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Insect farming as a future solution to sustainable agri-food systems in Scotland: A roadmap development



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Executive Summary

This report aims to present strategic plans and provide recommendations for utilising edible insects as animal feed to enhance sustainable agri-food systems in Scotland. The key results are derived from an in-depth study conducted on the challenges and opportunities faced by insect farmers, insect-related businesses, and feed operators in Scotland and the UK as well as the EU. The focus of this report centres on the potential benefits of using insects as feed, with particular Black Soldier Fly (BSF). Strategic plans are formulated based on valuable insights from insect farmers, industry experts, and stakeholders, which shed light on the opportunities and challenges associated with insect farming and insect-based animal feed. These insights serve as crucial guidance for policymakers and the government.

The results of this research identify several opportunities in the insect farming and insect feed industry, affirming insects as a sustainable protein source. Additionally, the results highlight the circular economy and waste management benefits achieved through insect farming, along with the potential for value-added product development and enhancements in livestock welfare. However, this research presents key obstacles hindering the industry's growth, including limited information and research on insects as feed, ambiguous regulations, high production costs, challenges in practical insect-to-livestock feeding, and public acceptance concerns.

To overcome these challenges, this research provides key strategic recommendations as follows:

- **Regulatory Framework** Policymakers must prioritise collaboration with farmers, industry experts, and regulatory bodies to establish clear and transparent regulations specifically tailored to insect farming and insect-based animal feed. Addressing key aspects such as licensing, food safety, animal welfare, and environmental considerations is crucial to ensure the responsible development of the industry. Additionally, it is imperative for insect-related regulations for animal feed in Scotland (and Great Britain) to swiftly catch up and align with those of the EU, as they currently lag significantly behind.

- **Financial Incentives** The government should implement policy incentives, such as grants and subsidies, to foster investments in insect farming and feed production facilities. Access to financing can empower insect farmers and business operators to enter the market and explore new commercial opportunities, enhance cost competitiveness, and address identified research and process development gaps.

- **Industry Collaboration** Facilitating industry collaboration and networking through associations, working groups, and events will promote knowledge sharing, problem-solving, and innovation, enhancing the industry's competitiveness.

- **Public Awareness** Raising public awareness about the benefits of using insects as feed is significant in expanding the market. To achieve this, the government should establish awareness campaigns and education initiatives that aim to shift perceptions, ultimately increasing the demand for insect-based animal feed and edible insects.

- **Research and Development** The government should invest in research related to insects, particularly in areas such as circular economy and waste management, animal welfare in insect farming, and the use of insects for ruminant feed. Investing in this innovative research can help foster a more sustainable and resilient insect farming and feed industry, promoting economic growth and food security.

In conclusion, the successful implementation of the recommended strategies can create an enabling environment for the development and growth of insect farming and the insect feed industry in Scotland (and the UK). This advancement can contribute significantly to sustainable agri-food systems, addressing resource challenges, and promoting a more environmentally conscious and resilient food production landscape. By embracing insects as a sustainable protein source and integrating them into the circular economy, Scotland can lead the way in sustainable agriculture practices, ensuring long-term food security and environmental management.

Black Soldier Fly larvae



Introduction

According to the [FAO, IFAD, UNICEF, WFP and WHO \(2017\)](#), the global demand for livestock products is projected to increase more than twofold by 2050. This rise in demand is concerning, as livestock production is already responsible for approximately 18% of global carbon emissions and uses up 70% of all agricultural land worldwide ([FAO, 2020](#)), which increasingly contributes to rising pressure on the environment. Consequently, the UN's [Sustainable Development Goals](#), particularly [Goal 12: Responsible Consumption and Production](#) and [Goal 13: Climate Action](#), have drawn attention to the food system's impact on climate change and sustainability challenges.

The use of insects, such as Black soldier flies (BSF), could provide a sustainable solution by offering an alternative source of protein for human consumption and livestock feed ([van Huis, 2015](#)). In 2017, the EU approved the use of selected insect meal in aquaculture feed, and this allowance has now been extended to include the use of processed insect protein in pig and poultry feed ([PIFF, 2021](#)). However, after Brexit, the use of insect protein (processed insects) is still not allowed in the UK ([WWF, 2021](#)). If the UK feed regulations on insect protein were lifted, the total demand for insect meal from the UK's pig, poultry, and salmon sectors is projected to be 540,000 tonnes annually by 2050 ([WWF, 2021](#)), with the allowance expected to cover the use of processed insect protein in pig and poultry feed. This development could reduce Scotland's reliance on soya imports and other protein sources, as its feed industry currently depends heavily on imports from the EU and non-EU countries ([FSS, 2020](#); [Wiltshire et al., 2020](#)). There is a desire within Scottish agriculture to move away from reliance on soya due to its detrimental impact on the environment. The global soya trade is a major source of greenhouse gas emissions and is a

main contributor to land being deforested. Moving to more homegrown protein could not only be more sustainable, but it could also prevent problems with supply and reduce the price of protein. In particular, farming insects, especially BFS, can convert organic residues into feed, helping to fill the protein gap and reduce waste ([Clark, 2021](#)).

