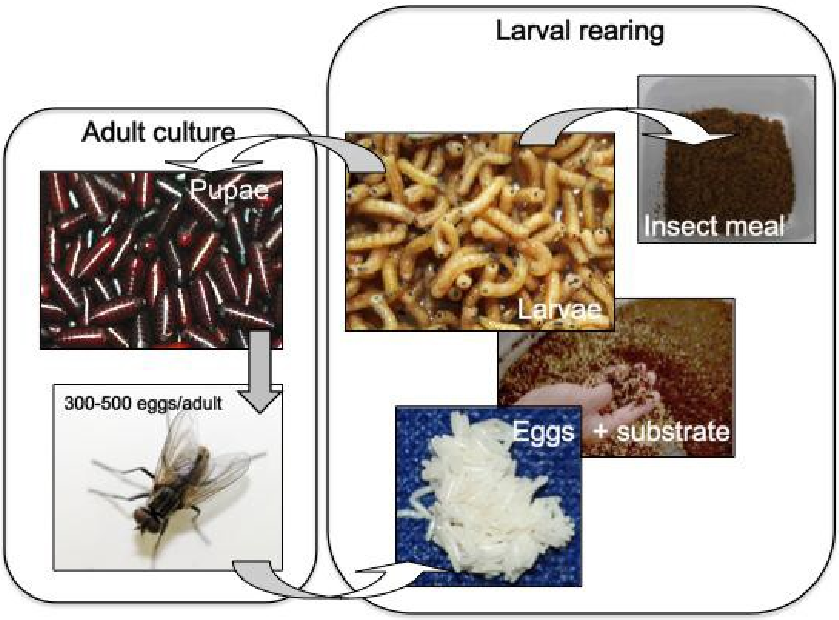


Figure 1.1 Schematic depicting larval production system for *Musca domestica*

1. UK - *Musca domestica* (Grantbait and FERA)

A new system for the rearing of *Musca domestica* on poultry manure has been established at the Grantbait maggot farm (Figure 1.2). Production methods are being refined and adapted in conjunction with laboratory-based research being carried out at FERA. Production is scaleable but labour intensive. This system now produces 40-50 kg wet weight larvae (10-12.5 kg dry wt.) per week. Variation in productivity is experienced and is thought to be largely attributable to variation in substrate quality; the age of the manure (time in storage) is considered to be a major factor in determining quality for insect rearing.

2. Mali – *Musca domestica* with adult rearing (Institute D'Economie Rurale and CABI)

The original system in Mali (Figure 1.3) differs to others in the project in that it is based on natural oviposition by flies on exposed substrates in rearing beds, rather than on the seeding of substrates with eggs derived from maintained adult cultures. This system has disadvantages, however: (1) yield fluctuates with fly population and seasons throughout the year; (2) it needs a large ground surface for a sizable production since adults prefer to oviposit on the ground; (3) house flies are not the only species produced as some substrates may also provide a mixture of different fly species, including blow flies. Therefore, a new adult rearing and egg production system has been set up, based on the expertise of the Chinese partners. Substrates used for rearing include chicken manure + water; sheep manure + fish offal + water; sheep manure + blood + water. The different components have been tested in various proportions. Interestingly, although there are seasonal variations, as expected (the worse period for fly activity being the hot dry season of April-May), intra-seasonal variations seem much more important, i.e. yield varies tremendously within the same week or month. The same results were obtained using controlled quantities of eggs from adult rearing and thus variation most certainly comes from high variation in the substrates' quality. The current system based on natural oviposition has a production capacity of 20 – 80 kg wet larvae per week (5-20 kg dry wt.).

Figure 1.2. Adult fly and larval rearing of *M. domestica* at Grantbait.

Figure 1.3. Adult fly and larval rearing of *M. domestica* in Mali.

3. Ghana – *Hermetia illucens* (Fish for Africa and Stirling)

Fish for Africa and the University of Stirling have been working together to develop a black soldier fly production system in the rural conditions of Ghana (Figure 1.4). Substrates used for larval rearing include chicken manure, fish feed waste, brewery waste, yeast and pig manure. Mixtures with fish feed waste provide the best results but this substrate is rarely available elsewhere and cannot be recommended for technology transfer. One of the main issues regarding substrates is variability in quality and availability. The quality of manure is particularly variable, even when obtained from the same farm, and results in highly variable yields of larvae. The production system is small and labour intensive but scalable producing on average 25 kg wet weight (approximately 7 kg dried) larvae per week.

4. China – *Musca domestica* and *Chrysomya megacephala* by individual farmer (Huazong Agricultural University [HZAU])

Research at HZAU mainly focuses on the blow-fly, *C. megacephala,* as this species is much less studied than *M. domestica* but also shows promise in the HZAU maggot production unit. *Chrysomya* is a more robust species than *M. domestica* in hot summer conditions and research is focussed on establishing temperature requirements to optimise production. An experimental house-fly production system has been established at an average single family farm in Hunan Province. This system is designed to produce sufficient larvae (fed live) to feed a few dozen hens and chickens. This system can produce 50-80 kg wet weight of house-fly larvae or 50-100 kg wet weight of blowfly larvae per week. Pig manure is the primary substrate used for rearing although chicken manure, wheat bran and distillers grains are also used.

5. China – *Musca domestica* in a large poultry production company (Guandong Entomological Institute [GEI])

GEI University is working in collaboration with a poultry production company in Guandong Province rearing house-fly larvae on chicken manure on a pilot scale (Figure 1.4). This system currently produces 200 – 250 kg wet larvae (50-62.5 kg dry wt) per week and larvae are fed live to poultry substituting conventional feed at a level of 5-10%. Research to optimise the production process includes improving separation of larvae from the substrate (based on decreasing oxygen to force larval egression); methods to reduce the moisture content of the residual material to make it more suitable for use as a fertiliser; improvements in automation of certain parts of the process (e.g. chicken manure and residue conveying machinery). The chemical ecology of ovipositing females and oviposition attractants is also being studied in Beijing by CABI staff, in collaboration with GEI and HZAU, in order to see if egg production rates can be improved upon. The limiting factor for economic viability in this system is the increasing cost of labour in China.

Figure 1.4. Pilot scale *M. domestica* production in Guandong Province,

Summary of findings

The potential use of waste substrates to yield fly larvae has been demonstrated by the successful establishment of systems with varying production capacities (25-250 kg wet larvae per week) in China, Africa and the UK. Similarities in bottlenecks to production have been identified, of which variability in substrate quality appears to be the most significant in terms of its impact on yields. Production processes are, in the main, labour intensive and therefore not economically viable for industrial scale production. Nevertheless, a clear understanding of the biology and requirements for success paves the way for future expansion of this approach particularly for small-scale (50 kg wet larvae per week) set ups in countries such as West Africa and Mali. It is envisaged that the pilot-scale production system currently being developed on a poultry farm in China will achieve economic viability and encourage the establishment of similar units elsewhere. It is hoped that the production system established in the UK will form a starting point for the future development of a semi-automated system more suitable for adoption in Europe. In all cases either trained entomologists or “know-how” has been seen to be vital to the successful establishment of larval production systems.

Session Two: Protein Processing Briefing

Introduced by Geert Bruggeman – Nutrition Sciences

1. Introduction

For the activities within PROteINSECT the consortium mainly focusses on insects suitable for animal nutrition. Some insects for human nutrition (also called “mini-livestock” such as meal worm, crickets, grasshopper, …) are already well studied, while insects such as house fly (*M. domestica*) and black soldier fly (*H. illucens*), need further research for evaluation of their potential as protein source in animal nutrition (and subsequently also in human nutrition). From Table 2.1, it is clear that both house fly and black soldier fly are rich in proteins and have the clear potential for protein source in animal nutrition.

Table 2.1 Protein composition of house fly and black soldier fly

Insect	Development stage	Protein content (% of insect)
House fly	Larvae	37-68
House fly	Pupa	58-80
Black soldier fly	Larvae	37-48

The briefing summarises and analyses (in terms of Strengths, Weaknesses, Opportunities and Threats, SWOT) existing methodologies for protein extraction from the above insects and their residual substrates (biomasses), for inclusion as protein source in animal feed applications. The purpose is to define at least two methodologies within each of the following categories: physical, chemical and biotechnological approach. The aim is to derive some general approaches but always based on existing literature, patents and practices in participating countries. Claims of patents from Chinese applications were translated by the Chinese partners within the PROteINSECT consortium. Besides literature on insects (including larvae, pupae and adult insects), literature on biomass was also consulted. Reason: most literature on insects was focussed on recombinant protein expression in insect cell lines, showing other characteristics (based on fundamental research activities) compared to conventional protein processing technologies.

2. Overall approach defined by a Protein Development Plan

The Protein Development Plan (Figure 2.1) starts with setting up an inventory for possible methods for protein isolation, extraction, enrichments and decontamination. These methods are identified in literature, patents and daily practices, and screened and reviewed by all partners involved in Work Package 2. In addition, extended expertise of partner Nutrition Sciences N.V. (and its’ network) was taken into account. Based on this inventory, a SWOT analysis was performed for each processing step and some leading methods for protein isolation, extraction and enrichments were derived. These methods will be tested and fine-tuned in pilot scale. This way, sufficient protein material can be produced in order (1) to proceed towards the efficacy trials in animals and (2) to test the safety of the outcomes (Work Package 3).

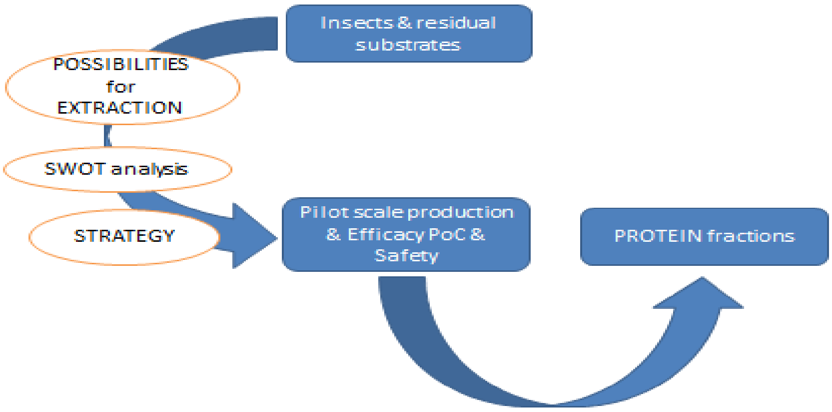


Figure 2.1 Protein Development Plan

3. Step-wise approach for protein extraction: possibilities for protein processing and corresponding SWOT characteristics of the methodologies

After consulting existing literature, patents and daily practices, it was clear that the following approaches can be used:

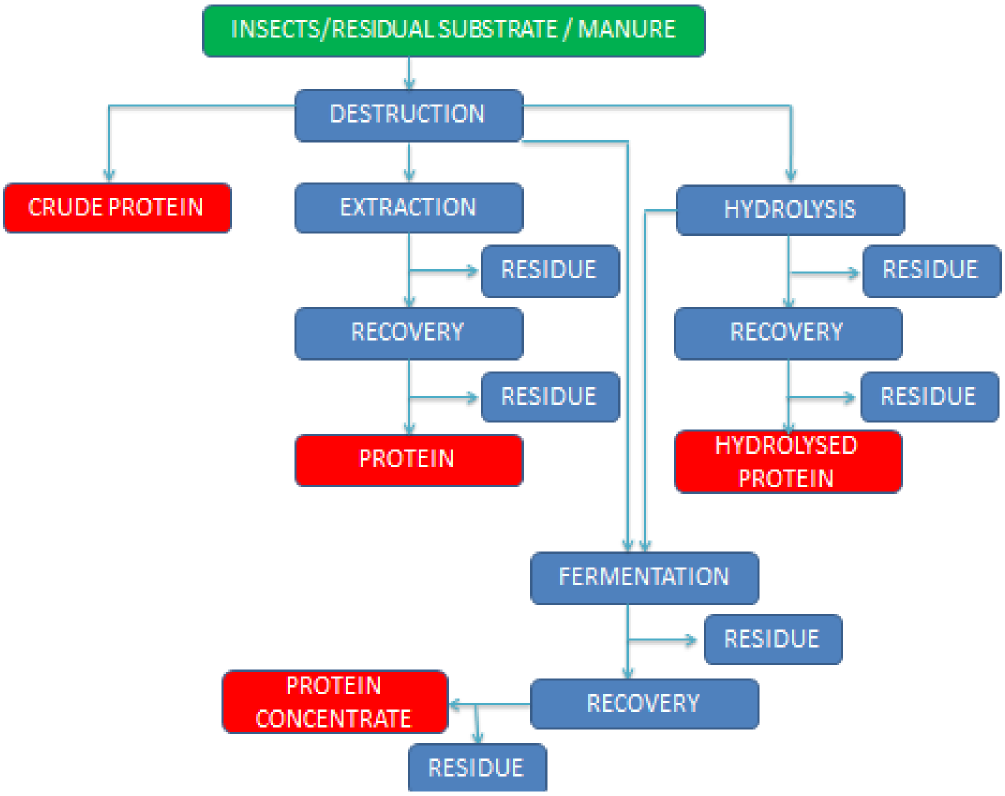


Figure 2.2 Extraction approaches

INPUTS (green box)	A/ **INSECTS**: small, big (including spiders and scorpions) at different development stages (pupae, larvae, adult) and in different physical form (preferentially boiled and dried, although alive or fried can be an option) B/ **RESIDUAL SUBSTRATE / MANURE** (mainly consisting of vegetables, rice, residual water). Possibly pre-drying will be necessary.
OUTPUTS (red boxes)	Crude **PROTEIN** → (extracted) protein → hydrolysed protein → protein concentrate. The last one has the highest protein content.

Above approaches can be qualified as follows:

Physical	**Chemical**	**Biotechnological**
Crude protein	(extracted) protein	Hydrolysed protein Protein concentrate

The *modus operandus* for the SWOT analysis per processing unit is illustrated in the table below (as an example “pre-(sun)drying”):

Technique	Strength	Weakness	Opportunity	Threat
Pre-(sun) drying	mature technology easy to do easy to upscale manpower and skills large process volume no large investment (even outside, positive in ICPC countries) solar energy high yield	need for surface (land) slow evaporation, long duration less flexibility mixed extracts non-controlled process (seasonal effects) allergenic reaction toxic substances (when dried in sun) denaturation of functionalities limited applications	easy implementation (easy training and application, standard approach) cheap (basic infrastructure)	competition public acceptance (towards deterioration) legislation (towards deterioration and safety)

After applying the SWOT analysis on the existing literature, patents and daily practices, it was clear that the following approaches can be used for protein processing from insect larvae: DESRUPTION technologies, EXTRACTION technologies, HYDROLYSIS technologies and FERMENTATION technologies, all followed with adequate DOWNSTREAM PROCESSING technologies.

In conclusion the following results were obtained:

- Ranking of DESTRUCTION technologies is **mechanical treatment (RTHV 100%)** → **sieving/filtration (RTHV 84%)** → **temperature (RTHV 68%)** → **pre-(sun)drying (RTHV 52%)** → sonification (RTHV 11%) → high pressure (RTHV 0%)

- Ranking of EXTRACTION technologies is **water (RTHV 100%) → salting in = temperature (RTHV 81%) → selective adsorption (RTHV 62%) → solvents = pH (RTHV 56%)** → multi-detergent (RTHV 44%) →extraction aids (RTHV 31%) → ionic fluids (RTHV 25%) → microwave = supercritical CO2 extraction (RTHV 0%)

- Ranking of HYDROLYSIS technologies is **enzymes = acid = alkaline (RTHV 100%)**
- Ranking of FERMENTATION technologies is **lactic acid bacteria = yeast (RTHV 100%)**

- Ranking of DOWNSTREAM PROCESSING technologies is **conventional air drying = conservation agent (when using non-patented conservatives !) = precipitation (RTHV 100%) → centrifugation (RTHV 50%)** → drying = membrane technology (RTHV 42%) → Sterilisation/pasteurisation/HTST/radiation (RTHV 0%)

The PROteINSECT consortium agreed that the relative threshold value (RTHV) in the SWOT analyses is set at **50 %** (= 1/2 of the points, see **blue** indications), in order to have been selected for further trials.

