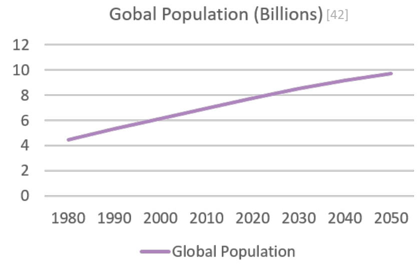
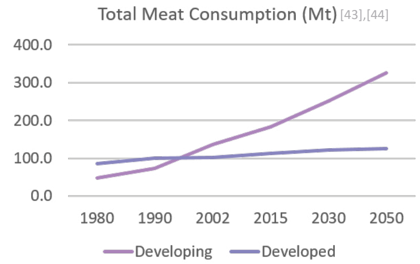
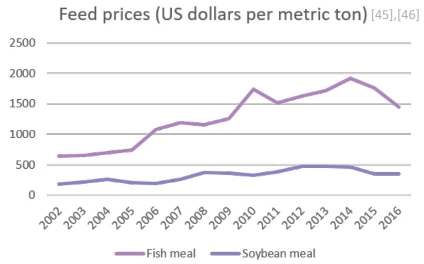
INSECTS AS LIVESTOCK FEED

DRIVERS

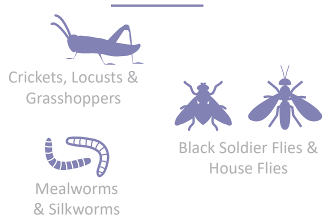




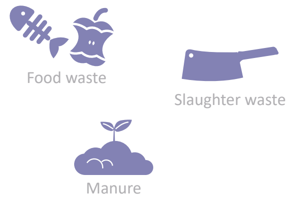


(PRE)CONDITIONS

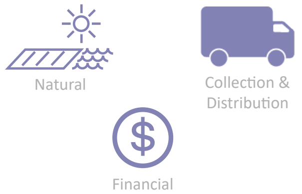
INSECTS



SUBSTRATE



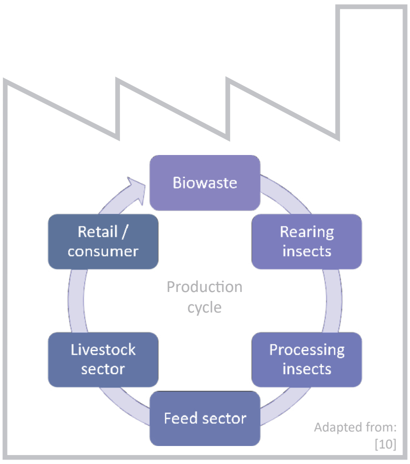
RESOURCES



INDUSTRY

AgriProtein (South Africa) [36],[37]
- Mass production of BSF larvae
- Nutrient recycling by using (organic) waste streams
- Produces insect based protein meal (Mag-Meal™), an extracted fat (MagOil™) and a nutrient rich soil conditioner (MagSoil™)
- Natural, cost-effective alternative to fishmeal
- Valued at USD 117 million
- 8.5 billion flies, recycling 250 tonnes of waste per day, produces 50 tonnes of larvae per day

ENTERRA (Canada) [38]
- Mass production of BSF larvae
- Nutrient recycling through (organic) waste streams
- 'Recover over 4 million gallons of fresh water annually from the fruits and vegetables that we consume as feedstock'
- 6 Million flies at full capacity
- Use pre-consumer waste food
- Produce organic fertilizer and natural oils as by-product
- Complements the Canadian landfill ban [30]