The insect sector, including insect farmers and business operators, in Scotland could benefit from this opportunity. Nonetheless, post-Brexit, the legislation and regulations regarding insects for animal feed in Scotland and the UK are still under development by the Food Standards Scotland (FSS) and Food Standards Agency (FSA), which are currently behind those in the EU ([Tiwasing, 2022](#)). These unclear regulations and directions could pose challenges for insect farmers and business operators, potentially jeopardizing the future of their businesses. Therefore, this SEFARI Gateway-funded project aims to explore the challenges and opportunities associated with insect farming and industry, particularly BSF, to develop strategies for using insects as feed in Scotland.



2. Literature Review (1)

2.1 Global demand for insect-processed products for animal feed

The global demand for insect-processed products, particularly insect protein for animal feed, has witnessed significant growth in recent years. Several academic studies have highlighted the potential of insect protein as a sustainable and alternative protein source in animal feed (Akhtar and Isman, 2018; Chia et al., 2019; Hawkey et al., 2021). Insects, such as black soldier flies (BSF), are rich in protein and can serve as a viable substitute for traditional protein sources like fishmeal and soybean meal (WWF (2021)). This has led to increased interest in the use of insect protein in animal feed formulations to address the growing demand for animal protein (Sánchez-Muros et al., 2016). Furthermore, the report from WWF (2021) indicates that the use of insect protein in animal feed can contribute to reducing the environmental impact of livestock production, such as greenhouse gas emissions and land use. As the global demand for animal feed rises, the demand for insect-processed products, including insect protein, is expected to grow in the future.

Figure 1 illustrates the global insect protein market segmented by regions, as estimated by Polaris Market Research (2021). In 2020, the insect protein market was valued at \$271 million, and it is projected to reach \$1,480 million by 2028 worldwide. Notably, the EU is anticipated to emerge as one of the fastest-growing markets in this sector. The expansion of the market for insect-processed products for animal feed is driven by several factors. Ooninx et al., (2015) highlight the nutritional benefits of insect protein for livestock, including its high protein content, balanced amino acid profile, and potential positive effects on animal growth and health. This makes it an attractive ingredient for animal feed formulations. Additionally, Filou (2021) reports that the use of insect protein in animal feed can contribute to reducing feed costs and improving feed conversion rates. Insects, with their efficient feed conversion ratios, can convert feed into protein more effectively compared to traditional livestock. This cost-effectiveness and efficiency have fuelled the interest in insect protein as an ingredient in animal feed.

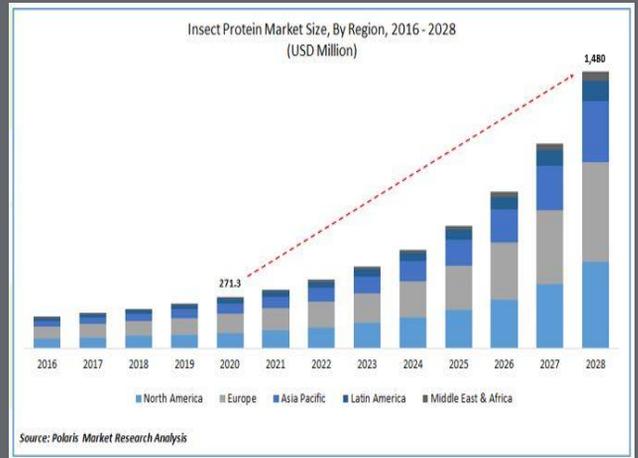


Figure 1 Global insect protein market by region between 2016 and 2028

Looking towards the future, the global demand for insect-processed products, including insect protein for animal feed, is expected to continue growing. Hawkey et al., (2021) and Tiwasing (2022) indicate that the increasing global population and the rising demand for animal protein can drive the need for sustainable and alternative protein sources in animal feed. Insect protein has the potential to fill this gap, offering a sustainable solution with a lower environmental footprint compared to the protein sources that are currently used. Ffoulkes et al., (2021) also suggests that advancements in insect farming technologies, such as automation and optimised production systems, will further enhance the scalability and efficiency of insect protein production for animal feed. However, challenges such as regulatory frameworks, consumer acceptance, and the establishment of insect protein supply chains need to be addressed for the full realisation of the future potential of insect-processed products for animal feed (Tiwasing, 2022; Żuk-Golaszewska et al., 2022).