This resulted in the following overall processing methodologies:

PHYSICAL APPROACH

APPROACH/PRIOTITY N°
1 Mechanical destruction
2 Sieving/filtration (possibly after mechanical destruction)
3 Temperature/(sun)drying

CHEMICAL APPROACH

APPROACH/PRIORITY N°
1 Water
2 Salting in
2bis Temperature
3 Selective adsorption
4 pH (both extraction and hydrolysis*)
4bis Solvents

*hydrolysis compared to enzymatic hydrolysis

BIOTECHNOLOGICAL APPROACH

APPROACH/PRIORITY N°
1 Enzymes (+ catalyst)
2 Lactic Acid Bacteria
3 Yeast

DOWNSTREAM PROCESSING

(after chemical and biotechnological approaches)

Centrifugation

↓

OPTIONAL: precipitation

↓

(air)drying, conservation agent

Above approaches can be translated into following types of protein based outcomes:

Physical	Chemical	Biotechnological
Crude protein	(extracted) protein	Hydrolysed protein Protein concentrate

4. From lab-scale to pilot testing for protein processing

Most promising technologies are selected and are tested both on lab and pilot scale. In this context, all insect producing partners within the PROteINSECT consortium, as well as from the international advisory board, were requested to send insect larvae. The characteristics of the insect larvae are: 1) Collected from their best controlled rearing system so far, 2) Instar “wandering” development stage or ‘ready-to-feed” development stage and 3) Killing of the larvae: heat treated for 2 hours at 65°C. In case of cleaning (for removal of dirt), The larvae need to be washed in water after the first heat treatment, and dry them again for 2 hours at 65 °C.

To date, all physical, chemical and enzymatic (as part of biotechnological approach) processing steps have been evaluated, and the most promising technique was solvent extraction. This technology can be summarized as follows:

- Starting material (10% w/v)
    - Insect *as such*
- Solubilisation in solvent
- Filtrate
- Freeze-drying of residue

This solvent extraction methodology gave the best protein extractions, as given in the tables below:

Table 2.2 Protein recovery rates after solvent extraction

Insect sample	% protein recovery
A. Musca domestica - UK	94,7
B. Calliphora – UK	116,7
C. Musca domestica– China	88,1
D. Calliphora– UK	125,3
E. Musca domestica– Ghana	96,1
F. Calliphora– Ghana	96,5
G. Black soldier fly – Ghana	97,3
H. Musca domestica– Mali	97,1
I. Musca domestica– China	100,8

Table 2.3 Protein content before and after solvent extraction

Insect sample	**% protein (initial)**	**% protein (after extraction)**
A. Musca domestica - UK	41,8	68,1
B. Calliphora – UK	44,5	72,6
C. Musca domestica– China	60,7	71,8
D. Calliphora– UK	42,9	73,0
E. Musca domestica– Ghana	57,8	67,8
F. Calliphora– Ghana	56,7	65,0
G. Black soldier fly – Ghana	43,9	57,9
H. Musca domestica– Mali	56,2	68,7
I. Musca domestica– China	55,0	68,6

However, it is clear that also a fibrous fraction (chitin?) is co-extracted:

Table 2.4. Crude fibre content before and after solvent extraction

Insect sample	**% crude fibre (initial)**	**% crude fibre (after extraction)**
A. Musca domestica - UK	2,7	9,8
B. Calliphora – UK	6,1	8,7
C. Musca domestica– China	6,2	8,6
D. Calliphora– UK	6,6	9,5
E. Musca domestica– Ghana	10,6	12,5
F. Calliphora– Ghana	12,2	14,9
G. Black soldier fly – Ghana	7,0	9,7
H. Musca domestica– Mali	8,7	10,1
I. Musca domestica– China	7,3	9,4

5. Conclusion on protein processing

From the evaluated processing technologies, solvent extraction – as a model for EXTRACTION technologies - yielded the highest and most dense protein concepts. In addition, a complete recovery of proteins was obtained after solvent extraction. However, one major disadvantage is that the fibre fraction was co-extracted together with the protein. This fibrous fraction contains mainly chitin, which is questionable in terms of safety towards animal and subsequently human consumption.

6. Challenges/opportunities for extraction processes

The major challenges/opportunities for extraction processes based on solvents are:

- Animal welfare issues. Suitable killing protocol for insects before extraction.
- Designing generic processing technologies for larvae of different insect species (preferentially already allowed in feed and food applications).
- Toxicity issues on co-extracted chitin. This will be the basis for further biotechnological processing methods, based on fermentation and enzymatic treatments.
- The presence of parasites on larvae, influencing safety of extracted insect protein.
- Solvent residues in protein extract, increasing the pressure for looking for alternatives and more sustainable solutions for solvent extraction.
- Residual substrates in the gastrointestinal tract and on the surface of insect larvae, in case of contaminated substrates for insect growing.

Session Three: Quality & Safety Briefing

Introduced by Adrian Charlton - Food and Environment Research Agency

Introduction

There is an urgent need to increase the supply of protein from sustainable sources and the use of insects as animal feed provides a potential alternative to imported protein crops. However, the safety and quality of feed protein from insects - and subsequently the meat and fish fed on such a diet - needs to be assessed.

Safety

A major consideration in the use or applicability of any novel feed product is to demonstrate its safety, in particular if the initial substrate used for its production is a waste product. Information on the safety of the use of insect protein is very scarce in the literature. The safety of insects for food and feed has recently been reviewed (Belluco et al., 2013; van der Spiegel et al., 2013) but little data is available to support risk analysis, particularly for the use of insects as feed where only a small number of safety related studies has been published (e.g. Awoniyi et al., 2004). Only isolated information in relation to the chemical risks of insects has been published (e.g. Diener et al., 2011) with inferences to food/feed use sometimes made.

In the European Union, the use of insects as a source of protein for animal feed is currently prohibited for animals raised for human consumption under regulation EC 999/2001, which prohibits all processed animal protein, with the exception of hydrolysed proteins and in some cases fishmeal, being used in animal feed. A recent amendment to this legislation (EU Regulation 56/2013) allows the use of non-ruminant processed animal protein (PAP) in fish feed. Further proposed amendments, such as the use of non-ruminant PAP (possibly including insects) for feeding to non-ruminants, are currently difficult to implement owing to the lack of a clear method for species origin determination in PAP. It is therefore highly unlikely that insects will be permitted in animal diets until thorough consideration of the safety of their use has been made and diagnostic methods for the detection of processed insect protein in animal feed are available.

A key consideration for feed suppliers is the safety of raw materials and potential risks from the use of insect protein include chemical contaminants, parasites, microbiological threats, allergens and prions. The latter is a particularly emotive area and is epitomised by the bovine spongiform encephalopathy (BSE) or mad cow disease crisis, associated with the feeding of meat and bone meal (MBM) or PAP to ruminants. Whilst there is no evidence to suggest *infective* forms of prion proteins are present in insects, there may be a greater risk that prion protein transmission occurs through the use of meat-containing food waste or slaughterhouse waste as a feed stock for insects, which may then act as disease vectors by retaining residual specified risk materials (SRM), such as undigested spinal cord or brain in their digestive track.

Safety considerations of insect species that can be used in food and feed are species specific. For example, there is an unknown risk that insects will contain natural metabolites or proteins which are toxic to humans or animals when eaten. This may extend beyond known venoms, in, for example, bees and wasps. A safe history of human consumption of several insect species has recently been reported (van Huis et al., 2013).

Current regulations that limit undesirable substances in animal feed are described in EC Directive 2002/32. This covers a range of contaminants and residues including heavy metals, pesticides, veterinary medicines, and environmental contaminants. The potential for insects to bioaccumulate chemical substances and pathogens present in waste streams has yet to be explored to the standards required to fulfil regulatory requirements for the use of insects as food or feed, raising significant concerns about the safe use of insects in the food chain.

The persistence of chemical residues, such as antibiotics and pesticides through the food chain, is of particular concern where, for example, manure or anaerobic digestate is used as feedstock possibly leading to longer term issues such as antibiotic resistance in livestock. The use of food waste as feedstock generates further concerns over microbiological safety and the formation of natural toxins produced during food spoilage such as mycotoxins. Industrial toxins such as dioxins may also be important depending on insect rearing and preservation processes. To some extent, processing insects into a protein meal will reduce the chemical risk of using insects as a protein source for animal feed. For example, highly toxic lipophilic endocrine disruptors such as dioxins could be removed as a potential issue by defatting the insects before feeding.

Research to assess the potential effects of the presence of some metals (cadmium, lead and zinc) and to determine possible bioaccumulation revealed accumulation patterns according to metal type and concentration; cadmium was accumulated, lead suppressed and zinc remained constant (Diener et al., 2011, 2009). In addition, it was observed during field experiments that high concentrations of zinc in the growth substrate led to problems with the fly populations. The authors recommended developing a process that allows separation of heavy metals from prepupae and residue.

There is currently an unknown risk for livestock of allergenic proteins in insects. Tropomyosin, an allergen responsible for shellfish allergy, is also present in many insect species. For example, tropomyosins from house dust mites and cockroach have sequence identities to shellfish tropomyosin of around 80% (Ayuso et al., 2002; Santos et al., 1999). Cross-reactivity of insect proteins to crustacean allergic individuals has been demonstrated (Leung et al., 1996; Reese et al., 1999; Ayuso et al, 2011; Verhoeckx et al., 2013). Whilst this is clearly important in making choices in relation to entomophagy, it is also a major consideration in relation to insects for use as animal feed because allergenic response in farm animals will result in animal welfare concerns, in addition to economic and nutritional implications in relation to, for example, weight gain and meat yield.

Microbiological risks may be effectively managed through the heat and pressure treatments that are already used in the animal feed industry. One persistent concern is Salmonella, which is routinely screened for in animal feed. Other persistent microbiological risks are likely to be viral and may include hepatitis E. Initial data from PROteINSECT has also shown that manure grown fly larvae will carry a high volume of Enterobacter.

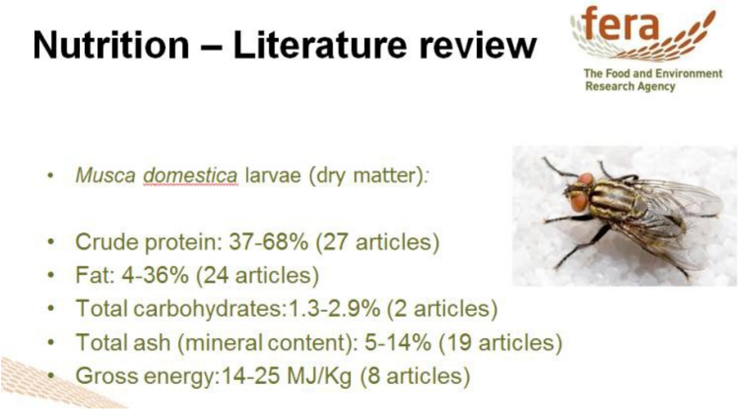
Quality

In animal nutrition, an appropriate available energy and amino acid supply in a balanced diet for efficient protein use by livestock is of critical importance and a high energy to protein ratio is needed to optimise the use of the protein. Different species have different protein requirements and these requirements also differ according to age and growth stage of the animals. The difference between 'essential', 'semi-essential' and 'conditionally indispensable' amino acids in relation to protein inclusion in the diet is also important. The amino acid strengths and weaknesses of today's protein feed ingredients is well known, such as methionine and cysteine limitations in soybean, and the lysine limitation in maize. These are key issues for appropriate protein use and feed formulation. However, amino acid composition revealed by chemical analysis may not correctly identify the availability of these amino acids at tissue level in the animal. The significance of 'ileal digestibility' of amino acids for diet formulation, rather than total amino acid content, is important. Sources of protein for animal feeds are many and varied, with considerable opportunities for further diversification and substitutions in terms of quality and safety. Whilst preliminary studies indicate that insects may be a good source of digestible protein for incorporation into animal feeds, relatively little comprehensive and comparative analysis for suitability for different livestock has been published to date.

The nutritional and economic value of insects in the context of protein substitution is dependent on both the total protein content and the amino acid composition of product. It has been demonstrated that house fly larvae contain relatively high levels of key amino acids such as methionine and lysine providing an economic incentive for the use of insect protein in animal feed. This is particularly evident when the data are compared to plant based materials that are often low in these growth-limiting compounds. Additional nutritional components that may add value to insect products include fats/oils and vitamins & minerals.

At present the scientific literature around the nutritional value of insects for animal feed is dispersed in many papers. Figure 3.1 below summarises the data that could be consolidated from the literature in a sensible way. This highlights the wide diversity in the values reported from the study of just two fly species, with the sources of this variation most likely being the different production methods used and importantly the lack of data from accredited laboratories.

Figure 3.1: A comparison of the reported basic nutritional parameters of the 2 fly species most likely to be used for animal feed a) *M. Domestica* b) *H. illucen*

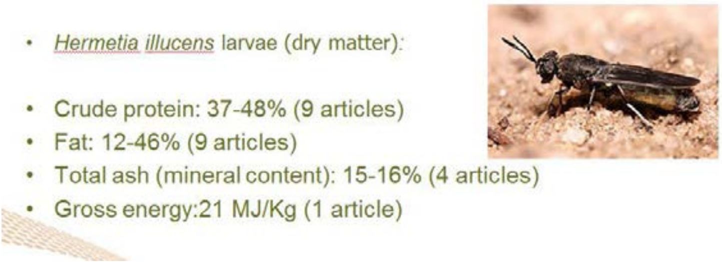


Nutrition – Literature review

fera
The Food and Environment Research Agency

- *Musca domestica* larvae (dry matter):

- Crude protein: 37-68% (27 articles)
- Fat: 4-36% (24 articles)
- Total carbohydrates:1.3-2.9% (2 articles)
- Total ash (mineral content): 5-14% (19 articles)
- Gross energy:14-25 MJ/Kg (8 articles)



- *Hermetia illucens* larvae (dry matter):

- Crude protein: 37-48% (9 articles)
- Fat: 12-46% (9 articles)
- Total ash (mineral content): 15-16% (4 articles)
- Gross energy:21 MJ/Kg (1 article)

There has yet to be a thorough assessment of the quality parameters of meat produced from insect fed livestock. Considerations such as taste, texture, odour and colour may be important factors in determining whether insect fed animals provide high quality meat that can compete with meat produced using conventional feeding regimes. Other parameters such as the fatty acid profiles of the meat/fish will be particularly important in certain sectors e.g. salmon farming.

Session Four Briefing: Life Cycle Analysis

Introduced by Bart Muys - KU Leuven

The largest portion of a product's environmental impacts and costs of manufacturing and use result from decisions taken in the conceptual design phase long before its market entry. To foster sustainable production patterns, an application of Life Cycle Assessment in the very early product development stage, called Life Cycle Design, has proven most effective. The concept of Life Cycle Assessment is based on an evaluation of impacts of products and services over their complete life cycle, i.e. from extraction of raw materials, transport, processing and assembly to distribution, end use, and waste disposal. To address all of sustainability's dimensions, the Work Package 4 (WP4) within PROteINSECT employs different life cycle thinking methodologies including environmental Life Cycle Assessment (Env. LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA).