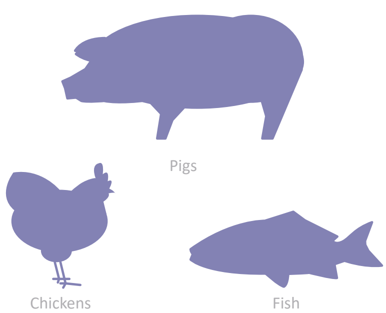
SMALL-SCALE

Case-study Kenya [23]
- Large- and small-scale production
- Mainly BSF, though other insect species also used
- 80% of insect rearing is small-scale
- Try to use only local materials and insects
- Use different waste streams: food waste, brewery waste, manure, human waste etc.
- Insects are also used for improving sanitation
- Promotes inclusion, especially of women and children. It's cost-effective and can lead to empowerment
- Legislation and policies are developing
- Kenya has a 6-month annual ban on fishing. Insects are a cheap, easy, high quality alternative protein source for feed
- Raising awareness and mobilising farmers is essential
- Waiting for EU legislation to change

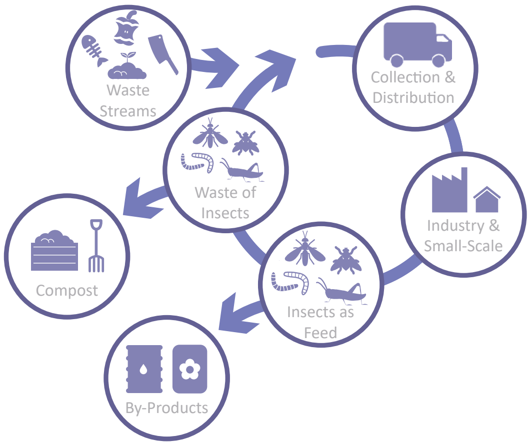
BY-PRODUCTS

- Oil [36]
- Biodiesel production [39],[40],[41]
- Natural fertilizers
- Reduce antibiotic dependency
- Reduce human waste streams; improve sanitation and waste-water systems [26], [30]
- Reduce heavy metal contamination [19]
- Medicinal Use [34]
- Food colorant; biological pest control; pollination [34]

LIVESTOCK FEED



WASTE MANAGEMENT



DEFINITIONS & ABBREVIATIONS

Biorefinery: Producing biologically-based products and energy from biomass
Oviposition: The laying of eggs
Pathogens: A bacterium, virus, or other microorganism that can cause disease
Prions: An infectious, transmissible protein thought to be the cause of TSE
Substrate: The material on or from which an organism lives, grows, or obtains its nourishment
Valorisation: Recovering of value from disposed materials, especially by the food and agricultural industries

BSE: Bovine Spongiform Encephalopathy ('mad cow disease')
BSF: Black Soldier Fly
EC: European Commission
EFSA: European Food Safety Authority
PAP: Processed Animal Protein
TSE: Transmissible Spongiform Encephalopathies

INSECTS AS LIVESTOCK FEED

KEY MESSAGES

- **Insects are highly suitable to be used as feed due to their high nutritional values, and because they are naturally a part of some livestock diets.**
- **Insect feed is a sustainable addition to conventional feed, as insects are reared on waste streams and can generate diversified livelihood incomes.**
- **Challenges to overcome are ethics, food safety and legislation. Which can be overcome by close cooperation of government, academia and industry.**

INTRODUCTION

Global population growth, increasing wealth, and urbanization, particularly in Asia and Africa, create changes in global consumption patterns, lifestyles and food preferences, leading to an increase in animal protein demands [1],[2]. This will affect the demand for livestock feed and inevitably place heavy pressure on already limited resources [1]. FAO estimates that food production will have to increase by 70% to be able to feed the world in 2050, with meat outputs (beef, poultry and pork) expected to double [3]. The raising demand leads to protein shortages and the search for alternative supplies of sustainable protein sources is needed [4],[5]. One of the major constraints is the costs of feed, including substitutes like fishmeal and soybean meal, which represent 60–70% of production costs [3]. However, conventional feed streams, including protein sources, fluctuate in supply and import price.