2. Literature Review (2)

2.2 Current legislation and regulations related to insects as feed in Scotland

The use of insects in animal feed in Scotland and the UK is predominantly governed by EU regulations. In 2017, [Regulation \(EU\) No 2017/893](#), amended Regulations (EC) No 999/2001 and (EU) No 142/2011, made a significant change in the use of insects for animal feed, allowing for the feeding of seven insect species to aquaculture animals in the EU and UK. These species include

- 1) Black Soldier Fly (BSF) (*Hermetia illucens*),
- 2) Common Housefly (*Musca domestica*),
- 3) Yellow Mealworm (*Tenebrio molitor*),
- 4) Lesser Mealworm (*Alphitobius diaperinus*),
- 5) House Cricket (*Acheta domestica*),
- 6) Banded Cricket (*Gryllobates sigillatus*), and
- 7) Field Cricket (*Gryllus assimilis*) ([Sogari et al., 2019](#)).

However, in November 2021, following [Regulation \(EU\) No 2021/1925](#), Silkworm (*Bombyx mori*) was added to this list, while this change has not yet been implemented in Scotland, England and Wales.

More significantly, The EU legislative framework has been extended since September 2021 to allow the use of processed insect protein in pig and poultry feed intended for human consumption ([IPIFF, 2021](#)). This move removes unnecessary regulatory restrictions referred to as “[Feed Ban Rules](#)” and could potentially stimulate the growth of the insect protein industry in the EU. However, after Brexit, Scotland and Great Britain (GB) still prohibit the use of processed insect protein in animal feed for any farmed livestock intended for human consumption, including pigs, poultry, and cattle ([WWF, 2021](#)). As a result, this legislative development creates an uneven playing field between the EU and GB markets in terms of regulation.

2.3 Insect farming and industry in Scotland

According to [Riera and Lebaghan \(2023\)](#), Scotland has potential to become a global leader in the insect industry due to the Scottish Government's circular economy objectives, food waste reduction targets, and thriving aquaculture, agriculture, and food and drink sectors. However, the insect farming industry in Scotland, as well as in the UK, is still in its infancy and is mainly made up of micro- and small-scale facilities that focus on research, development, and production of insect-derived products for a variety of uses, including feed for birds, reptiles, and hedgehogs. Currently, small amounts of processed insect protein are being used in aquaculture and pet foods, and feeding live insects is being trialled on poultry farms ([WWF, 2021](#)).

How does insect farming work in Scotland? According to [Better Origin \(2021\)](#), insect farming involves the breeding and cultivation of various insect species for various purposes, such as food, feed, and fertiliser. Following the [Pollution Prevention and](#)

[Control \(PPC\) \(Scotland\) Regulations 2012](#), if your breeding or rearing activities involve using more than 5kg of animal or vegetable matter per week, they will be regulated and considered as a prescribed activity. In such cases, you will need to obtain a PPC Part B permit from [Scottish Environment Protection Agency \(SEPA\)](#), and ensure compliance with the [DEFRA statutory guidance on insect installations](#). Similarly, if you produce insects intended for animal feed use (for aquaculture or pet food), you must be registered as a 'Feed Business Operator' (FeBO) with national competent authorities such as trading standards. You may also require a [Waste Management Licence](#) and have to register as [a collector and transporter of waste](#) depending on the nature of your business and substrate ([Clark, 2021](#)).

Following [Regulation \(EU\) No 2017/893](#), farmed insects are classified as farm animals. Therefore, they must adhere to the same regulations of rearing and breeding, prohibitions, feeding and feed restrictions as traditional livestock. Insect feed often uses pre-consumer agri-food waste with nutritional value for animal feed. This includes out-of-specification food, breakfast cereals, crisps, liquid chocolate, and surplus bread from retailers and bakeries ([Clark, 2021](#)). The [Catalogue of Feed Materials under Regulation \(EU\) No. 2017/1017](#) provides a valuable reference for identifying permitted feedstocks, and guidelines for the feed use of food no longer intended for human consumption are also available. However, these materials must be obtained from only FeBO-registered businesses and adhere to the feed businesses' registration and approval standards.

Moreover, to establish an insect feed business and/or to process insects for feed, it is necessary to register the enterprise as a FeBO with the relevant local trading standards authority and the competent authorities for feeds (FSA in England and Wales and FSS in Scotland). Also, approval from the [Animal and Plant Health Agency \(APHA\)](#) is also required. Additionally, FSA provides [guidance on the type of activity and registration requirements](#) that businesses need to follow when they plan to start their animal feed businesses.