In order to design sustainable insect production systems that are suitable for adoption by small and large-scale operations in different regions of the world, WP4 examines different pilot-production systems in different biophysical and socio-economic environments. Given the large geographical spread of partners in the PROteINSECT consortium, the WP4 survey spectrum is correspondingly diverse. With a focus on applications of Houseflies [*Musca domestic*] and Black Soldier Flies [*Hermetia illucens*], WP4 surveyed insect pilot-production systems in Europe (Spain), Asia (China) and Africa (Ghana, Mali). The systems under research show variation in production orientation (e.g. application in waste management, production of protein feed for monogastric livestock and aquaculture), substrates (e.g. manure, residues from the food and feed industry), and technological setup, ranging from simple labour intensive process organisation to intensive partially automated production flows. The collected, site-specific biophysical and socio-economic input and output data will be used to build ex-ante modelled industrial scale rearing systems, representative for an associated accommodating environment.

At the current stage of research, we have assessed the driving factors of performance and the environmentally sensitive aspects of two distinguished, up-scaled rearing processes in Spain: the rearing of Houseflies (HF) on fresh and dewatered pig manure and the rearing of Black Soldier Flies (BSF) on brewery waste in function of two different harvesting techniques. For both systems we have assessed the environmental impacts with regards to agricultural land occupation, water use and fossil energy depletion.

Our preliminary research findings served well to identify a number of current process inefficiencies and environmental burdensome production characteristics. Although different in their production orientation, i.e. manure reduction and protein production, the HF systems as well as the BSF systems showed favourable results in terms of their space requirements and considerable improvement potential for heating related energy usage (fossil energy depletion potential) and water consumption. The HF system, designed to facilitate a maximum of pig manure dry matter (DM) reduction, showed a fossil energy depletion potential of 3.0 $kg_{oil\ eq}$ attributed to the reduction of 1 kg DM from fresh manure (fm), respectively 1.7 $kg_{oil\ eq}$ per reduction of 1 kg DM from dewatered manure (dm). The water depletion potential was estimated 31 m^3 (fm) and 57 m^3 (dm). Regarding the space requirements, per kg manure DM reduction the modelled manure treatment systems were estimated to occupy 1.4 m^2yr (fm) and 2.6 m^2yr (dm) agricultural land. The BSF system, designed to facilitate a maximum output of insect (pre-pupa) DM, showed a fossil energy depletion potential of 2,9 $kg_{oil\ eq}$ per kg insect DM assuming a manual harvest (mh) process, respectively 0,6 $kg_{oil\ eq}$ per kg insect DM in conjunction with a semi-automated harvest (sah) process. The water depletion potential per kg insect DM was estimated 9.7 m^3 (mh) and 1.9 m^3 (sah). The space requirements per kg insect DM in the different BSF production models were estimated 0.09 m^2yr (mh) and 0.02 m^2yr (sah).

To lower the fossil energy depletion caused by energy usage and heating requirements, we recommend an application of more efficient heating devices and adequate insulation of the production facilities. To lower the water use we challenge future research to conceive and design alternative cleaning measures and/or rearing vessels with more favourable volume/surface ratio. We also recommend the design of suitable automated separation devices, as manual separation of larvae and residue substrates requires substantial labour input. As the fragmentation of the process went along with cumulative cleaning and labour efforts we also advise to aggregate rearing steps and slenderize the technological setup to benefit from economy of scale effects.

It has been further established that the application potential of these novel manure treatment and protein production concepts is subject to site-specific geographical and socio-economic circumstances. Regions with year-round high temperatures, high density of concentrated animal operations and presence of food processing industry appear most suitable. The geographical context and the utility of the co-products, i.e. residue substrates and insect products, were determined as influential variables to the application potential. However, to find the appropriate point of reference, it requires further research to validate the yet hypothetical utility potential of the co-products.

The results of our studies, applied at the earliest stages of the design of these processes, assist evaluation of the feasibility of such systems and provide guidance for future research and development activities.

References

Awoniyi, T.A.M., Adetuyi, F.C. and Akinyosoye, F.A., 2004. Microbiological investigation of maggot meal stored for use as a livestock feed component. Journal of Food, Agriculture and Environment. 2(3&4):104-106.

Ayuso, R., Grishina, G., Pascal, M.), Sanchez-Garcia, S., Towle, D., Smith, C., Ibanez, M. & Sampson, H. A. (2011) Hemocyanin, Troponin C and Fatty Acid-binding Protein (FABP) May be Cross-reactive Allergens Between Crustaceans, Cockroach and Dust Mites. Journal of Allergy and Clinical Immunology 127 (2) AB235-AB235

Ayuso, R., Lehrer, S.B. and Resse, G. 2002. Identification of continuous, allergenic regions of the major shrimp allergen Pen a 1 (tropomyosin) International Archives of Allergy and Immunology 127(1): 27-37.

Belluco, S., Losasso, M., Alonzi, C.C., Paoletti, M.G. and Ricci, A., 2013. Edible insects in a food safety and nutritional perspective: A critical review. Comprehensive Reviews in Food Science and Food Safety 12: 296-313.

Bondari. K and Sheppard D.C., 1987. Soldier fly, Hermetia illucens L., larvae as feed for channel catfish, Ictalurus punctatus (Rafinesque), and blue tilapia, Oreochromis aureus (Steindachner). Aquaculture and Fisheries Management 18: 209-220.

Cassidy, E.S., West, P.C., Gerber, J.S. and Foley, J.A. 2013. Redefining agricultural yields: from tonnes to people nourished per hectare. Environmental Research Letters 8: 034015.

Chapagain, A.K. and Hoekstra, A.Y. 2003. Virtual water flows between nations in relation to trade in livestock and livestock products. UNESCO Institute for Water Education Research Report Series No. 13 202pp.

Diener, S., Zurbrugg, C., Gutierrez, F. R., Nguyen, D. H., Morel, A., Koottatep, T. and Tockner, K. 2011. Proceedings of the WasteSafe 2011 – 2nd International Conference on Solid Waste Management in the Developing Countries 13-15 February 2011, Khulna, Bangladesh.

Diener, S., Zurbrügg, C., Tockner, K., 2009. Conversion of organic material by black soldier fly larvae – Establishing optimal feeding rates. Waste Management & Research, 27, 603-610.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D. and Zaks, D.P.M. 2011. Solutions for a cultivated planet. Nature 478: 337-342.

Häusling, M. 2011. The EU protein deficit: what solution for a long-standing problem? (2010/1111(INI)). European Parliament A7-0026/2011 17pp.

Leung, P.S., Chow, W.K., Duffey, S., Kwan, H.S., Gershwin, M.E. & Chu, K.H. (1996) IgE reactivity against a cross-reactive allergen in crustacea and mollusca: evidence for tropomyosin as the common allergen. J. Allergy Clin. Immunol. 98(5:1), 954-61.

Newton, L., Sheppard, C., Watson, D.W., Burtle, G and Dove, R. 2005. Using the black soldier fly, Hermetia illucens, as a value added tool for the management of swine manure. Unpublished report, available at: http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase2report05/cd,web%20files

/A2.pdf. Hem, S. et al., 2008. Bioconversion of palm kernel meal for aquaculture: Experiences from the forest region (Republic of Guinea). African Journal of Biotechnology 7: 1192-1198.

Pimentel, D. and Pimentel M. 2003. Sustainability of meat-based and plant-based diets and the environment American Journal of Clinical Nutrition 78: 660S-3S.

Reese, G., Ayuso, R. & Lehrer S.B. (1999) Tropomyosin: An Invertebrate Pan–Allergen. Int. Arch. Allergy Immunol. 119:247–258.

Santos, A.B., Chapman, M.D., Aalberse, R.C., Valles, L.D., Ferriani, V.P., Oliver, C., Rizzo, M.C., Naspitz, C.K. and Arruda, L.K. 1999. Cockroach allergens and asthma in Brazil: identification of tropomyosin as a major allergen with potential cross-reactivity with mite and shrimp allergens. J. Allergy Clin. Immunol. 104 (2) 329-337.

Van der Spiegel, M., Noordam, M.Y. and van der Fels-Klerx, H.J. 2013. Safety of novel protein sources (insects, microalgae, seaweed, duckweed and rapeseed) and legislative aspects for their application in food and feed production. Comprehensive Reviews in Food Science and Food Safety 12: 662-678.

van Huis, A., 2013. Potential of insects as food and feed in assuring food security. Annual Review of Entomology 58: 563-583.

van Huis, A., van Itterbeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G. and Vantomme, P., 2013. Edible insects future prospects for food and feed security. FAO Forestry Paper 171.

Verhoeckx, K. C. M., van Broekhoven, S., Broekman, H.C.H.P., Jager, C. F. den Hartog, Gaspari, M., de Jong Govardus A. H, Wichers, H., van Hoffen, E., Houben, G. F. & Knulst, A. C. (2013) Are house dust mite or shellfish allergic patients at risk when consuming food containing mealworm proteins. Toxicology Letters 221, S119-S120.

Appendix Three

Round Table Attendees

PROteINSECT Round Table 14th November, Brussels

Attendees List

Organisation represented	**Named Attendee**	**Role**
PROteINSECT Project	Elaine FITCHES (Food and Environment Research Agency)	Co-Chair & Presenter
Independent consultant	Emile FRISON	Co-Chair
PROteINSECT Project	Geert BRUGGEMAN (Nutrition Sciences)	Presenter
PROteINSECT Project	Adrian CHARLTON (Food and Environment Research Agency)	Presenter
PROteINSECT Project	Bart MUYS (KU Leuven)	Presenter
Minerva Communications UK Ltd	Edward BARNES	Event management
Minerva Communications UK Ltd	Rhonda SMITH	Event Sponsor
Minerva Communications UK Ltd	Rosie PRYOR	Rapporteur
European Federation of Animal Science	Nils Th. GRABOWSKI (Hannover University of Veterinary Medicine)	Contributor
European Reference Laboratory for Animal Proteins (EURL-AP)	Frederic DEBODE	Contributor
European Feed Manufacturers' Federation (FEFAC) and European Aquaculture Technology and Innovation Platform (EATiP)	Ole CHRISTENSEN (Biomar)	Contributor
Waste & Resources Action Programme (Wrap)	Nina SWEET	Contributor
International Producers of Insects for Food and Feed (IPIFF)	Kees AARTS (Protix Biosystems B.V.)	Contributor
European Supermarket	Hans-Juergen MATERN, (Metro Group)	Contributor
World Wildlife Fund (WWF)	Erik GERRITSEN (WWF Europe)	Contributor
European Commission - Directorate General for Health and Consumers (DG SANCO)	Wolfgang TRUNK	Contributor
Association of Poultry Processors and Poultry Trade in the EU (a.v.e.c.)	Cees VERMEEREN	Contributor
European Aquaculture Society	Margriet DROUILLON (Ghent University)	Contributor

European Rural Poultry Association	Catherine DIEMER	Contributor by correspondence
Copa – Cogeca	Javier VALLE	Contributor by correspondence
Belgian Compound Feed Industry Association (Bemefa)	Liesbeth VERHEYEN	Contributor by correspondence
European Food Safety Authority (EFSA)	Qasim CHAUDHRY (Food and Environment Research Agency)	Contributor by correspondence
Food Standards Agency (UK)	Ray SMITH	Contributor by correspondence

Appendix Four

Round Table Session One to Four Presentations

Session One	Production
Session Two	Processing
Session Three	Quality & Safety
Session Four	Life Cycle Analysis

PROteINSECT
INSECTS AS A SUSTAINABLE SOURCE OF PROTEIN
www.proteinsect.eu

Safe and Sustainable Utilisation of Protein from Insects for Animal Feed

Round Table 14th Nov. 2014

Elaine Fitches: elaine.fitches@fera.gsi.gov.uk

The Protein Deficit

EU initiative to find sustainable protein sources

- Currently < 30% self-sufficient

  - Land-use i.e. food crops vs feed crops
  - Global feed markets volatile
  - EU reliance on imported soya
  - Global consumption of meat rising

Alternative protein sources required.

Can Insects be part of the solution ?

- Insects highly efficient in the rapid conversion of waste into biomass

  e.g. housefly larvae can complete development in 7-10 days at room temperature with 60 % reduction in substrate mass

- Protein digestibility (86-89%) higher than most vegetable based proteins

  Insects have been shown to be an excellent source of protein for monogastrics, fish and shrimp.

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

Land Use

<u>Protein crops (e.g. soya)</u>

2.5 t/ha./year

90% dry wt & 40 % crude protein = <u>0.9 t protein</u>

<u>Fly larvae potential (non-optimised)</u>

25 t/ha./8-10 days = 1000 t/ha./year.

25% dry wt & 60 % protein = <u>150 t protein</u>

<u>200</u> fold reduction in land use

- Value of product ?
- Cost of production ?
- Safety/legislation ?

<u>2013 values</u>

Insect Production - Global Research

Primary focus on fly species able to develop on a range of waste substrates

Black soldier fly *Hermetia illuscens*

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

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

South Africa

- Established 2009
- First industrial scale factory established 2014
- Producing 800 kg wet wt larvae per day (approx. 100 kg protein)
- Goal 7 tonnes MagMeal™, 3 tonnes MagOil™, 20 tonnes MagSoil™ per day by October 2015
- Committed to 10 more sites by 2020
- House-fly and Black Soldier Fly
- Substrates: “clean” organics, vegetable food processing & restaurant waste

Enterra
Feed Corporation

Canada

Feed Products:
Grubbinz™ - dried whole insects: feed supplement for birds, fish, reptiles and amphibians
Enterra Feed Meal™ - 65% protein,15% oil substitute for fishmeal in fish and poultry feed

Fertiliser Product:
Enterra Natural Fertilizer™ - soil conditioner for agriculture, horticulture, greenhouse & home

Bottleneck to production capacity is supply of waste/substrate

Europe

Spain

Universidad de Alicante

bioflytech

Netherlands

PROTIX Biosystems BV

KOPPERT BIOLOGICAL SYSTEMS

Germany

Hermetia

France

Ynsect

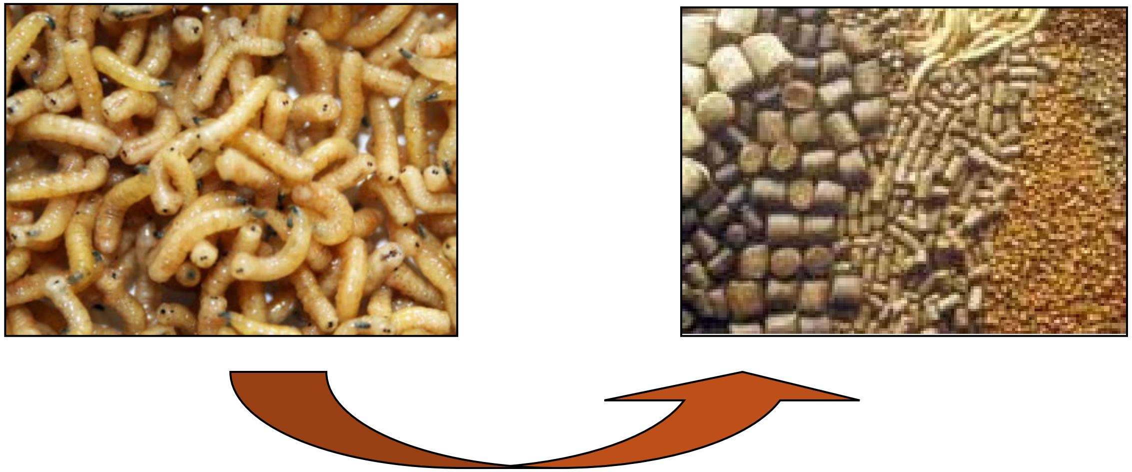
Development of this industry is constrained by EU legislation that currently prohibits the use of insects in animal feed.