The urgency to find an alternative livestock feed ingredient for fishmeal and soymeal has led to market recognition of insect protein [3]. This has low requirements for land and water and a high conversion efficiency of feed into insect biomass [4]. Insect production systems reduce the reliance on conventional feed streams (e.g. soymeal, fishmeal, grains) [12] whilst bringing valuable ingredients from organic waste materials from agriculture, food industries and other sectors back into the food chain [2]. Insects as a feed can significantly reduce the environmental footprint of livestock production if mass-production delivers protein quantities comparable to fish or soy [5].

At present, the scale of current production cannot compete with conventional feed sources [6]. However, the insect rearing industry is developing and shifts from semi-automated to fully automated systems will soon be reached. A new industrial sector for insect rearing is ripe for development and individual market actors already serve as 'role models' trying to ensure greater cost-effectiveness [1],[3]. This novel industry still depends on site-specific and socio-economic circumstances, which challenges the product availability, utilization and consistency and quality [2],[7]. Nonetheless, this flourishing sector could experience a fundamental breakthrough if legislation and regulation, particularly in Europe, was able to adapt to this emerging insect protein market.

The multipurpose aspect of insect rearing shows great potential to work towards the Sustainable Development Goals (SDGs). Primarily, insects as a source of feed offers opportunities to increase food security (SDG 2) by, for example, reducing land competition between energy- and food crops [3]. Secondly, co-benefits such as improved waste management infrastructure, especially in middle- and low-income countries, can have positive effects on human health and well-being (SDG 3) [8]. In line with the previous mentioned purposes, insect farming with standardized techniques on industrial scale is a novel economic sector able to improve the sustainability of global food chains (SDG 9) [1].

The intended goal of insect farming depends on both the selection of insect species and rearing substrates. Goals can vary between the reduction of waste, producing high quality protein or the extraction of by-products. This brief has opted for the exploration of using insects as livestock feed (see figure 1).

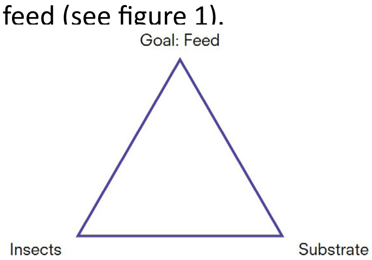


Figure 1: Insect farming triangle

CURRENT SITUATION

Insects: Benefits of using insects for livestock feed include high nutritional values, feed efficiency, and reproductive capacities. Insects have the ability to produce by-products; are naturally present in some livestock diets (e.g. fish, poultry, pigs) and can create additional socio-economic and environmental benefits [2],[9]. A wide range of suitable insects exists, e.g. Black Soldier Fly (BSF) larvae, house fly maggots, mealworms, silkworms and locusts-grasshoppers-crickets [10],[12]. BSFs are considered to have the most potential for feed (see Box 1).

Target Livestock: Mainly fish, poultry and pigs [11]. Ruminants are generally excluded, as they are already efficient in converting non-edible proteins (e.g. grass) into edible proteins [12].

Production: Both commercial mass-producing insect rearing companies and small-scale, household-level enterprises exist on a global scale [2]. In tropical countries, locally obtained feed as well as local species should be used as they pose minimal risk to the natural environment. Furthermore, "productivity of traditional management systems" should be maximized [14, p.19]. Industrial automated mass-scale production most often occurs in temperate climates, and consists of at least one ton/day of dry insect weight [2],[13].

Consumers: Insects as feed appears to be favourable; research by PROteINSECT showed over 70% consumer acceptance rate [2]. Insect feed is *perceived* as "more sustainable, to have better nutritive value, but a lower microbiological safety compared to conventional feed" [15, p.72]. Also, perceptions included a lower protein import dependency and a higher valorisation of waste; in general, consumers perceive benefits to outweigh the risks involved [14]. However, there is a need to better inform the public on the use of insects as feed, for example evidence from the recent EFSA report which demonstrates that "insects raised on pure vegetable substrates in feed does not pose chemical or biological risks to consumers" [15, p.2],[16].