To sum up, insect farming industry in Scotland faces challenges related to existing regulations, particularly after Brexit, as the legislative framework surrounding the use of processed insect protein in animal feed differs between the EU and Great Britain. Despite these challenges, Scotland has the potential to become a leading player in the insect industry, aligning with the government's circular economy objectives and efforts to reduce food waste. However, further developments in legislation and supportive measures are required to fully harness the benefits of insect farming and incorporate insects into sustainable agri-food systems.



3. Data and Methodology

In this study, semi-structured interviews were used to explore in-depth insights into the topic. This approach allows for a rich understanding of the experiences, perspectives, and challenges related to insect farming and related businesses. A total of ten interviewees were carefully selected from diverse backgrounds, including insect farmers, business operators, feed businesses, and academics in Scotland, the UK, and the EU, representing different aspects of the insect industry. Due to the small numbers of participants and small number of people currently involved in the insect sector, the quotes that have been used in this report are not attributed to an interview identifier due to concerns that this would make them identifiable. To accommodate the availability and preferences of the interviewees, remote interviews were conducted, and the conversations were recorded and transcribed verbatim to ensure accuracy.

The data analysis process involved an iterative approach, where key themes were extracted from the transcribed interviews. The transcripts were read thoroughly to familiarise the researcher with the content and develop a comprehensive understanding. Through a process of identification, common patterns, ideas, and recurring topics were identified across the interviews. These identified themes were further refined and organised to information create a set of themes. This final set of themes formed the basis for the subsequent analysis and discussion, focusing on the key challenges and opportunities associated with insects as feed in Scotland and the broader UK context.

4. Results and Discussion (1)

4.1 Opportunities for insect farming and industry for animal feed

Interviews found that there were broadly 4 main opportunities that interviewees focussed on throughout the interviews. These were: 1) insects as a sustainable protein source, 2) circular economy (including waste management), 3) future business opportunities and value-added products that can be derived from insect farming and 4) benefits to livestock health and welfare.

4.1.1 Insects as a sustainable protein source

One of the primary motivations expressed by most of the interviewees for incorporating insects into livestock feed was the desire to replace unsustainable protein sources, particularly soya, with a more environmentally friendly alternative. Some of the viewpoints of the interviewees are listed below.

“Animal feed is currently using soya, which has quite a detrimental effect on the environment and ... you have by product that you can't utilise like you can do with insects... 100% can be used for useful end products such as let's say fertiliser.”

“One of the big motivations for the farmers is reducing reliance on imports... So they are soya free, but they don't ideally want to feed fish meal or rapeseed meal.”

“...being able to specifically avoid things like soya, which does have such a big environmental footprint in terms of habitat destruction.”

4.1.2 Circular Economy including waste management

The concept of a circular economy, specifically the potential to rear insects on food waste and then used them as feed for livestock, resonated strongly with the interviewees. They were keen to promote this cyclical approach, emphasising the importance of minimising waste and maximising resource efficiency in insect farming. The prospect of utilising waste food to produce valuable feed for livestock was viewed as a highly desirable aspect of insect farming practices.

“So it's yeah, it's reducing food competition, but also recycling “waste” back into the food system using nature as a solution in nature, there's no such thing as waste, and insects are part of that system where they are waste recyclers.”

“There are very few barriers and the regulators have seen a very proactive approach and would applaud, you know, Animal Plant Health Agency, Food Standards Scotland and the other UK operators in terms of seeing this as an opportunity in working with the industry really to move from a linear standpoint in terms of the regulations across the circular possession. You know they're thinking about waste management. So really the regulators are always happy to help. The system is already in place and those businesses who are in a position to help.”

“Keeping that food waste in the food system seems to be a really big deal. Rather than using it for ... energy production or something like that, you know it seems the food system can be circular.”

Using insects to recycle waste offers significant advantages in terms of greenhouse gas emissions reduction when compared to landfill disposal or composting. By employing insects to recycle waste, we not only avoid emissions from waste disposal in landfills but also surpass emissions from composting methods. This finding highlights the potential of insect-based waste management as an effective and environmentally friendly solution with superior greenhouse gas mitigation benefits.

“...using insects to recycle waste and it's more you avoid the greenhouse gas emissions from just discarding that waste into landfill, but also comparing it to composting.”

4.1.3 Future business opportunities and value-added products

Interviewees identified numerous business prospects for insect-based products. The main focus was on frass, which refers to insect excrement which is currently being used as a fertiliser. Interviewees emphasised the increasing value of frass, highlighting that it often holds greater commercial potential than the larvae itself. This is primarily due to the flexibility it offers in terms of commercialisation, particularly for fertiliser purposes. Furthermore, frass is subject to fewer restrictions compared to other insect-derived products, making it an attractive market opportunity.