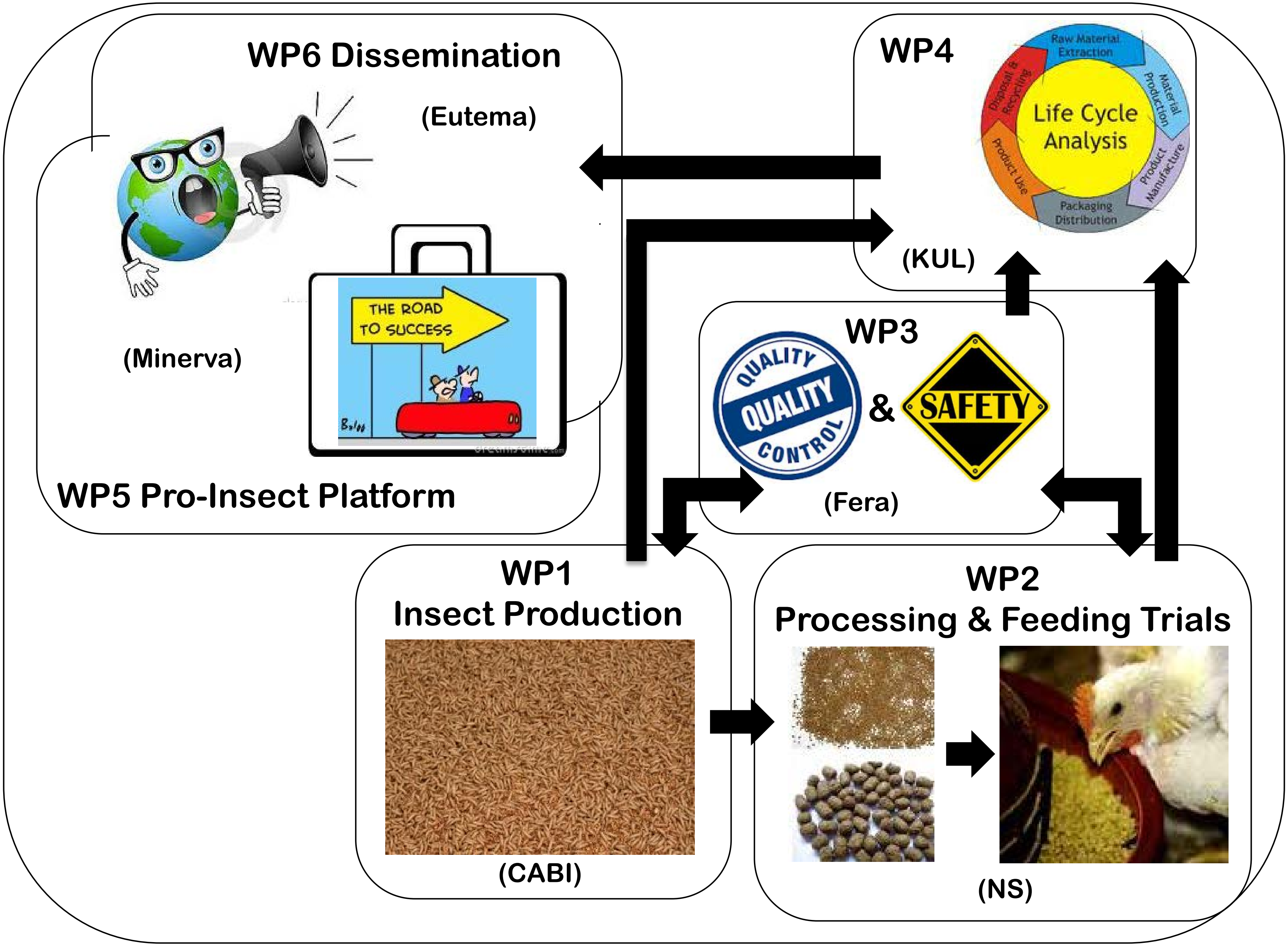
PROteINSECT

INSECTS AS A SUSTAINABLE SOURCE OF PROTEIN

www.proteinsect.eu

Enabling the Exploitation of Insects as a Sustainable Source of Protein for Animal Feed and Human Nutrition




WP6 Dissemination
(Eutema)
WP4
Raw Material Extraction
Material Production
Product Manufacture
Packaging Distribution
Product Use
Disposal & Recycling
Life Cycle Analysis
(KUL)
THE ROAD TO SUCCESS
(Minerva)
WP3
QUALITY
QUALITY CONTROL
&
SAFETY
(Fera)
WP5 Pro-Insect Platform
WP1
Insect Production
(CABI)
WP2
Processing & Feeding Trials
(NS)

Insect Production: Work Package 1

SUBSTRATE

ORGANIC WASTES
principally MANURES

INSECTS

House fly

Black soldier fly

Objective

To optimize existing, and develop new fly breeding methods for animal feed production, in the EU, China, Ghana and Mali, considering efficiency, energy use and residual flows.

Insect Production Systems: local to pilot scale

Africa

Mali

Natural oviposition
Production: 20 – 80 kg wet wt. larvae/ week

Ghana

Production system small (scaleable) & labour intensive. Production: 25 kg wet wt. larvae/week

China

Huazong Agric. Univ. (Central China)

Pit system. Production: 50-80 kg wet wt. of house-fly larvae or 50-100 kg wet wt. of blowfly larvae/ week.

Southern China

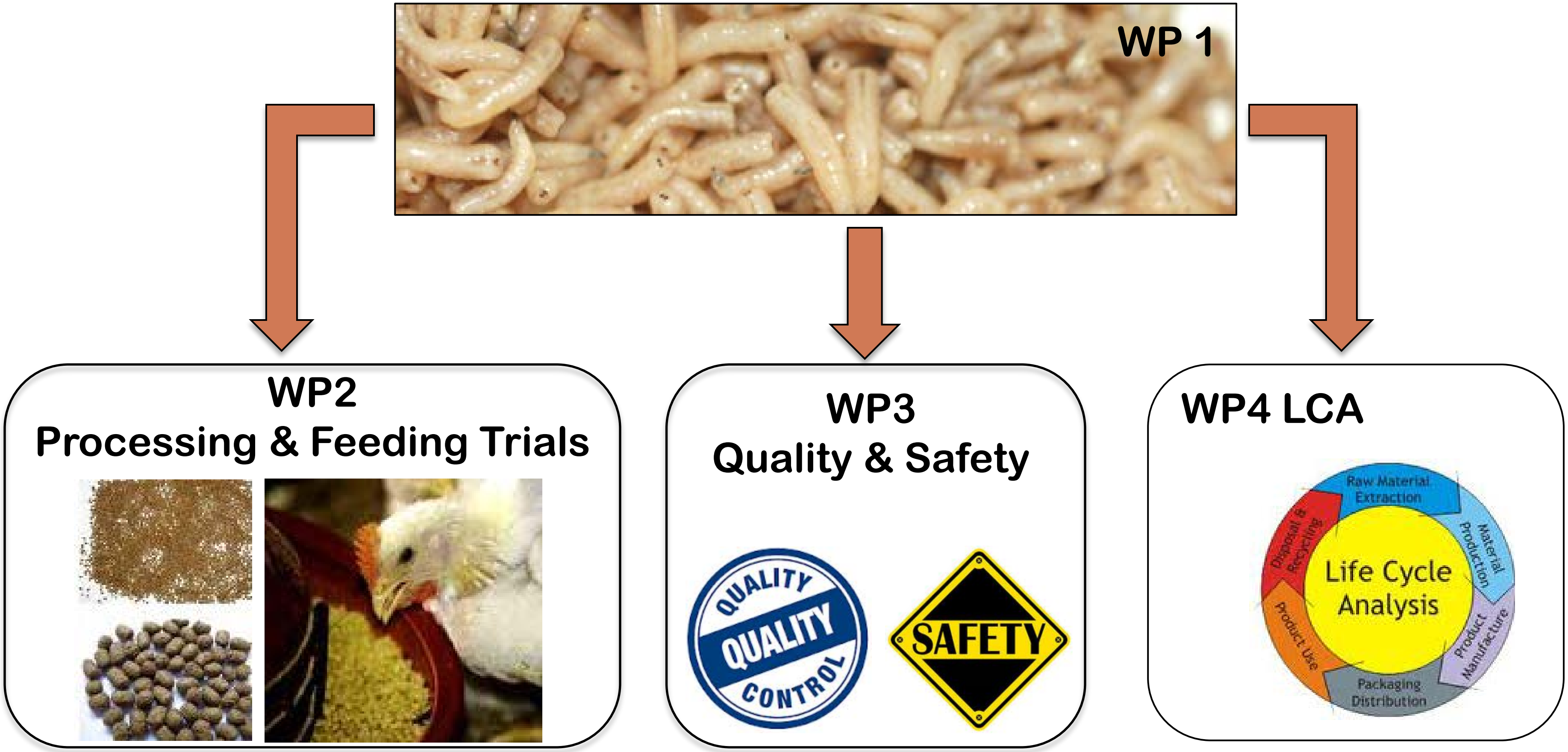
Guangdong
Entomological Institute
广东省昆虫研究所

Scaleable, semi-automated,
Produces 200 kg wet wt. of
house-fly larvae per week.

Europe: UK maggot farm

Production labour intensive but scaleable
40-50 kg wet weight larvae/week

Key output:
Supply of insect material and data to other partners



WP 1

WP2
Processing & Feeding Trials

WP3
Quality & Safety

WP4 LCA

PROteINSECT
INSECTS AS A SUSTAINABLE SOURCE OF PROTEIN
www.proteinsect.eu

Common themes:

Opportunities

- Successful establishment of new production systems in all cases but requires "know-how" and/or entomologists
- Real potential for impact in areas of subsistence farming (eg. Mali)
- Potential for impact in Europe (subject to legislation)

Challenges

- Labour intensive: automation necessary for economic viability in larger scale set ups (includes China)
- Variability in productivity due to variation in substrate quality

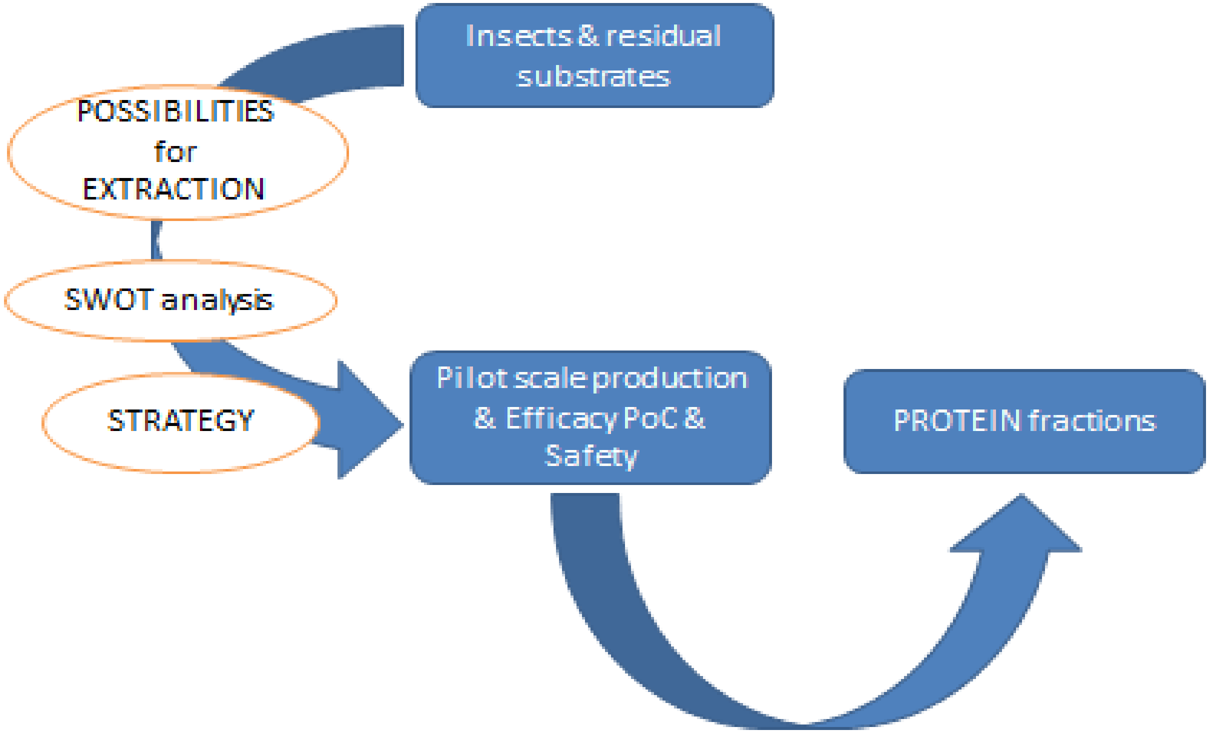
BRIEFING

Geert Bruggeman

PROTEIN PROCESSING

PROteINSECT
INSECTS AS A SUSTAINABLE SOURCE OF PROTEIN

Protein Development Plan



Insects & residual substrates

POSSIBILITIES for EXTRACTION

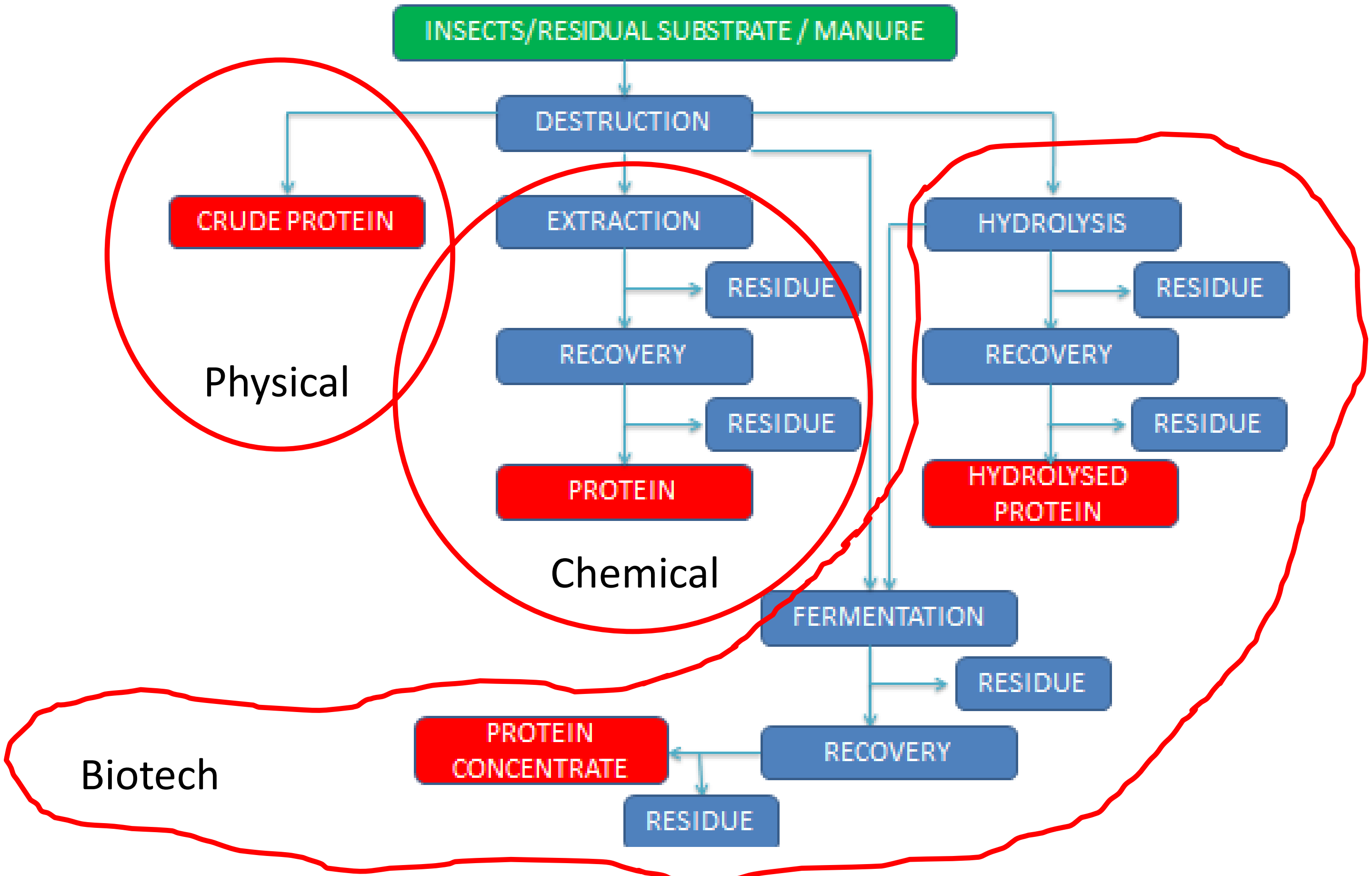
SWOT analysis

STRATEGY

Pilot scale production & Efficacy PoC & Safety

PROTEIN fractions

Scheme for protein isolation & upgrading



Main conclusion for physical approach

APPROACH/PRIOTITY N°
1 Mechanical destruction
2 Sieving/filtration (possibly after mechanical destruction)
3 Temperature/(sun)drying