BENEFITS

Environmental: Production of insects is context dependent, though generally they are favourable in space requirements and show significant improvements in water and greenhouse gas (GHG) emissions [6],[17] as compared to conventional feed [1],[2],[17]. Though some Life Cycle Assessments (LCAs) show higher energy consumption in the production of some insects (e.g. housefly larvae), technical innovations can aid a shift towards renewable energy, thus reducing global warming potential [18],[19]. The most suitable insect-rearing facilities are located in "regions with year-round high temperatures, high density of concentrated animal operations and presence of food processing industry facilities" [2, p.33]. Complementing conventional feed (e.g. soybean, fishmeal) with insects will reduce pressure on natural resources [12], nature reserves and global fishstocks [15].

(Socio-) Economic: With rising conventional feed prices and pressure on natural resources, insects appear to be part of a sustainable solution. Though current insect prices are relatively high, proper investment and up-scaling can reduce these costs significantly [10],[20]. For many small-scale producers, rearing insects can offer livelihood diversification strategies, subsequently mitigating vulnerability [21],[22],[23]. Additional socio-economic benefits, including women empowerment, are to be expected though more research is needed [6],[24].

BOX 1: BLACK SOLDIER FLIES [24]

General

- Widespread in tropical and warmer temperate regions between 45°N and 40°S.
- 14-day pupal stage under optimal conditions. Adults do not feed but rely on body fat reserves obtained throughout larval stage.
- Are not unsanitary or a vector of diseases. Instead, they repel oviposition (laying of eggs) of female house flies, thus reducing risks of diseases. [24]
- Naturally live and grow in high population densities.

Waste & Input

- Larvae can feed on different waste streams (organic, raw food waste, manure, slaughter waste).
- Relatively low input (space, water, energy) needed for rearing, low greenhouse gas emissions.
- Can reduce the mass of organic waste by 60% in 10 days. [26]

As feed & (by-)products

- High nutritional quality; whole dried BSF larvae con-tain on average between 36-48% protein and 31-33% fat contents depending on the nature of the sub-strate.
- Oil, fertilisers, compost, biodiesel etc. [18],[35],[36],[37] (see Infographic).

CHALLENGES

Legislation: A necessary aspect in the commercialisation of any product is guaranteeing a defined degree of safety. This is no different when it comes to utilizing insects as feed [3]. The challenge revolves around standardization. There are many insect species, rearing-substrate possibilities, insect-consuming countries, and thereby different legal frameworks, making this task challenging [2],[3]. In some regions, laws concerning the safety of the substrate insects are reared on, for instance, are not as restraining as they are in the European Union (EU). Experts believe that the restrictive EU regulations pose the main barrier for the industry to take off worldwide [12],[32].

In the EU, insects as feed are regarded as Processed Animal Proteins (PAPs) under Regulation EC Nr 1069/2009 [2]. After the BSE-crisis, Regulation EC Nr 999/2001 prohibited feeding PAPs to farmed animals, leading to a ban on insects as feed [16]. An amendment in Regulation EC Nr 56/2013 now allows non-ruminant PAPs to be fed to aquaculture species. However, this regulation does not apply to processed insect protein [2],[16]. In addition, the European regulation on slaughterhouse requirements prevents on-farm slaughtering of livestock including insects. This hampers efficient insect farming, because this regulation was not designed for insect slaughter [2],[33].

BOX 2: ORGANIC WASTE MANAGEMENT

Large amounts of manure and other agricultural waste are produced and often concentrated in small areas without appropriate waste disposal facilities. This contributes to nutrient imbalances, which could result in deteriorating soil and water quality, and air pollution [26]. Manure contaminates surface- and groundwater with nutrients, toxins (heavy metals) and pathogens [1]. Inadequate storage or management of manure can involve the emission of large quantities of ammonia, which can lead to acidification of ecosystems [3]. **In middle- and low-income countries, waste collection and inadequate treatment of waste is an increasing problem, leading to intolerable conditions especially in urban areas** [24]. Untreated (organic) waste deposits can become an ideal breeding place for disease transmitting insects and rodents, as well as the exposure of odour [24].