4. Results and Discussion (2)

“...of course insect protein is very important to upcycle, but the frass is actually becoming more and more valuable and in many cases it's even more valuable than the larvae itself because I mean the frass has more flexibility on how to commercialise especially for fertiliser and there's less restrictions.”

“We can talk about the insect protein as feed, we can talk about avoiding emissions from that land use change and the soya, but it really propagates through the whole system and fertiliser is the big story at the moment... we're working with SRUC colleagues to understand the full characteristics of the frass, particularly Black Soldier Fly, but also the benefits of the application of the field and there's some really interesting things coming out of that.”

In addition, interviewees identified the pet food sector as offering substantial opportunities for insect-based products. Premium pet food, in particular, was recognised as a significant market segment, and there was mention of the potential expansion into edible human protein supplements such as protein bars. These emerging market areas provide avenues for insect companies to tap into a diverse range of consumer demands and capitalise on the sustainability benefits offered by insect-based products.

“I think premium pet food is the most like the biggest opportunity and maybe they (insect companies) are pushing edible human protein supplements like protein bars and these kind of things.”

4.1.4 Benefits to livestock health and welfare

Interviewees who had direct experience of feeding BSF larvae spoke at length about the benefits to their poultry both in terms of nutrition and when fed live as a form of enrichment. The quote below summarises this well.

“They [BSF larvae] are an amazing source of nutrients for the hens. They up-cycle this waste into a brilliant nutrient package high in protein and good fats which benefits the hens eating them live, so the larvae have this amazing gut microbiome... that gets passed on to the hens. And there's been studies showing that gut health of hens that have been fed BSL larvae is improved and then in terms of welfare

benefits, it's just such a great source of enrichment. They're so high value to the hens, like it's just such a joy to see the hens eating them. They go crazy when they see you coming.”

Therefore, there is an opportunity to capitalise on the production and distribution of BSF larvae as a sustainable and beneficial feed option for livestock, catering to the needs of farmers seeking to enhance the health and welfare of their animal/poultry.

4.2 Challenges for insect farming and industry for animal feed

Key challenges within the insect feed sector were the focus of all interviews. The main themes of the interviews were found to be: 1) limited information sources and lack of information/research, 2) Legislation, 3) the costs to produce insects (in the UK), 4) the costs and practicalities of feeding insects to livestock 5) the acceptability of feeding insects to livestock including animal welfare and ethical concerns. These challenges were not rated by interviewees therefore they are not reported in order of importance.

4.2.1 Limited information sources and lack of information/research

It was reported by many interviewees that it was hard to find information on how to farm insects and the implications of using them as animal feed. A few interviewees felt that the difficulties surrounding access to information were deliberate as it provided a competitive advantage to some groups, this is summed up well in the following quote:

“There are a lot of venture capitalists and private equity involved in this industry so it's limiting the amount of information spread -they want to keep all the IP [intellectual property] to themselves.”

“There's so much going on around intellectual property rights and so on.”

4. Results and Discussion (3)

To overcome the information gaps, many interviewees relied on informal networks, such as WhatsApp groups, to obtain new insights and resources. Also, the interviewees reported that acquiring information was primarily through networking and contacts, stating:

"We have a WhatsApp group... so people share ideas and links and things."

"...really was through kind of networking and contacts. I didn't... really find any kind of useful information, just from a farmer's perspective I suppose."

The internet was identified as a valuable source of information, with interviewees mentioning online platforms and resources like YouTube videos - *"it's all online based"*, *"lots of YouTube videos."* However, only three participants said that they had accessed more formal training, one had attended a course in Holland, one received training through seminars at their work and another felt that groups including innovative farmers had more recently been putting on webinars.

During the interviews, several gaps in knowledge about insect farming and the use of insects as feed for livestock were highlighted. Some talked of gaps generically *"not been enough research"*, referring to a lack of sufficient research. Others specified specific research gaps and priorities, as exemplified by the following statements:

"...still gaps in knowledge about the life cycle assessment of the whole process, including the fresh side, some people have done LCA's [lifecycle assessments], but only focusing on the insects."

"We know the benefits of feeding them to hens looking at feeding the pigs."

"I think some studies to de-risk feeding other types of waste that we can't feed directly to vertebrate livestock, but we

could feed to insect livestock. I think those studies are really needed because at the moment there's still a lot of waste that is getting wasted because we can't feed it to insects."

These insights from the interviews underscore the limited availability of information and research in the field of insect farming. The reliance on informal networks, online sources, and the identification of specific research gaps highlight the need for more accessible and comprehensive information resources, as well as targeted research efforts to address knowledge gaps and drive the development of insect-based livestock feed systems.