VS

Main conclusion for chemical approach

APPROACH/PRIORITY N°
1 Water
2 Salting in
2bis Temperature
3 Selective adsorption
4 pH (both extraction and hydrolysis)
4bis Solvents

Main conclusion for biotechnological approach

APPROACH/PRIORITY N°
1 Enzymes (+ catalyst)
2 Lactic Acid Bacteria
3 Yeast

Main conclusion for downstream processing

DOWNSTREAM PROCESSING

(after chemical and biotechnological approaches)

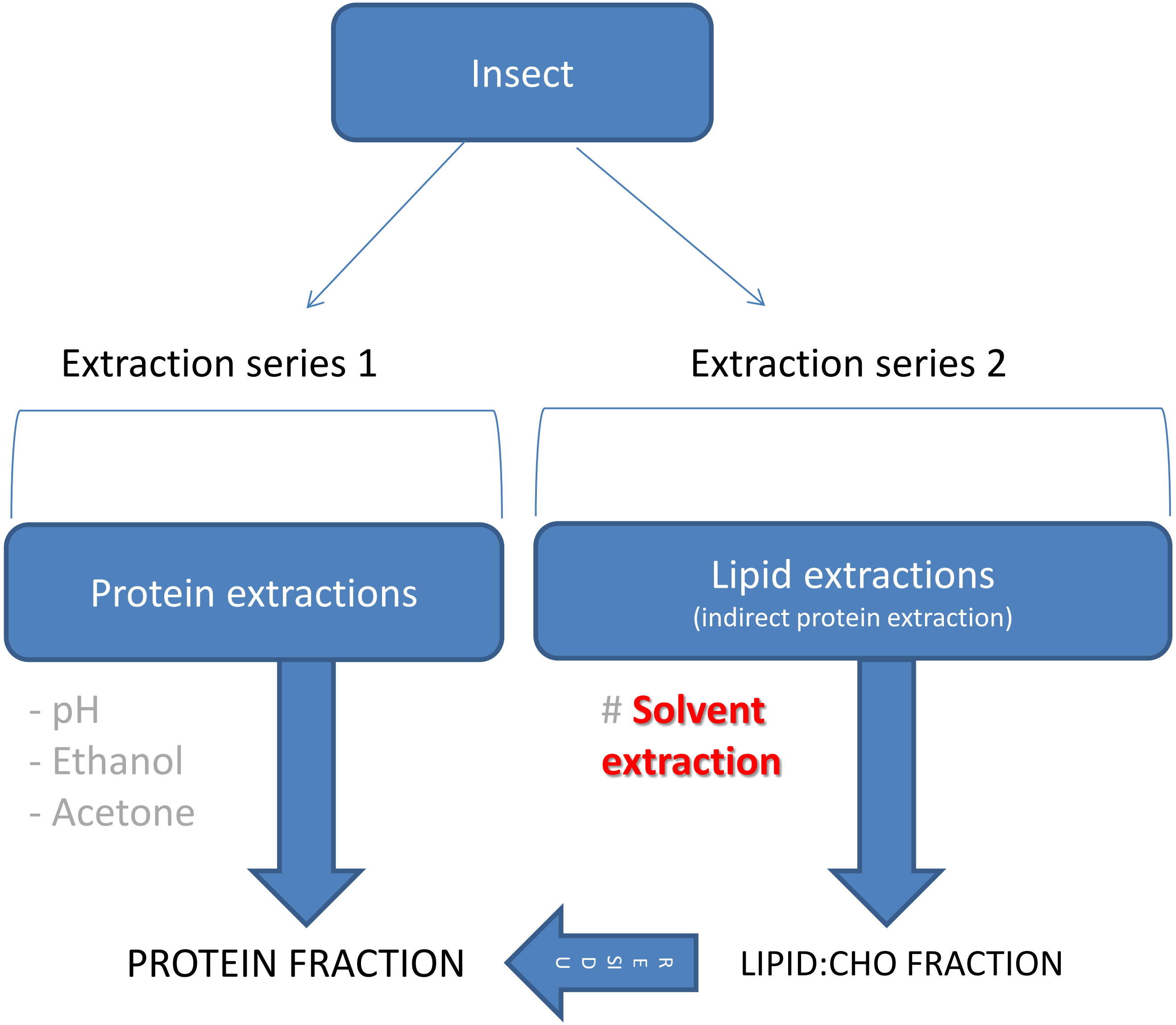
Centrifugation

↓

OPTIONAL: precipitation

↓

(air)drying, conservation agent



Insect

Extraction series 1

Extraction series 2

Protein extractions

- pH
- Ethanol
- Acetone

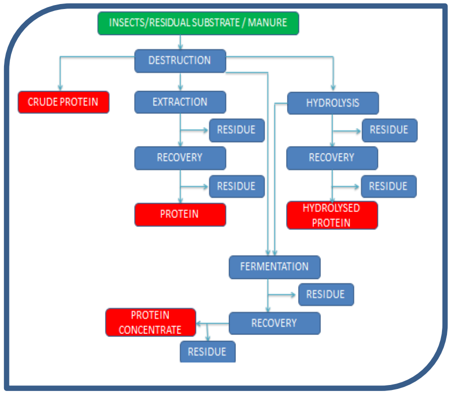
Lipid extractions
(indirect protein extraction)

Solvent extraction

PROTEIN FRACTION

RESIDU

LIPID:CHO FRACTION



INSECTS
from
PARTNERS

INSECT

Grinding

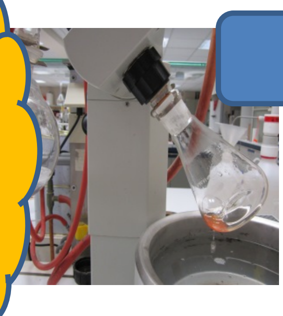
Solvent extraction

Filtration/centrifugation

Solvent fraction

Evaporation

Residue 2



FAT

Residue 1

PROTEIN + FIBRE

Enzyme + solvent

HYDROLYSATE

AA

chitine

FIBRE

Challenges / Opportunities

- Animal welfare issues. Suitable killing protocol for insects before extraction.
- Designing generic processing technologies for larvae of different insect species (preferentially already allowed in feed and food applications).
- Toxicity issues on co-extracted chitin. This will be the basis for further biotechnological processing methods, based on fermentation and enzymatic treatments.
- The presence of parasites on larvae, influencing safety of extracted insect protein.
- Solvent residues in protein extract, increasing the pressure for looking for alternatives and more sustainable solutions for solvent extraction.
- Residual substrates in the gastrointestinal tract and on the surface of insect larvae, in case of contaminated substrates for insect growing.

Q&A

Geert Bruggeman

PROTEIN PROCESSING

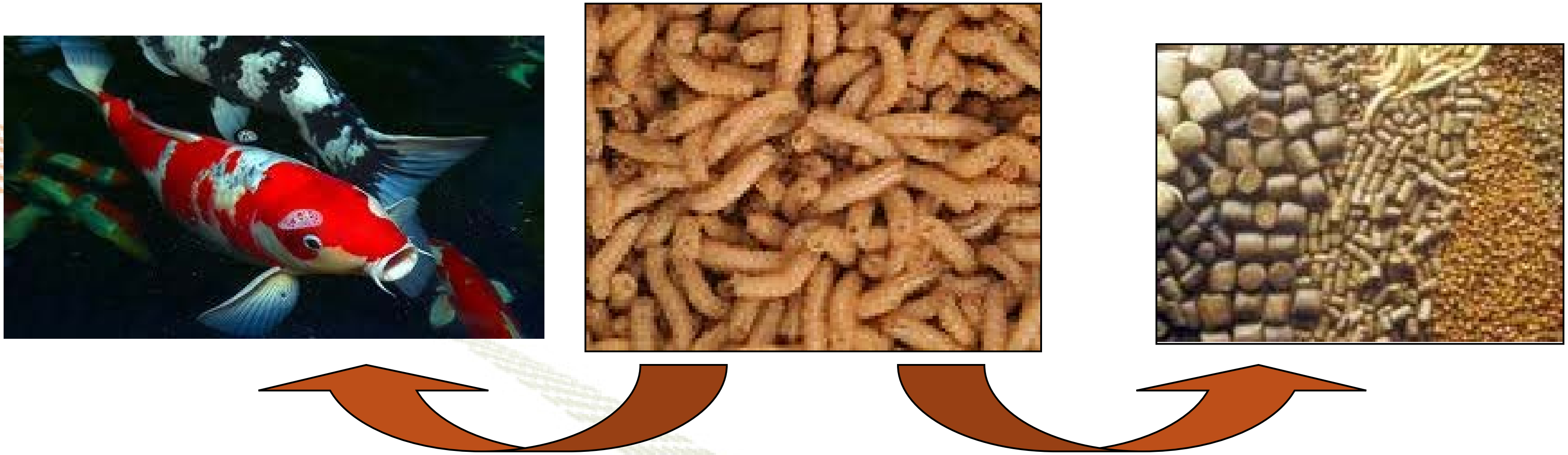
fera

The Food and Environment
Research Agency

Insects for Food and Feed: Examining the Safety and Quality Considerations

Dr Adrian Charlton

adrian.charlton@fera.gsi.gov.uk



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.

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 **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).

EU regulations in feed range from 0.5 to 5 ppm.

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

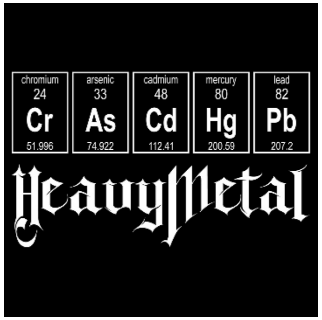


Image courtesy of www.angrygirlwear.com

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

The Food and Environment Research Agency

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

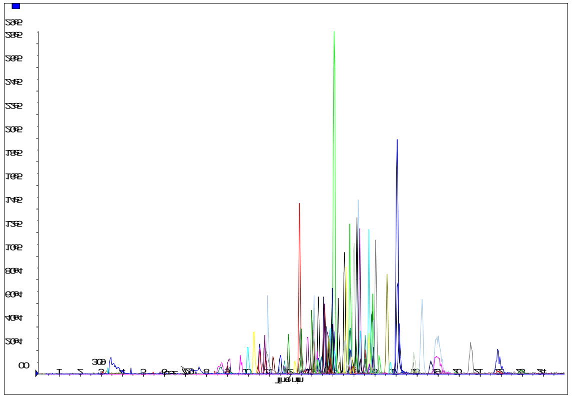
- Natural plant toxins – risk if rearing on food waste as produced by fungus.
- Aflatoxin B1 has 5 ppb regulatory limit 2002/32/EC.
- Fumonisins, deoxynivalenol, T2 toxins, Ochratoxin A and Zearalenone all with recommended limits between 50 and 5000 ppb.

Non-targeted Profiling

The Food and Environment Research Agency

- 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).



Shellfish toxins cause paralysis at very low levels of exposure

Microbiological Safety

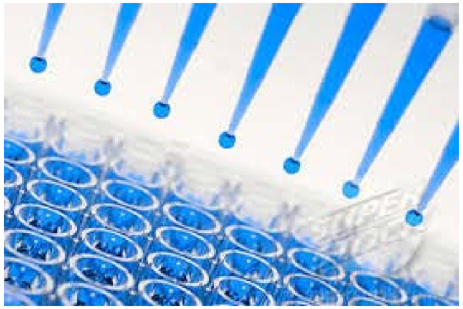
- Feedstock and insect species dependant. Potentially managed through processing e.g. heat, pressure.

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

Allergenicity

- Assessment of allergenicity in animals during feeding trials:
  - monitor **symptoms**, e.g., scratching, watery eyes
  - measure **IgE levels**: antibodies produced upon exposure to allergen.

Wikimedia.org



Resolvingimages.com

Nutrition & Quality

- Nutritional profiles of insects for designing feeding trials.
- Product quality parameters may include e.g. taints in meat from animals reared on insect based diets.

Nutrition – Literature review

- *Musca domestica* larvae (dry matter)*:*

- Crude protein: 37-68% (27 articles)
- Fat: 4-36% (24 articles)
- Total carbohydrates:1.3-2.9% (2 articles)
- Total ash (mineral content): 5-14% (19 articles)
- Gross energy:14-25 MJ/Kg (8 articles)

Nutrition – Literature review

- *Hermetia illucens* larvae (dry matter)*:*

- Crude protein: 37-48% (9 articles)
- Fat: 12-46% (9 articles)
- Total ash (mineral content): 15-16% (4 articles)
- Gross energy:21 MJ/Kg (1 article)

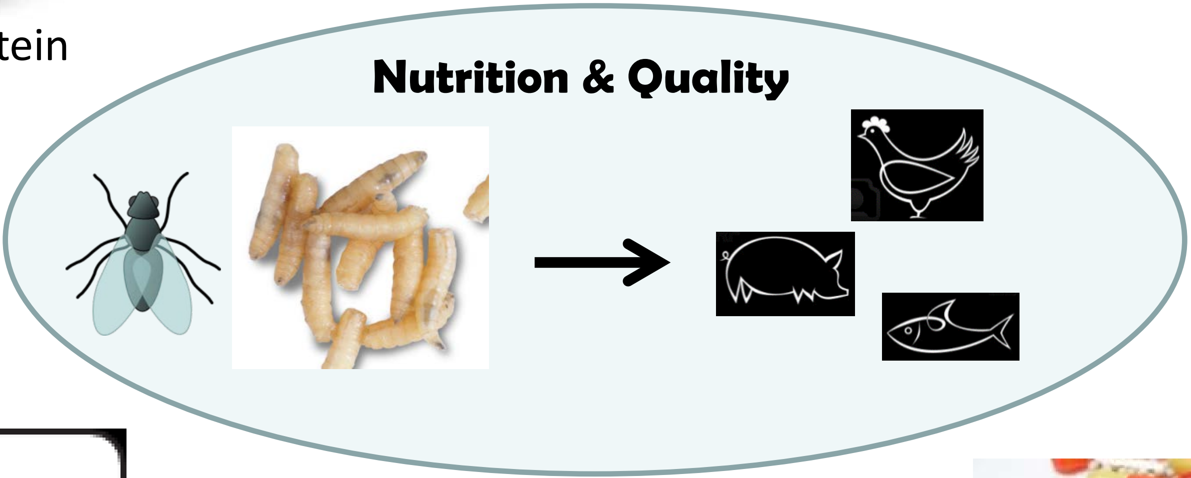
Added Value

- Investigate potential use of waste and by-products.
- Current insect products include chitin/chitosan and shellac.
- Insect oils may have value as fuel/lubricants.
- Insect manures as fertilisers?