BSF larvae as feed should be seriously considered for their reduced environmental footprint, but also for their ability to reduce mass, moisture and odours from decaying poultry, dairy, beef and pig manure [26]. BSF develop well on rotting fruits, vegetables and plant residues [3],[26]. BSF larvae can reduce the mass of organic waste by up to 60% in 10 days [2]. Furthermore, BSF sanitizes waste while inactivating bacteria such as Salmonella and E. coli [25]. However, BSF lack the ability to degrade wood residues and straw due to the low nutritious content [27]. BSF can be reared on most food-waste sources, but in many countries it is prohibited because of European Regulation EC Nr 999/2001 and perceived food safety problems.

BSF have the potential to improve sanitation in developing countries by providing a way to process dangerous human faecal waste [28]. A study has demonstrated that BSF feeding on fresh human faeces can develop successfully at least on small-scale experiments [28]. More R&D is needed, and an important link can be drawn to the SDG 6 – Clean Water & Sanitation.

Bioconversion processes are strongly linked with food waste management strategies by focusing not only on minimization, but also on valorisation of waste products (up-cycling). Collection and recovery of municipal organic waste can create a well-functioning informal waste management, which can be linked to income generation, such as already existing systems for inorganic material [24].

Ideally, organic waste would play a crucial role in a circular economy context, where waste is recognised to be a valuable source with potential uses, if reused [29].

Viable production practices have to be developed for the large-scale insect farming industry to thrive worldwide [32]. The need for standardization across the industry calls for the establishment of a legal framework that must be enforced throughout the entire industry and worldwide. In terms of international trade, standardization is challenging to achieve due to, in part, the different priorities (e.g. tackling the food waste problem) within each government [3]. Nonetheless, addressing this situation is crucial [3].

Research Gap: Farming insects for feed and food is relatively new; the sector is still in its infancy. Whilst progress is relatively rapid, further R&D is required to provide a strong scientific basis essential for the development of a new industry [32]. Key research areas that need to be further studied are, for instance, those relating to the substrates insects are reared on (e.g. the value of the left-over substrate), and the potential allergenic issues that may be faced by insect farmers [23],[32]. Bridging this research gap is crucial to bring together stakeholders and to better understand risks and benefits of this novel industry, so as to develop guidelines on producing insects on an industrial scale, as information required for up-scaling insect production is not well established [34].

Costs: Presently, insect feed prices are estimated to be higher than those of conventional feed. However, real data on insect prices is not yet available due to industry secrecy [13],[19],[20]. Fishmeal is currently the most competitive protein source as compared to insect feed, but fishmeal prices are expected to increase in the near future due to overexploitation of global fish-stocks [4],[10],[11]. For insects to be a competitive alternative protein source for pigs and poultry, the maximal price should be between € 1.00 and € 1.50 per kg. Such a reduction in insect prices is considered to be feasible according to expert judgement [10].

Risks: Risks within the mass-production of insects need to be determined, which can be achieved by closing the existing research gap. The use of manure still needs further research to ensure its safety [16]. Feed safety needs to be assured (e.g. pathogens, contaminants, allergens, heavy metals) and regulatory conditions must be developed and respected. Quality needs to be high and guaranteed; rearing substrates based on waste should be certified for future large-scale operations [3].

Ethics: Given the potential for a global insect rearing industry, animal welfare is to be considered. Insects are regarded as ‘mini-livestock’ and should therefore be slaughtered in a humane way [3]. Though it is not yet known if insects can experience the emotional side of pain in the same way mammals do, there is consensus that insects have *nociceptors*, or pain receptors, and can therefore react to harmful stimuli [20],[35]. Consequently, the aim should be to slaughter insects using the quickest and most effective way. Some experts believe freezing to be the best method, though it is regarded to be relatively costly; therefore, many resort to heating [7],[19],[20],[32].