4.2.2 Legislation and insect-related regulations

The current legislative challenges in the UK which are a BREXIT legacy have resulted in farmers only being able to feed insects to livestock live. The majority of interviewees did not feel that there was a rush to change legislation any time soon. One interviewee said that they had written to a Scottish politician about the challenges in the insect farming sector and received the response:

"It is on the agenda to look at this legislation and we can't give you a timeline."

Most interviewees felt that the legislation needed to be the same as in the rest of the EU.

"They just need to align it [UK legislation] with European legislation. Just get it done."

Based on the interviews, a significant legislative challenge that emerged was the comparatively stricter rules governing the feedstock for insects in the UK compared to other countries. These regulations impose limitations on the types and quantities of waste that can be used as feed for insects, potentially placing the UK industry at a disadvantage. The following quotes highlight this issue:

4. Results and Discussion (4)

“At the moment it's just crazy that there's sources of feed that we could be using for larvae that we're not allowed to use, and so I think the research around that to de-risk it, to show that it can be done safely, then legislative change.”

"Feedstock can't be animal manure or postconsumer food waste, it can't be abattoir waste."

4.2.3 The cost to produce insects (in the UK)

Currently, the UK only permits to feed insects live to livestock. This means that insects need to be produced near to where they will be consumed, thus making UK-based insect production essential. However, producing insects within the UK comes with its own challenges, primarily due to the need for controlled environments that incur significant costs in terms of energy consumption and labour. One interviewee expressed the difficulty of breeding insects, highlighting its financial inviability:

"The breeding side of things is quite challenging... quite costly and it's not viable financially."

“Cost that's been a big deal... So much of it is about, well, part of it is about automation to bring the labour costs down but then the other part is about getting the nutrient profiles right and consistent. I think achieving that seems to be potentially a big cost barrier. So I think actually scaling the industry up is the is the other big thing. I think it really comes down to cost and making it appealing to farmers on that basis.”

On the other hand, another interviewee believed that with the right equipment, insect production could be carried out in an energy-efficient manner:

“I found that I can do it in a not energy-intensive way.”

“I think having the right is set up so you know, for instance my setup, it's in an insulated container, so you might have to have some heat on in the winter, but it's insulated and the insects themselves produce heat.”

“One of the farmers with one of the X1 units is using renewable energy to supply that, so he's not paying big energy rates.”

The lack of established supply chains was identified as another contributing factor to the high costs of insect production in the UK. The delayed interest in the industry until recent years has resulted in significant gaps and the absence of a well-developed supply chain. For the insect farming industry to thrive in Scotland, one interviewee expressed the need for more BSF larvae producers in the country. They also suggested establishing a system for distribution and knowledge sharing among farms of various scales, catering to different requirements, including potential use in pig feed alongside poultry feed:

“There needs to be more producers of black soldier fly larvae in Scotland and figure out some kind of system for distribution or for learning or so if farms want to do it because like better bugs do starter kits and it's much more aimed at very small scale. But you know just different scales, basically of producers using it. And I don't really know how it works in terms of pig feed, but if it could also fulfil some pig feed requirements as well as poultry.”

"There's a serious lack of supply chain and that's because there hasn't been any interest until the last five years, I suppose."

"There's a lot of the gaps structurally or there's no supply chain setup for this at all."

Despite the challenges, most interviewees expressed optimism that production costs could be reduced in the future. The collective belief was that if there was sufficient demand from farmers, prices could decrease by leveraging breeding operations in different regions, such as Scotland, where lower costs could be achieved:

“I think ultimately if there were enough farmers wanting to do it, the price would come down because you could get somebody breeding in Scotland and for lower cost.”

This outlook suggests that as the industry grows and gains momentum, there is potential for cost optimisation through increased demand, regional specialisation, and improved supply chain infrastructure.

4. Results and Discussion (5)

4.2.4 The costs and practicalities of feeding (live) insects to livestock

The current restriction on feeding insects to livestock only in live form was not favoured by many interviewees, who expressed concerns about the associated expenses, inconvenience, and additional time to feed livestock. Those that highlighted these issues felt that incorporating dried or powdered insects into existing feeding systems, such as pelleted feed, would be a preferable method. The following quotes highlight this perspective:

"We are only allowed to feed live insects...we would ultimately prefer to use dried insects."

"It would probably mix quite well with pelleted feed and most of the farmers want pelleted feed, especially ones on the islands because of transporting and just being able to get bags of it. And you know, and for this and for it to keep longer storage, just all those things it's just a much easier system obviously."