Refined protein

Animal Feed

By-products



Nutrition & Quality

Oils & Fuels

Cosmetics & pigments

Bioactives

Summary

The Food and Environment
Research Agency

- 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 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.

The research leading to these results has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n° [312084].

PROteINSECT KEY OPINION LEADERS Round Table

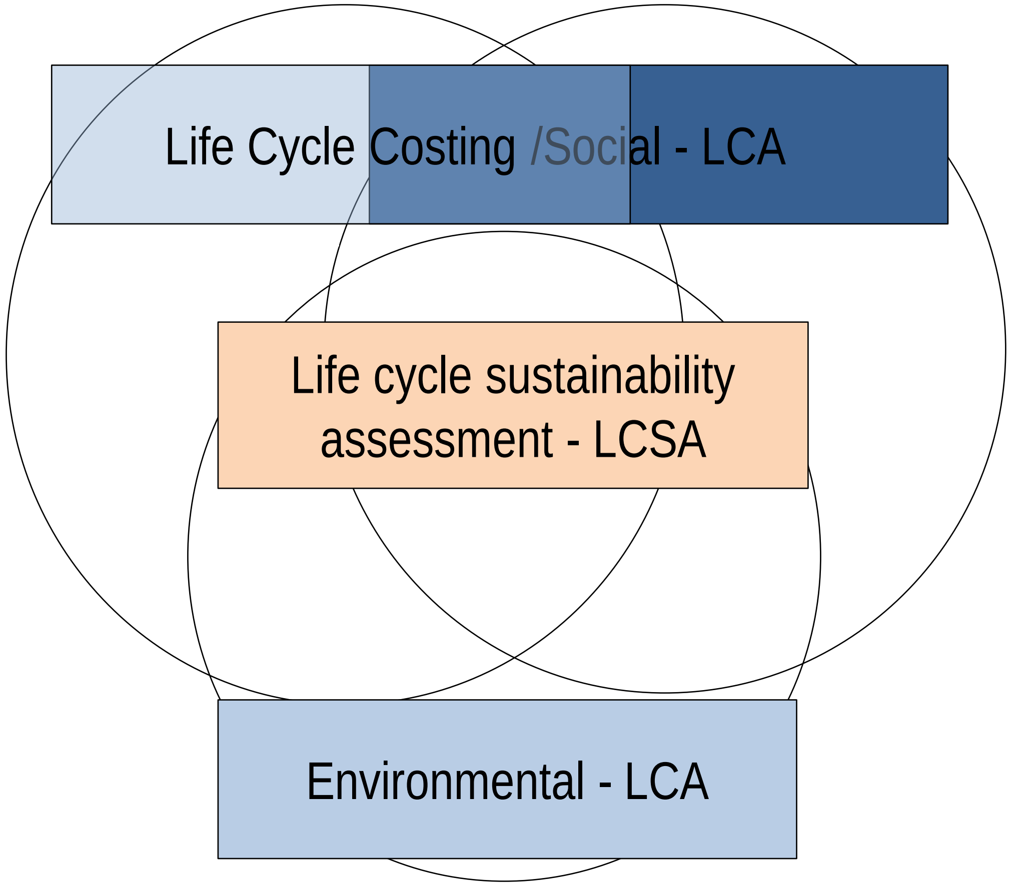
WP4: ENVIRONMENTAL, SOCIAL AND ECONOMIC LIFE CYCLE ASSESSMENT

Bart MUYS & Martin ROFFEIS
KU Leuven

Brussels 13/11/2014

PROteINSECT Life Cycle Design (WP4)

Life Cycle (LC) thinking tools tailored for sustainability's three dimensions



Life Cycle Costing /Social - LCA

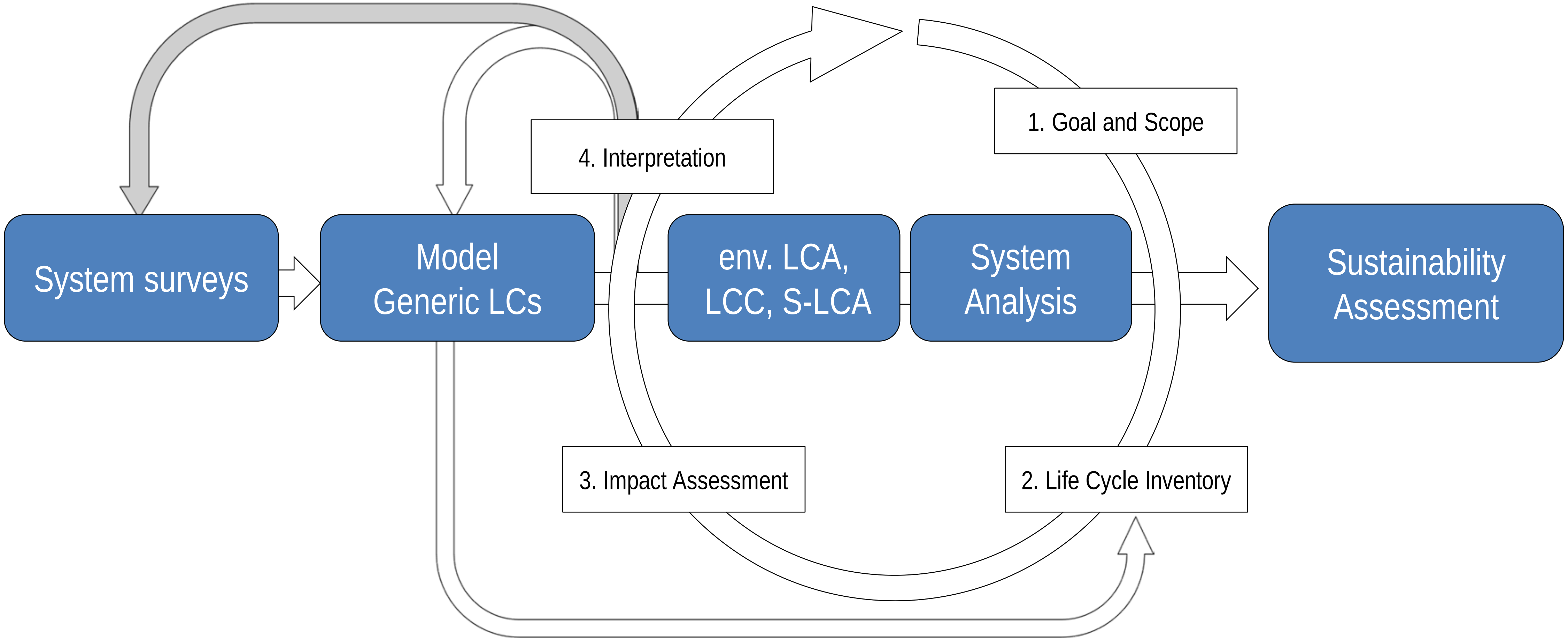
Life cycle sustainability assessment - LCSA

Environmental - LCA

- Assess environmental, social and economic life cycle impacts of insect based animal feed production in design stage
- Analyze ex-ante generic life cycle impact of different scaled-up production scenarios
- Analyze trade-offs, identify optimization options, formulate recommendations
- Compare life cycle impacts of insect based feed production with conventional feeds.

RESEARCH APPROACH

Sequence of operational phases within LC design



System surveys

Model Generic LCs

env. LCA, LCC, S-LCA

System Analysis

Sustainability Assessment

1. Goal and Scope

2. Life Cycle Inventory

3. Impact Assessment

4. Interpretation

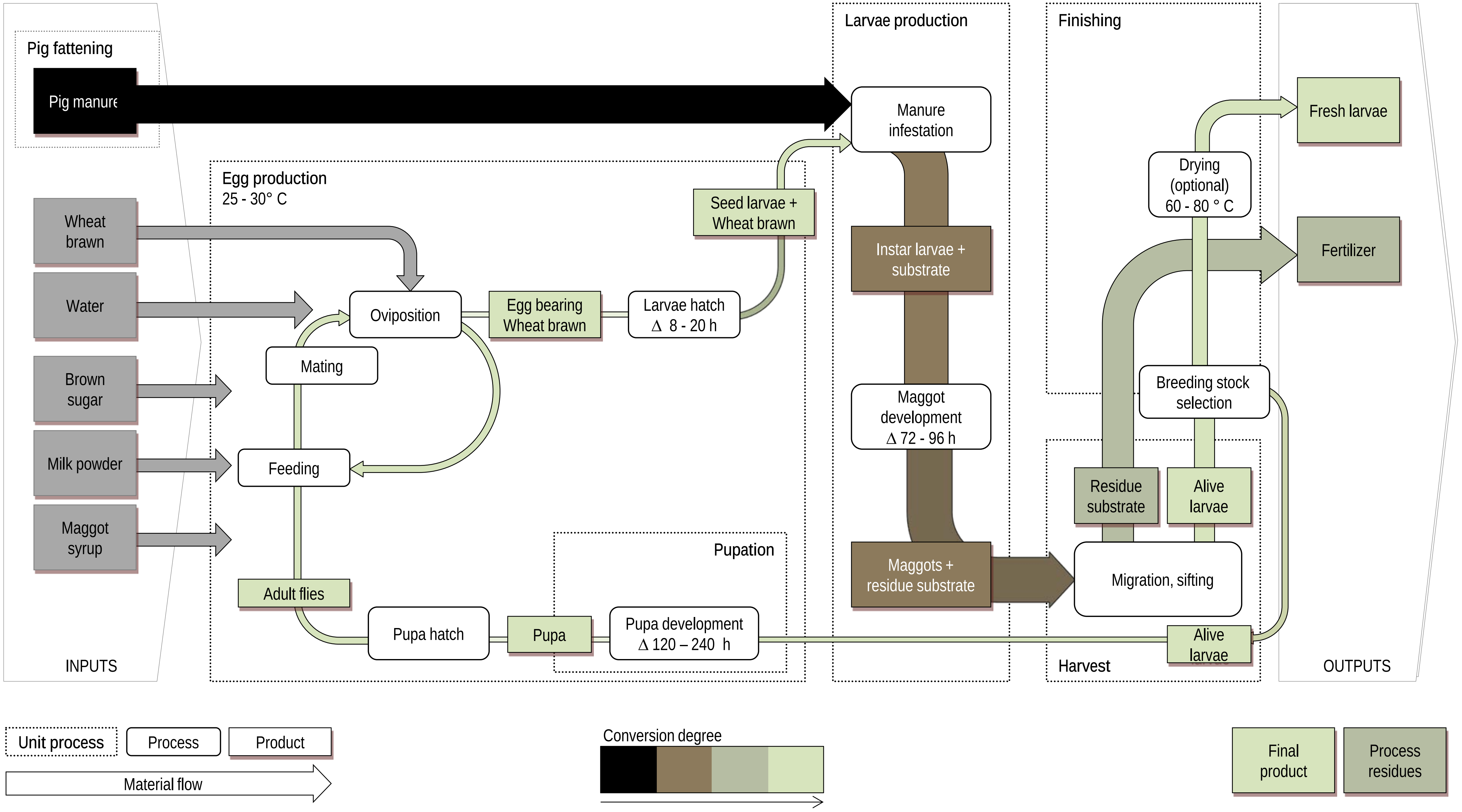
CASE STUDIES

SURVEY SCOPE

- Global survey scope: China, Mali, Ghana, UK, Spain
- Utilization of dipteran fly species: *Hermetia illucens* [BSF] and *Musca domestica* [HF]
- Different system orientation, i.e. waste management vs. insect-derived feed
- Application potential of insect products as feed for monogastric animals and aquaculture
- Various rearing substrates, e.g. manure, feed and food processing residues
- Different scales of production

PRELIMINARY RESULTS

Small scale, production system in China - unit processes and fundamental material flows House fly [*Musca domestica*] reared on fresh pig manure (#subsistence system)



INPUTS

Pig fattening

Pig manure

Wheat brawn

Water

Brown sugar

Milk powder

Maggot syrup

Egg production
25 - 30° C

Oviposition

Egg bearing Wheat brawn

Larvae hatch
∆ 8 - 20 h

Seed larvae + Wheat brawn

Mating

Feeding

Adult flies

Pupation

Pupa hatch

Pupa

Pupa development
∆ 120 – 240 h

Larvae production

Manure infestation

Instar larvae + substrate

Maggot development
∆ 72 - 96 h

Maggots + residue substrate

Finishing

Drying (optional)
60 - 80 ° C

Breeding stock selection

Harvest

Residue substrate

Alive larvae

Migration, sifting

Alive larvae

OUTPUTS

Fresh larvae

Fertilizer

Unit process

Process

Product

Material flow

Conversion degree

Final product

Process residues

PRELIMINARY RESULTS

Small scale, subsistence production system in China - conclusions and recommendations

CONCLUSIONS:

- Adult rearing and egg production unit processes result in significant environmental impacts
- Impact on “Human Health” and “Resources” is largely explained by electricity use for heating installations
- Pig manure, being a traded good in the particular region, partitions to the environmental load of the insect product (economic allocation)

RECOMMENDATIONS:

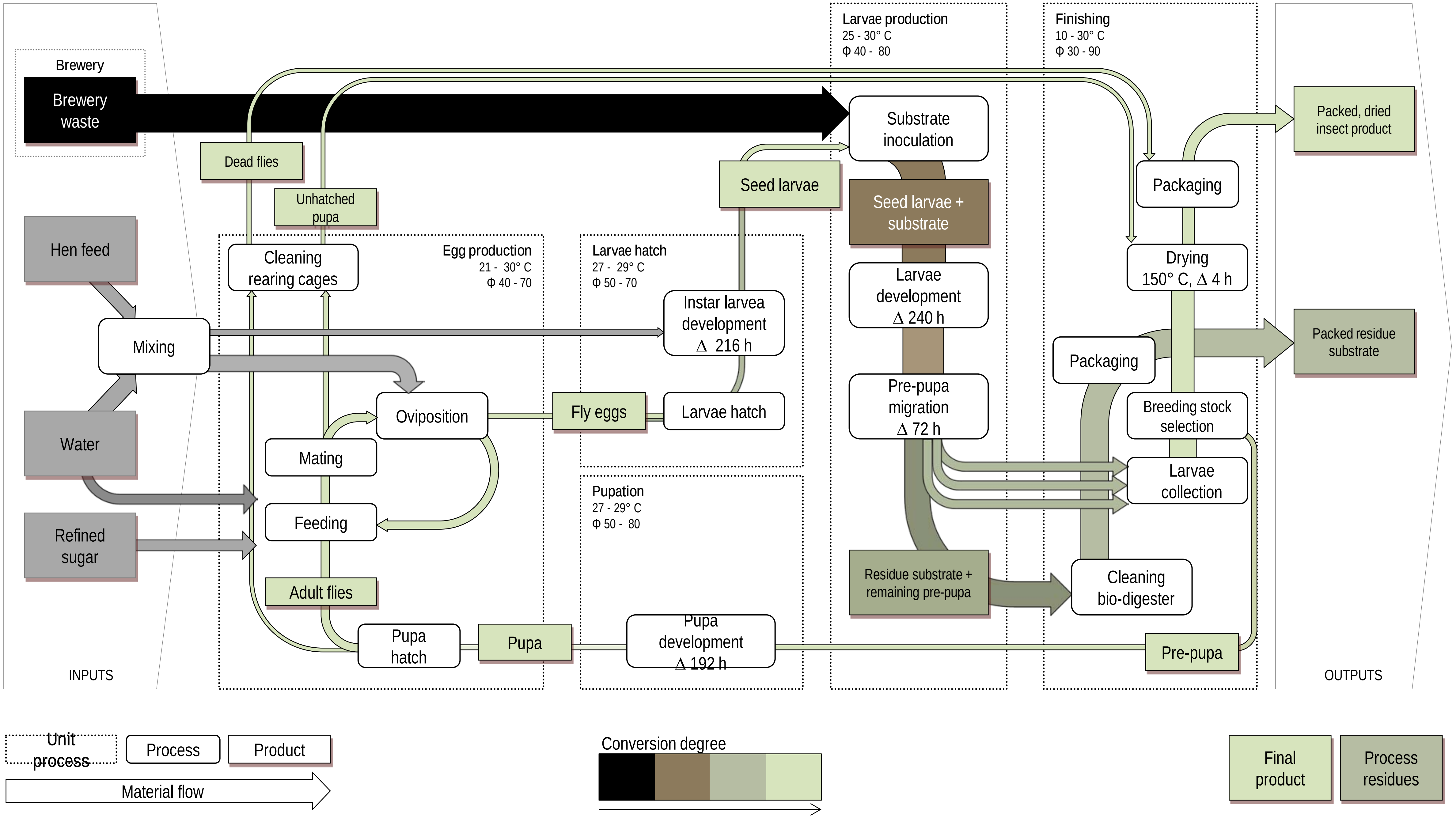
- Apply efficient insulation in building structure
- Employ more efficient heating devices, e.g. natural-gas heating systems
- Research the availability and application potential of less valuable rearing substrates in region under research