RECOMMENDATIONS

For the successful implementation of insects as feed, close cooperation of government, academia and industry is needed [10],[21],[23],[32]. Researchers need funds and industrial data to fill the research gap, governments need research results to validate regulatory amendments, and industries need amended regulations and a scientific foundation to produce safe and trustworthy products and operate at full capacity [23],[32].

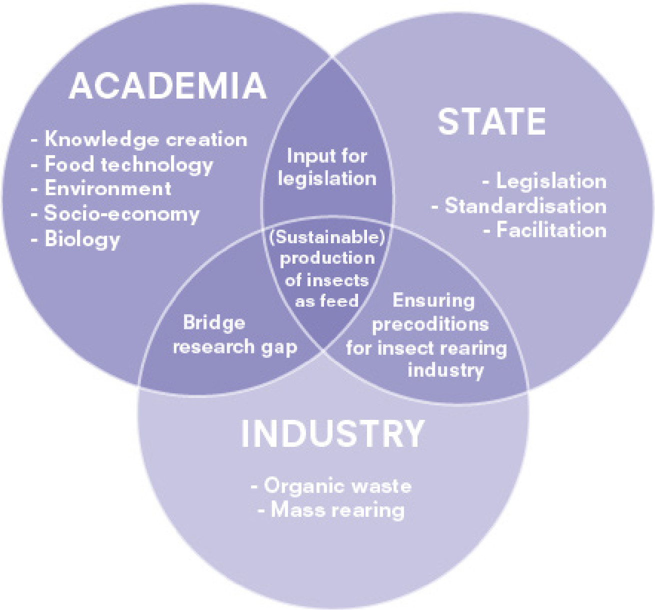


Figure 2: The integrated cooperation between state, industry and academia necessary to work towards sustainable insect production as livestock feed (adapted from van Huis, 2012)

This brief suggests a review of the following EU Regulations, based on recent literature and EFSA findings:

- EC Nr 1069/2009, which does not allow catering waste as an insect substrate.
- EC Nr 999/2001, which does not allow insect PAP in the feed of pigs and poultry.
- EC Nr 1099/2002, which does not allow on-farm slaughtering of insects.

PRODUCTION

- Create and develop regional platforms where various stakeholders (e.g. industries, governments) can safely (and anonymously) share information without compromising their market position.
- Identify and promote the use of local insect species and local waste streams.
- Invest in innovative technologies that use renewable energy required for insect rearing, e.g. for optimal ventilation.
- Establish well-functioning (informal/formal) waste management systems.
- Develop safety guidelines on producing insects on an industrial scale.

RESEARCH

- Invest in research for automation to decrease the labour costs.
- Improve rearing methods (e.g. alternative cleaning measures and/or rearing vessels with favourable volume/surface ratios) required to lower water usage.
- Further quantify environmental impacts and the sustainability of insect feed compared to conventional feed.
- Identify health risks of using animal and human waste as rearing substrate arising due to bacteria, viruses and prions.

REGULATORY

- Establish a liaison with policy makers and researchers to develop a clear and comprehensive legal framework.
- Increase quality and quantity of public-private partnerships.
- Ensure adequate preconditions for markets and infrastructure.

ADDITIONAL

- Educate and raise awareness on the benefits of rearing insects as an (additional) livelihood strategy.
- Determine and identify global consumer acceptance and differences for insect fed livestock.
- Identify and analyse possible effects for smallholder conventional feed crop farmers if insect meal becomes a major ingredient in feed.

FUTURE PROSPECTS

- Insect rearing can benefit the poorest and most vulnerable members of society [3].
- With enough technological innovations, insects will be a cheaper and more sustainable protein source as compared to conventional feed [3],[17].
- Rearing insects on waste can reduce and valorise global waste streams [17].
- Investing in renewable energy will decrease dependency on fossil fuels within insect rearing [17],[18].

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Andrea Merino Mayayo, and Xanthe Verschuur

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