While some interviewees acknowledged that feeding live insects could have benefits for livestock, such as chickens and pigs, including behavioural enrichment and nutritional health, they also recognised the advantages of incorporating processed insect forms:

"...and sort of behaviour if they're fed live insects over. ...that's missing is sort of the insect protein which would be what they would normally eat. So yeah, it's I guess it's health for the animals."

On the other hand, there were additional benefits associated with feeding insects in live form, particularly in terms of energy efficiency. Processing insects into meals or pellets was considered more energy-intensive and potentially compromised the sustainability benefits:

"A study showed that the hens do prefer the live insects to the processed ones. And so it's, you know, it's an enrichment and preference issue, it's also a health issue. You're taking away those guts benefits of the live larvae and then it makes it more energy intensive... when we took the larvae process and turned it into meal ... feed that that step so energy intensive like drying, the insect meal it takes a huge amount of energy, so it takes away some of the sustainability benefits as well."

These perspectives emphasise the potential drawbacks and limitations of exclusively feeding insects to livestock in live form. The integration of dried or processed insect forms into existing feeding systems is seen as a more practical, efficient, and sustainable approach, providing benefits in terms of convenience, storage, energy usage, and overall livestock well-being.

4.3.5 The acceptability of feeding insects to livestock (including animal welfare concerns)

Interviewees did not raise any major concerns about consumer acceptability of feeding insects to livestock. One interviewee stated that:

"A study a few years ago and I think it was 85% Scottish consumers are more than happy for insects to be included in the feed for salmon."

However, some interviewees acknowledged the need for outreach and consumer education to increase awareness and acceptance among both consumers and farmers. One interviewee expressed the following statement:

"I think a lot of work needs to be done to educate consumers but also the farmers."

It is noted that all interviewees discussed the feeding of insects to poultry and pigs, and not ruminants. The consensus among interviewees was that pigs and poultry are suitable candidates for insect-based feed due to their natural diet. However, interviewees expressed reservations about feeding supplementary protein from insects to ruminants, stating that it was not a route they believed should be pursued. One participant with agricultural experience admitted that they had not previously considered feeding insects to ruminants:

"I'm for doing it with pigs and poultry. They're obvious candidates because that's part of their natural diet. But I wouldn't wanna feed supplementary protein to a ruminant... I don't think that is a route we should be going down."

Therefore, further research in this field is necessary to explore the potential benefits and considerations of incorporating insect protein into ruminant diets.

4. Results and Discussion (6)

The welfare of insects was also discussed by some interviewees. The two main aspects that were discussed were how to farm insects to ensure good welfare and the other concerned the humane killing of them particularly when currently they are only being fed live to livestock in the UK. One interviewee believed that, with the right knowledge and understanding, the needs of farmed insects could be met to ensure their well-being:

“I think with the right knowledge... we can meet the species-specific needs of the insects and we can keep them healthy.”

Another felt that insects were very different to other farmed species and therefore the use of the five freedoms which were devised with traditional livestock species in mind may not be appropriate for insect farming.

“There are guidelines and standards and so on now for farming insects. They tend to draw on the five freedoms, but it's really problematic because ...you know, freedom to express themselves well, you know, they might actually like to be in really close confinement...whereas for other animals you could probably say well, it's much better for them to have more space and so on. So ...it's not a simple transposition [from traditional farmed animals to insect farming].”

Another aspect of insect welfare that was discussed by interviewees was that evidence points to insects being sentient therefore a humane death was important and required further research. There was discussion about conducting experiments to determine the most humane methods of killing insects, taking into account the hypothesis that they fall unconscious and are killed further down the digestive tract:

“It's something I think about quite a lot because obviously I'm kind of an advocate of feeding them live. The definition of a humane death is one that's instant or they're rendered insensible first. ... If we're gonna process them, I think they can be killed humanely. I'd really like an experiment done looking into feeding BSL live. There's a hypothesis that so they're not macerated... they go into the crop, they fall

unconscious, and then they're killed further down the digestive tract. So, if that happened, and if they fell unconscious quite quickly, that would meet the definition of a humane death. And I'd love to think that nature has developed, you know, devised humane deaths for everything.”

“...showing that we do have good evidence pointing towards sentience and insects, so we should really be kind of thinking about it.”

“I think there's a bit more about, I don't know, feeding chickens and the possible welfare advantages and so on... but for the insect, I think there's so much ambiguity around, what good welfare is and whether it even whether it is even a thing, but the at the same time there's more research coming out about insects and pain and relationship between pain and nociception, and so on, and I think that how farmers deal with that and how consumers might feel about these things, I think they're probably all quite significant areas.”