Universitat d'Alacant
Universidad de Alicante

PRELIMINARY RESULTS

Pilot-scale production system (Alicante, Spain) - unit processes and fundamental material flows

Black Soldier Fly [*Hermetia illucens*] reared on brewery waste (#semi-automated harvest)



INPUTS

Brewery
Brewery waste

Hen feed
Mixing
Water
Refined sugar

Dead flies
Unhatched pupa

Egg production
21 - 30° C
Φ 40 - 70

Cleaning rearing cages
Oviposition
Mating
Feeding
Adult flies
Pupa hatch
Pupa

Larvae hatch
27 - 29° C
Φ 50 - 70

Instar larvea development
Δ 216 h
Fly eggs
Larvae hatch

Pupation
27 - 29° C
Φ 50 - 80

Pupa development
Δ 192 h

Larvae production
25 - 30° C
Φ 40 - 80

Substrate inoculation
Seed larvae
Seed larvae + substrate
Larvae development
Δ 240 h
Pre-pupa migration
Δ 72 h
Residue substrate + remaining pre-pupa

Finishing
10 - 30° C
Φ 30 - 90

Packaging
Drying
150° C, Δ 4 h
Packaging
Breeding stock selection
Larvae collection
Cleaning bio-digester
Pre-pupa

OUTPUTS

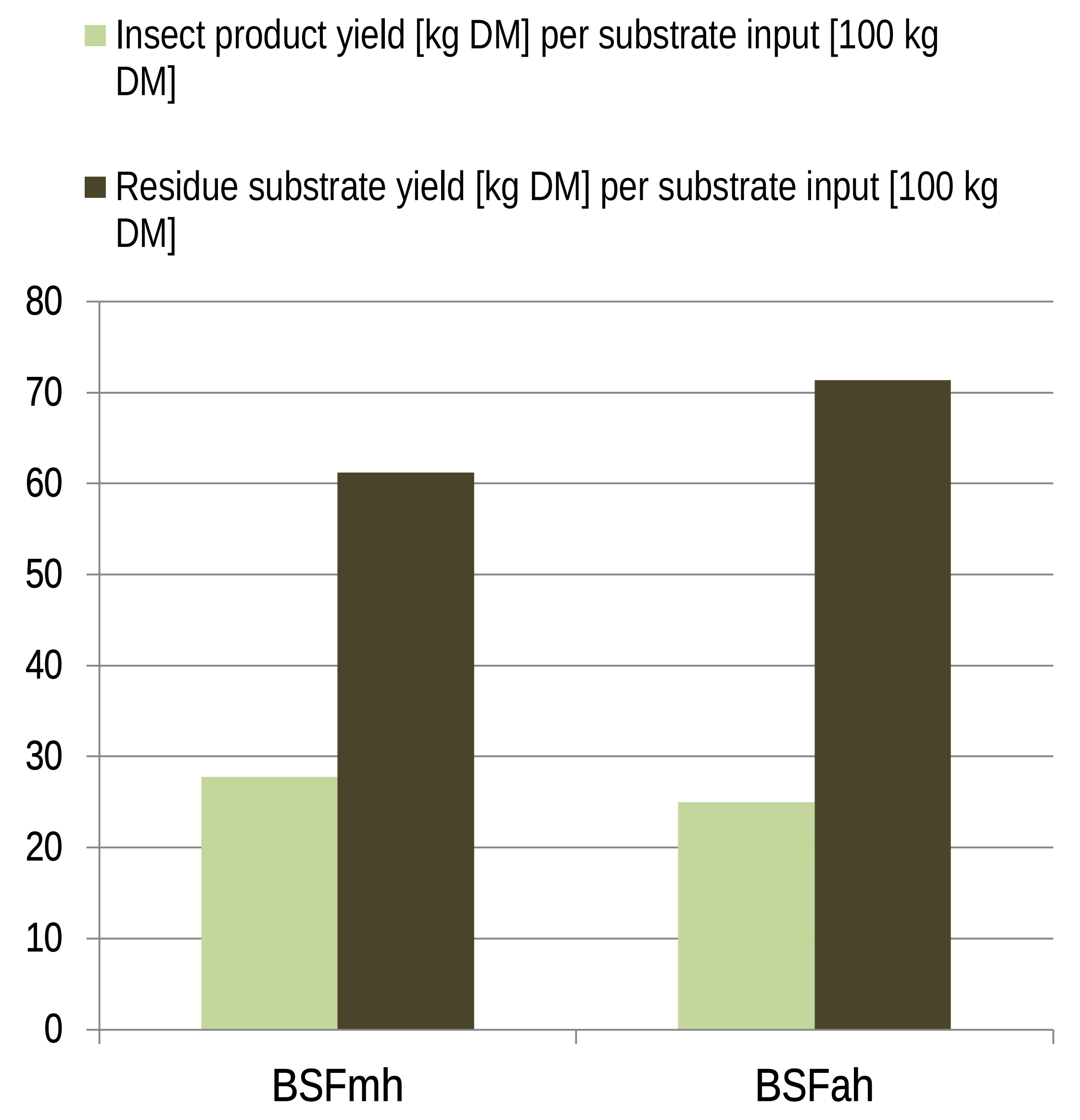
Packed, dried insect product
Packed residue substrate

Unit process
Process
Product
Material flow

Conversion degree

Final product
Process residues

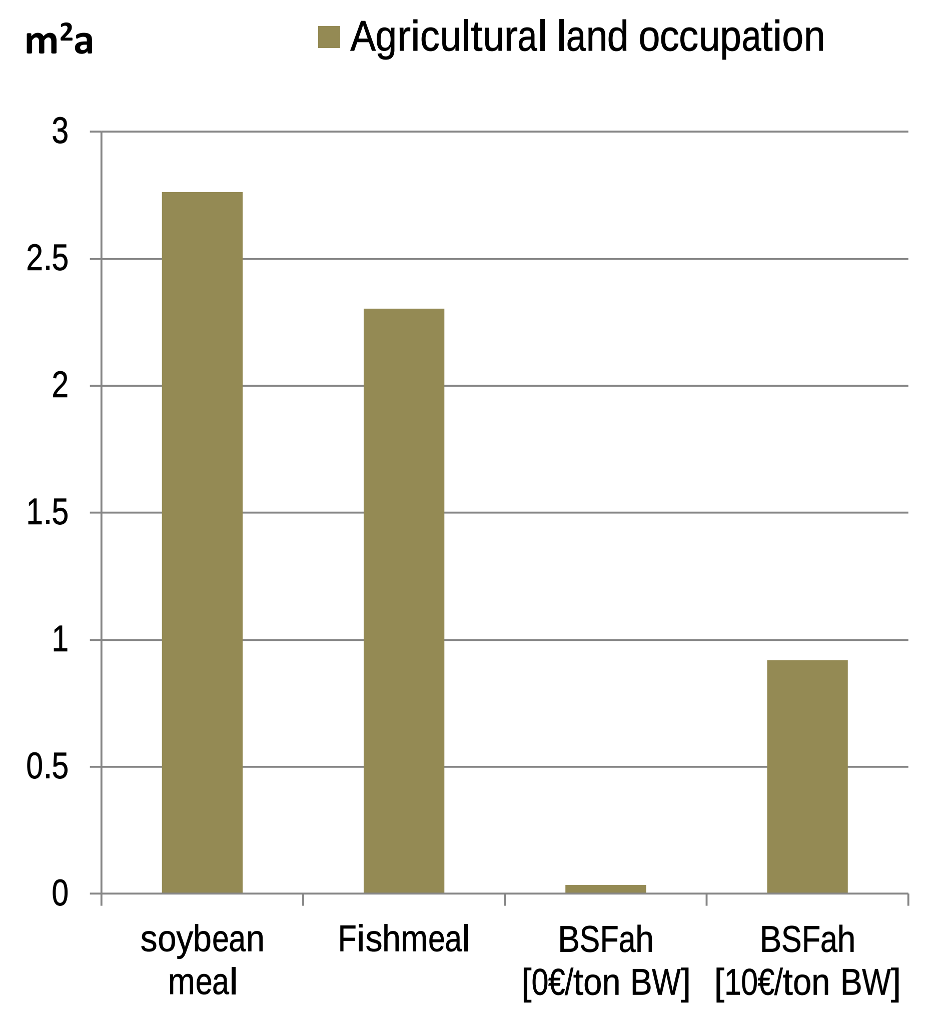
Material flow: yield per 100 kg input substrate

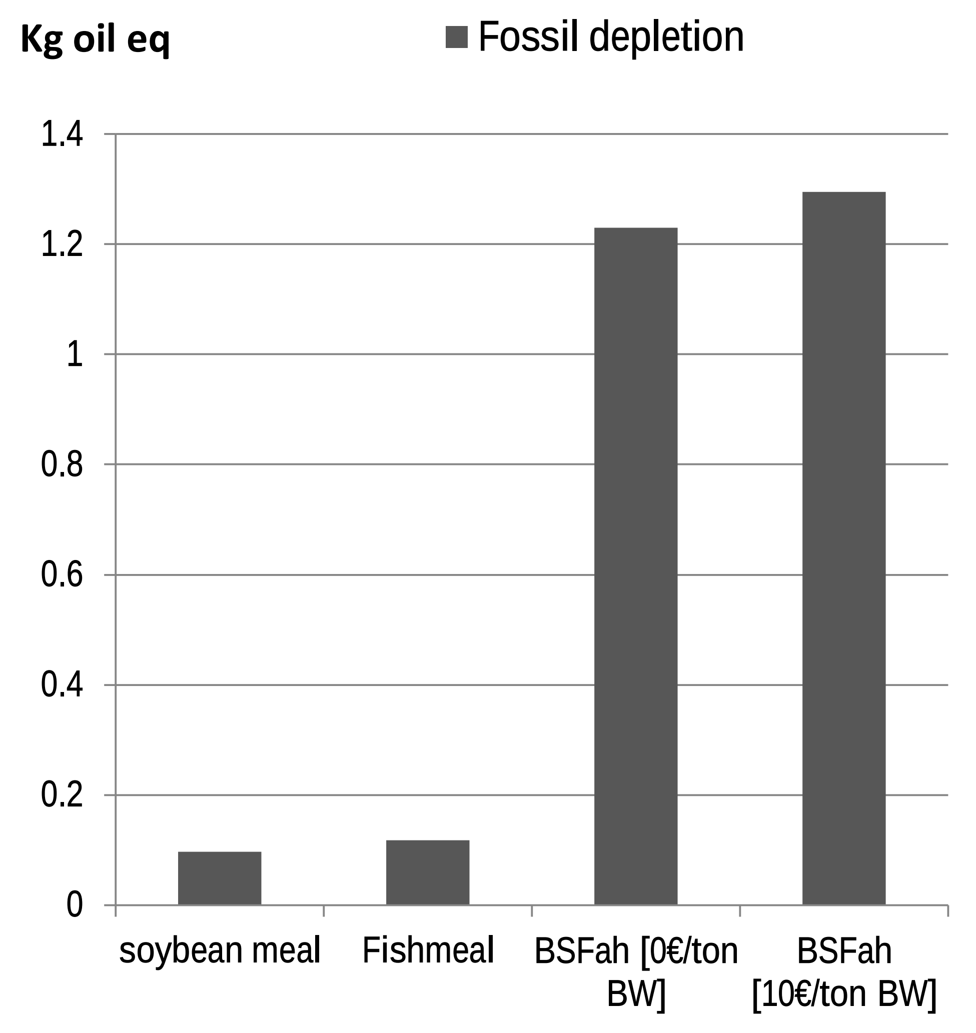


Good conversion rate, a little affected by automation

BLACK SOLDIER FLY REARING FOR PROTEIN PRODUCT

Life Cycle impacts (ReCIPe midpoint categories) per 1kg of insect product [DM]





- ☐ Benchmarking against related products reveals strengths and improvement challenges

PRELIMINARY RESULTS

Pilot-scale production system BSF(Alicante, Spain) - conclusions and recommendations

CONCLUSIONS:

- Implementing semi-automated harvesting measures results in comparable lower larvae yields (lower recovery rate), but goes along with substantial savings in labour input
- Advantages over conventional feed protein sources in terms of agricultural land occupation, unfavorable performance when compared by “fossil depletion potential”
- Trade value of employed substrates influences environmental impacts (economic allocation)

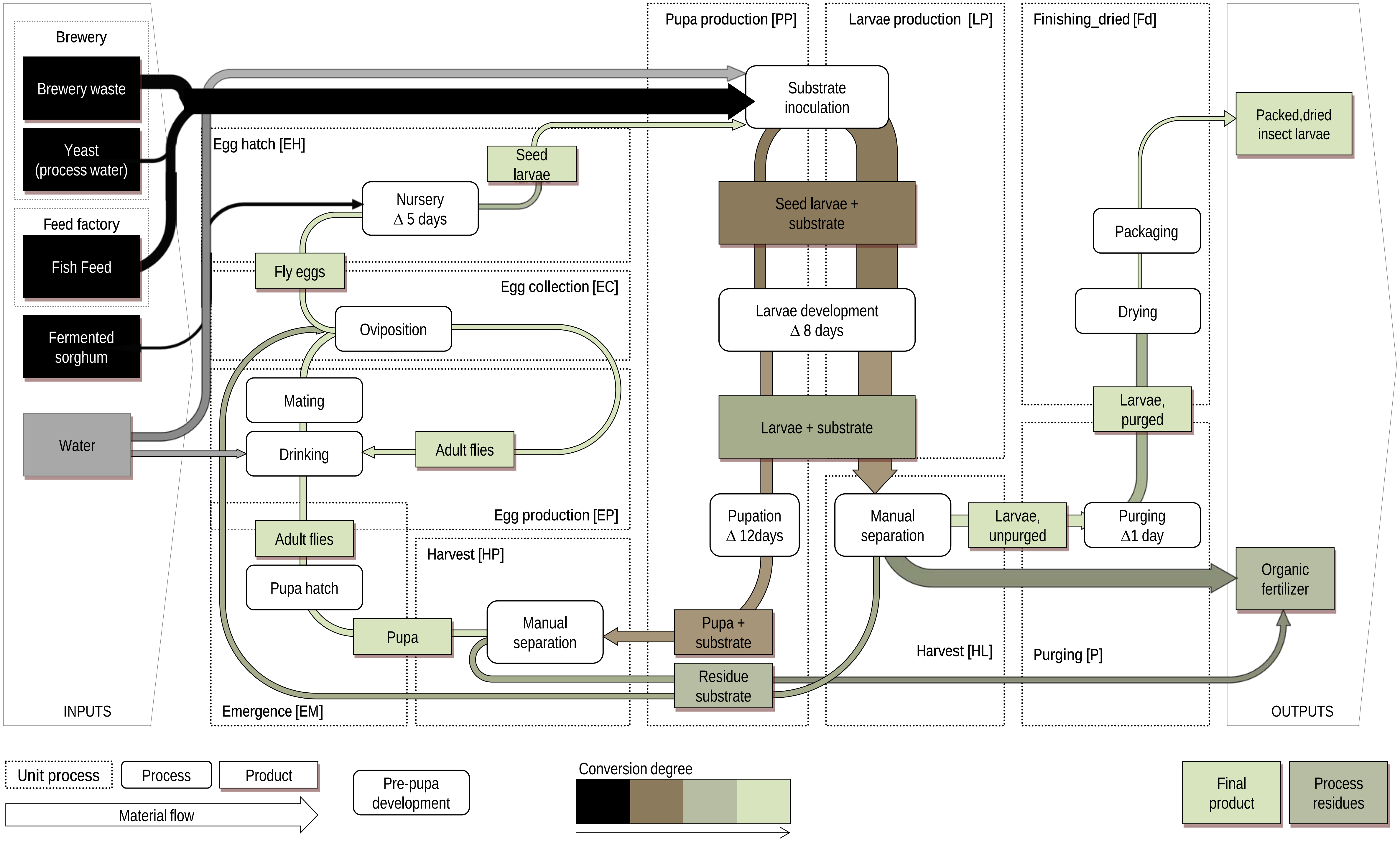
RECOMMENDATIONS:

- Increase energy efficiency and further aggregate rearing units
- Research application potential of residue substrates, e.g. organic fertilizer
- Research the availability and application potential of less valuable rearing substrates in region under research

PRELIMINARY RESULTS

Up-scaled production system in Ghana- unit processes and fundamental material flows

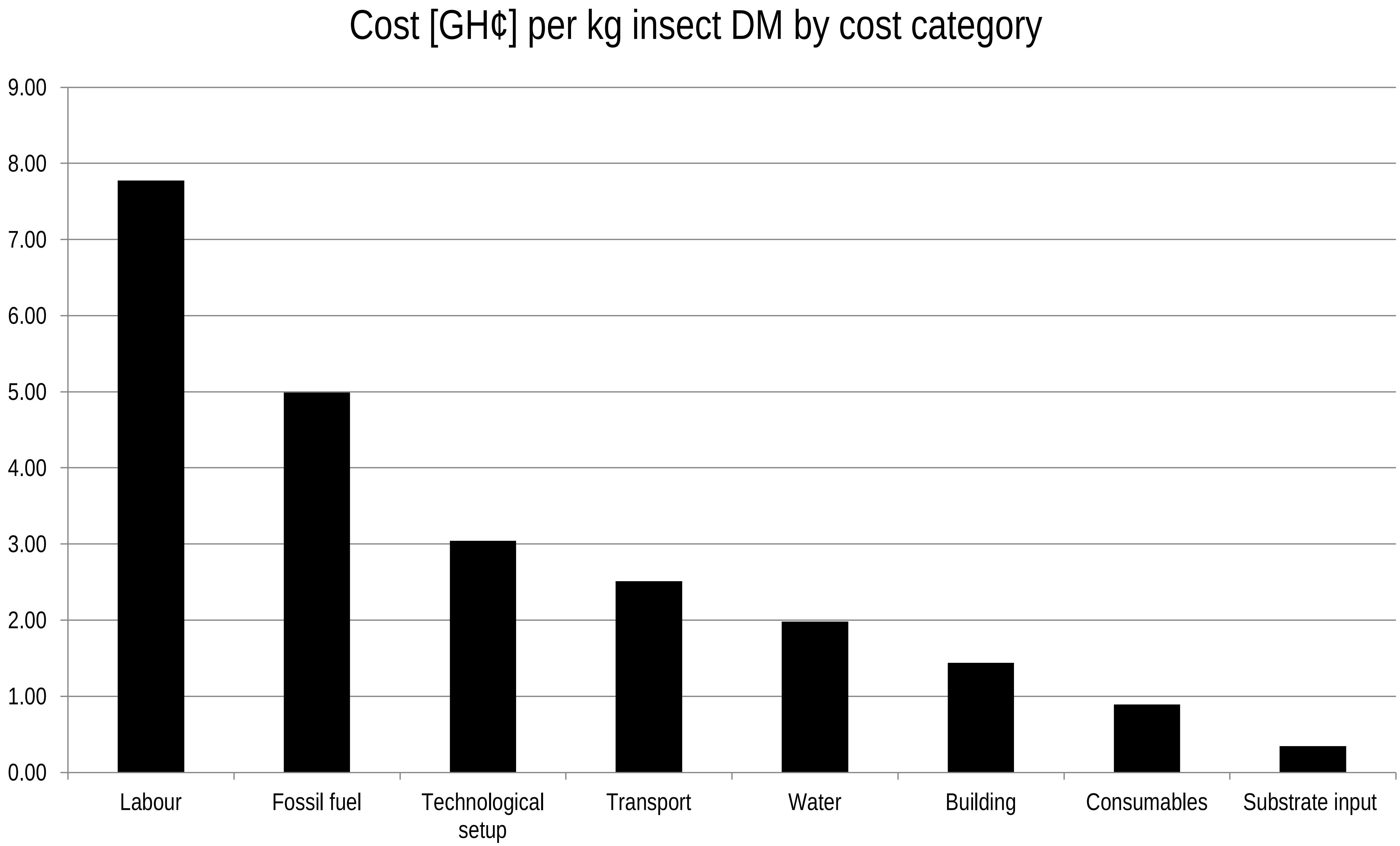
Black Soldier Fly [*Hermetia illucens*] reared on various substrates (#aggregated adult rearing unit)



PRELIMINARY RESULTS

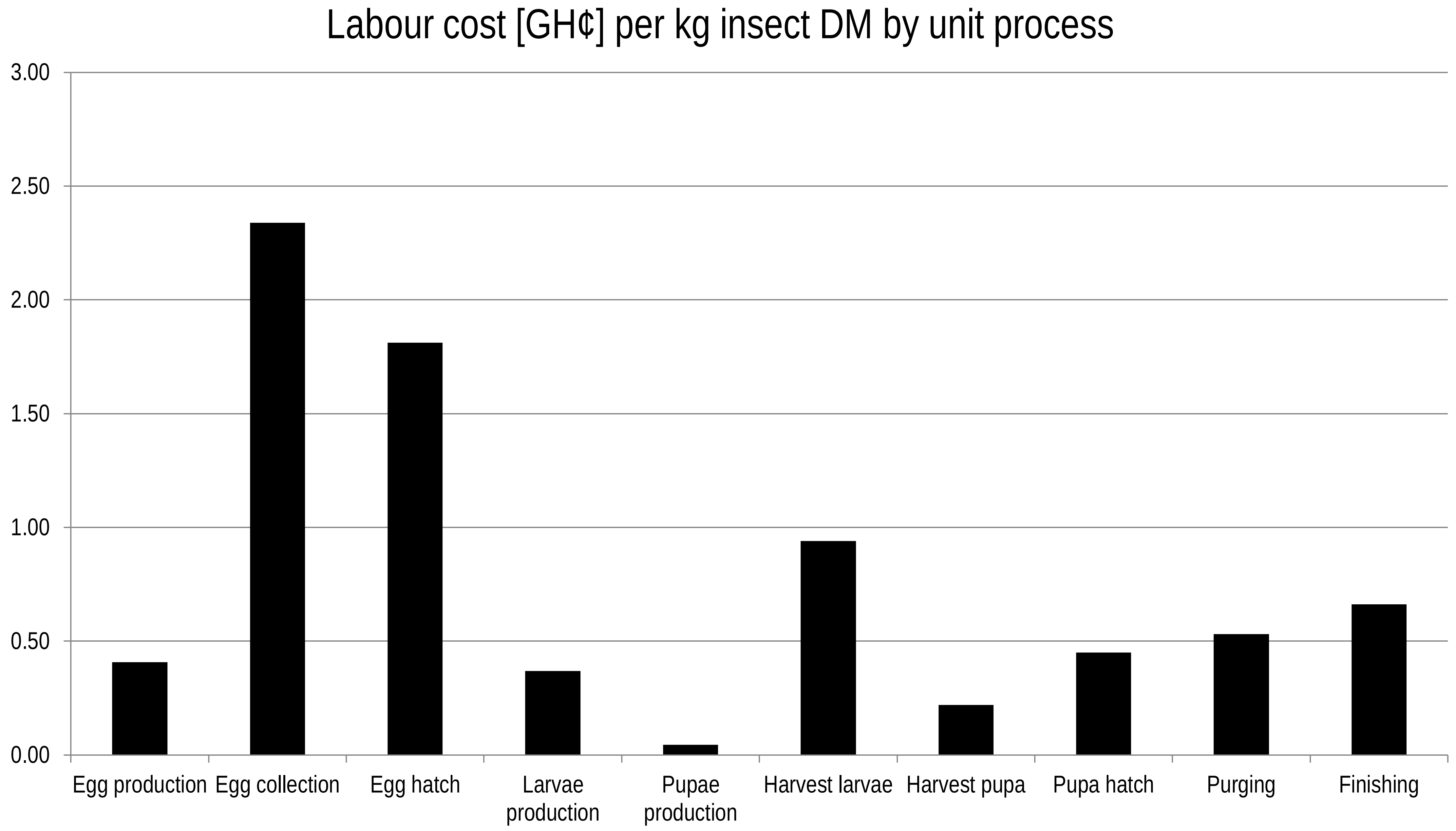
Up-scaled production system in Ghana - preliminary LCC results

Scenario assumption: 35 GH¢ / ton brewery waste, 3GH¢ / m3 water



PRELIMINARY RESULTS

Up-scaled production system in Ghana - preliminary LCC results



PRELIMINARY RESULTS

Up-scaled production system in Ghana - conclusions and recommendations

CONCLUSIONS:

- Labour, Fossil fuel, technological setup and transport explain almost 75 % of the total costs
- Egg production, egg hatch and harvesting measures are unit processes with highest labour demand
- Water (cleaning measures) and natural gas prices (drying) are economically sensitive aspect of production

RECOMMENDATIONS:

- Aggregate rearing units and slim the technological setup to benefit from economy of scale
- Employ more efficient drying measures, e.g. solar dryers, consider selling fresh insect product
- Implement production facilities in close proximity to substrate providing systems (transport)

Some first conclusions (1/2)

1. Insect production is a versatile system to make livestock farming more efficient (waste reduction, adding value)
2. Value of substrate and end products affects environmental performance (economic allocation). Environmental advantage over alternative feeds depends essentially on the access to low value waste streams as a substrate
3. Scale optimization is crucial (advantages of economy of scale have a trade off with transport costs due to diluted substrate availability)
4. Systems are difficult to compare (differences in goals, species, sophistication, nutritional value, digestability)

Some first conclusions (2/2)

5. LCA is a design tool that helps to identify the critical unit processes for improvement of environmental & social impact, but also of economic profit
6. Conversion rates are promising but large room for efficiency improvements
7. Efficient heating, insulation and alternative heat sources are crucial elements of improvement
8. A large part of the impacts is due to non-productive processes (maintenance of the population)
9. Both Black Soldier Fly and House fly have advantages: BSF is higher yielding, but House fly has a shorter cycle and may be more cost efficient per unit of end product

KU LEUVEN

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
K.U.LEUVEN - BELGIUM

THANK YOU FOR YOUR ATTENTION

bart.muys@ees.kuleuven.be

Appendix Five

Project Partners Briefing

To: Consortium Colleagues, PROteINSECT project

From: Minerva UK

Re: **PROteINSECT Round Table - for Key Opinion Leaders (KOLs) 14th November 2014, Brussels**

Dear Colleague – in November we will be holding the PROteINSECT Round Table for Key Opinion Leaders (KOLs) 'Safe and sustainable utilisation of protein from insects for animal feed' event in Brussels. This managed Round Table meeting will draw together key European stakeholder groups and representation from the PROteINSECT project team to facilitate a discussion on state-of-the-art insect protein production and utilisation.

Attendees will receive detailed briefings on the topic in advance of the meeting and each session topic will be introduced with a short presentation by PROteINSECT members highlighting key evidence, barriers, challenges and opportunities for the topic. All attendees will then be invited to formally contribute on behalf of their organisations.

1. **Event outcomes**

   There are two key desired outcomes of the event:

   (1) A Report of the meeting reviewed and agreed by all participants (WP5 Deliverable)

   (2) A consensus 'Business Case' document that provides the evidence base (at that point in time) for use of insect protein which will be presented to key individuals in policy and political circles, feed industry, farmers, retailers, consumer groups and publicised more widely via the media (at a time to be determined). This document will also provide the 'stepping stone' to our planned White Paper for the European Parliament in 2015. (WP5 Deliverable)

2. **PROteINSECT representation**

   The project team will be represented by:

   - Elaine Fitches
   - Geert Bruggeman
   - Adrian Charlton
   - Bart Muys
   - Rhonda Smith, Edward Barnes and Rosie Pryor (event organisation and facilitation)

3. Organisations invited to contribute

- Food and Environmental Research Agency (Fera) http://www.fera.defra.gov.uk/
- Copa-cogeca http://www.copa-cogeca.be/Menu.aspx
- European Federation of Animal Science http://www.eaap.org/index.htm
- European Food Safety Authority http://www.efsa.europa.eu/
- Food Standards Agency www.food.gov.uk
- European Reference Laboratory for Animal Proteins EURL-AP http://eurl.craw.eu/
- European Feed Manufactorers' Federation (FEFAC) http://www.fefac.eu/
- Waste and Resources Action Programme (WRAP) http://www.wrap.org.uk/
- International Producers of Insects for Food and Feed (IPIFF) www.ipiff.org
- European Supermarket - tbc
- WWF http://www.wwf.org.uk/
- ENVI Committee on the Environment, Public Health and Food Safety http://www.europarl.europa.eu/committees/en/envi/home.html
- DG Health and Consumers (DG SANCO) http://ec.europa.eu/dgs/health_consumer/index_en.htm
- British Nutrition Foundation http://www.nutrition.org.uk/
- Food Drink Europe http://www.fooddrinkeurope.eu/
- The European Consumer Organisation (BEUC) http://www.beuc.eu
- European Council of Young Farmers http://www.ceja.eu/
- European Pig Selection and Production Association http://www.epspa.eu/organisation.html
- Association of Poultry Processors and Poultry Trade in the EU (a.v.e.c.) http://www.avec-poultry.eu/
- European Aquiculture Society http://www.easonline.org/
- European Aquaculture Technology and Innovation Platform (EATiP) http://www.eatip.eu/
- European Rural Poultry Association http://www.erpa-ruralpoultry.eu/en/who.php
- International Federation of Organic Agriculture Movements (EU Group) http://www.ifoam-eu.org/

4. Agenda & Speakers

Welcome from Co-Chairs - explain scope and objective of the meeting

Session 1: Production (Introduced by Elaine Fitches)

Session 2: Processing (Introduced by Geert Bruggeman)

Session 3: Quality & Safety (Introduced by Adrian Charlton)

Session 4: Life Cycle Analysis (Introduced by Bart Muys)

Session 5: Consensus Discussion (Led by Co-Chairs with facilitation/further recording as required from Minerva)

5. Contact for queries - edward@minervacomms.net