One interviewee highlighted the importance of minimal intervention and a natural approach to insect farming, emphasising that such practices align with economic viability and sustainability:

“Why we're thinking welfare? Because I mean if we do all the complexities and everything around them and legislation and all the rules, we're basically kind of restricting us to ever using them like economically or sustainable way...It has to be as naturally as possible with minimal technology, minimal intervention, and that's the natural way to do it.”

Interestingly, when some interviewees were asked about animal welfare, they assumed the question was about the welfare of poultry or pigs, not the insects.

These insights from the interviews shed light on the acceptability of feeding insects to livestock, considerations regarding animal welfare, and the potential growth of the industry in Scotland.

Conclusion and Recommendations

This study aims to support the development of a farming and business strategy for insects as feed, particularly BFS, to support sustainable agri-food systems in Scotland. The strategic plan is based on insights gathered from interviews, which have identified numerous key opportunities and challenges associated with insect farming and the use of insects in animal feed within Scotland and the UK. Notable opportunities in this sector include insects as a sustainable protein source, circular economy and waste management, future business opportunities including the development of value-added products (e.g., fertiliser, pet food, etc.) as well as the benefits to livestock welfare. However, the interviews also highlight some key obstacles including limited information sources and lack of research related to insects as feed, slow and unclear insect-related legislation and regulations, the cost to produce insects, the costs and practicalities of feeding insects to livestock and the acceptability of feeding insects to livestock.

Based on the insights gained from interviews with industry experts and stakeholders, policymakers and the government can consider implementing the following key recommendations and strategic plans to develop insect farming and the insect feed industry in Scotland (and the UK). **Firstly**, it is urgent for the government to collaborate with industry experts and regulatory bodies to establish clear and transparent regulations and guidelines that are specifically tailored to insect farming and the use of insects in animal feed. These regulations should encompass licensing requirements, quality control standards, animal welfare considerations, food safety regulations, and environmental factors. By providing a robust regulatory framework, the government can ensure accountability, compliance, and the responsible development of the industry.

Secondly, the government should introduce policy incentives, such as grants and subsidies, as well as other forms of support to encourage investment in insect farming and feed production facilities. These incentives can offer financial incentives and facilitate access to financing, business development services, and market opportunities. Consequently, the government can create a favourable environment for startups and encourage existing players to expand their operations. This will help stimulate growth and innovation within the insect farming and feed industry.

Thirdly, facilitating industry collaboration and networking is essential for knowledge sharing, experience exchange, and collective problem-solving. Policymakers should foster platforms

such as associations, working groups, conferences, and networking events that bring together stakeholders from the insect farming and feed industry. By promoting collaboration, stakeholders can share best practices, address common challenges, and drive innovation, ultimately enhancing the industry's overall development and competitiveness.

Next, to accelerate the acceptance and adoption of insects as feed, the government and policymakers should focus on raising public awareness about the benefits of using insects as an alternative feed source. By promoting a shift in people's and farmers' perceptions, the demand for insect-based animal feed and edible insect market can be significantly expanded. Also, awareness campaigns, education initiatives, and targeted information dissemination can play a significant role in informing the public, consumers, and relevant stakeholders about the nutritional, environmental, and economic advantages of incorporating insects into animal feed.

Finally, it is crucial to prioritise further research and development in the areas of circular economy and waste management, animal welfare in insect farming, and insects for ruminant feed. The government should allocate resources and support scientific studies to explore innovative approaches and technologies that enhance sustainability and resource efficiency within the industry. By investing in research and implementing these solutions, the government can foster a more sustainable and resilient insect farming and feed industry, while creating new opportunities for farmers and business operators. This will not only contribute to environmental conservation and animal welfare, but also promote economic growth and food security in a more sustainable manner.

Overall, the implementation of these recommendations will help create an enabling environment for the development and growth of insect farming and the insect feed industry in Scotland and the UK. This will, in turn, contribute to the advancement of sustainable agri-food systems, address resource challenges, and promote a more environmentally conscious and resilient food production landscape.

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Acknowledgements

We would like to express our thanks to SEFARI and the Scottish Government for their support throughout this research project. Their funding, review and guidance are the instrument in driving the success of our research. We are also grateful for Dr William Clark from Scottish Forestry (former researcher from Zero Waste Scotland), Clem Sandison from Landworkers' Alliance, David Tavernor from Fly2Feed, Ykä Marjanen from Manna Insect, Dr Lizzie Rowe from the University of Reading, Tom Clarke and Michael Krauss from NETZSCH Mastermix Ltd., and Dr Christopher Bear from Cardiff University for their incredible contributions to our project. Their expertise and insights have enriched our study and provided valuable perspectives in our research. Lastly, we would like to thank Keele Business School, Keele University, for providing us with the opportunity to carry out this project to completion. Any errors in this research are entirely our responsibility.



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