# THE FUTURE OF FEED:

## A WWF ROADMAP TO ACCELERATING INSECT PROTEIN IN UK FEEDS

WWF

FOR YOUR WORLD

## ACKNOWLEDGEMENTS

This research was commissioned by WWF-UK and funded through the WWF-UK and Tesco partnership, which aims to halve the environmental impact of the UK shopping basket. The report was prepared by WWF-UK, Tesco, ADAS and Michelmores, with input from Multibox and stakeholders across industry. The report is underpinned by a Supporting Technical Report, prepared solely by ADAS and Michelmores, with input from Multibox (further details in References). We would like to acknowledge the following individuals and organisations that contributed to and made this research possible.

### Authors

We would like to thank the WWF-UK and Tesco team that managed and directed the project, provided feedback on the draft outputs and engaged with the project throughout:

**WWF-UK:** Mollie Gupta, Piers Hart, Sabrina Gonçalves Krebsbach, Lilly Da Gama, Cathrine Baungaard, Joanna Trewern, Sarah Halevy, Liam Walsh, Abigayil Blandon, Callum Weir, Anne Ryan, Sarah Wakefield and David Edwards

**Tesco:** Laurence Webb, Helena Delgado Nordmann, Ben Weis and Kené Umeasiegbu

**ADAS:** Charles Ffoulkes (Project Manager), Harriet Illman, Kath Behrendt, Olivia Godber, Mark Ramsden, John Adams, Phil Metcalfe, Laura Walker, Jason Gittins and Sarah Wynn (Project Director)

**Michelmores:** Rachel O'Connor, Freya Lemon, Kurt Wickland, Seema Nanua and Ben Sharples

**Multibox:** Paul Wright

**Report design and development of infographics by Creative RSK:** Alison Short, Dominic Bebbington, Emma Blaney and Peter Taylor

With thanks to colleagues no longer at WWF and/or Tesco but who inputted into the project: Emma Keller, Richard Perkins and Daniel Salter.



### Participants in the stakeholder consultations

We would like to thank representatives from the following organisations (as well as those who wished to remain anonymous) who participated in this research through either the telephone interviews, the online survey, or through providing feedback on the draft report:

Agricultural Industries Confederation (AIC), AgriGrub Ltd, APPI Biotech Ltd, Auchterlonie Consulting, Avara Foods Ltd, Beta Bugs Limited, Better Origin, BioMar Group, British Aqua Feeds Ltd, British Standards Institution (BSI), Cardiff University, Cargill, Cefas, Centre for Agriculture and Bioscience International (CABI), Cimex, Co-op, DAB Renewables, Davidson Brothers (Shotts) Limited, Davidsons Feeds, Enterra Feed, Entobel, Entocycle, Entomatrix Technology Corporation, Extrusion-Link Ltd, FabraUK, Great British Aquatech, Green Grub Solutions, Harper Adams University, Hilton Seafoods UK, Immune Macro Biotic Technology (IMBT), InnovaFeed, Innov'Aquaculture, Insects in Service of Mankind (ISMK), Inspro, International Platform of Insects for Food and Feed (IPIFF), JLG & SL McLane, Melrose Pigs Ltd, Lerøy Seafood Group, Monkfield Nutrition, Monterey Bay Aquarium Seafood Watch, Multibox, Nasekomo, National Pig Association, Novento Foods, Nu-Tree Ltd, NUTRIFARM-Rwanda, Nutrition Technologies, Peregrine Livefoods, Poseidon, Queen's University Belfast, Red Tractor (Assured Food Standards), Research Institute of Organic Agriculture (FiBL), Roberts Bakery, Sainsbury's, Scotland's Rural College (SRUC), SEFARI and JHI, Skretting, SMCW Consultants Ltd, Unconventional Connections and the Woven Network, University of Edinburgh, University of Nigeria Nsukka, University of Surrey, Vodnik Fisheries and Zero Waste Scotland.





# CONTENTS



# TABLES



# FIGURES

# GLOSSARY

| | |
|---|---|
| **Anaerobic digestion (AD)** | A form of waste processing whereby organic matter, such as animal, food or other materials, is broken down, or digested, to produce biogas and biofertiliser. Considered a form of 'recycling' within the food and drink material hierarchy. |
| **Animal by-products (ABPs)** | Entire bodies or parts of animals, products of animal origin or other products obtained from animals, which are not intended for human consumption. |
| **Animal protein** | Protein derived from meat and/or seafood intended for human consumption. This includes whole animal protein (e.g., chicken breast), processed protein (e.g., chicken pieces present in a ready meal) and products derived from animals (e.g., milk and eggs). |
| **By-product** | An incidental or secondary product resulting from the manufacture or synthesis of something else. |
| **Chitin** | A substance found in the exoskeletons of insects, other arthropods and in fungi. Chitin is used in a range of industrial processes, including the production of pharmaceuticals, food and cosmetics. |
| **Defatting** | A step within the processing of feed materials which involves removing the lipid, or fat, content of the material to concentrate the protein content. |
| **Docosahexaenoic acid (DHA)** | A polyunsaturated omega-3 fatty acid. These can be produced by micro- and macroalgae, and can be synthesised from linoleic acid by animals. DHA is present in fishmeal and fish oil and is an essential component of fish nutrition. |
| **Eicosapentaenoic acid (EPA)** | A polyunsaturated omega-3 fatty acid. These can be produced by micro- and macroalgae, and can be synthesised from linoleic acid by animals. EPA is present in fishmeal and fish oil and is an essential component of fish nutrition. |
| **Farmed animal** | Any animal that is kept, fattened or bred by humans and used for the production of food, wool, fur, feathers, hides and skins or any other product obtained from animals or for other farming purposes. |
| **Feed** | Refers to any substance or product, including additives, whether processed, partially processed or unprocessed, intended to be used for oral feeding to animals. |
| **Feedstock** | The raw material(s) required to supply or fuel a machine or industrial process. |
| **Food** | Refers to any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be, ingested by humans. |
| **Frass** | The excrement of insects. Frass is high in nitrogen and a by-product of insect farming. |
| **Hydrolysed proteins** | Proteins which have been broken into their smaller constituent parts, including large peptides, small peptides and/or amino acids, by hydrolysis. This enables the extraction of protein from animal by-products, brewers' grains and plant material containing anti-nutritional factors. Hydrolysed protein derived from these permitted materials may be added to feed to improve growth. |
| **Insect meal** | A high-protein dry meal that is derived from the processing of whole insects. |
| **Insect protein** | Proteins for consumption as food or feed derived from rearing insects. Insect protein could refer to the meal, whole or hydrolysed forms. |
| **Monogastric** | Organisms that have single-chambered stomachs, such as humans, horses, pigs and chickens. |
| **Processed animal protein (PAP)** | Protein derived from animals that has been through a stage of processing. This includes meat meal, bone meal, blood meal, dried plasma and other blood products, hydrolysed protein, hoof meal, horn meal, poultry offal meal, feather meal, dry greaves, fishmeal, dicalcium phosphate, gelatin and any other similar products, including mixtures, feeding stuffs, feed additives and premixtures, containing these products. |
| **Ruminant** | Herbivorous, hoofed mammals which digest food via fermentation across four stomach chambers, enabling more efficient uptake of nutrients from feedstocks. These include livestock such as cows, sheep and goats. |
| **Substrate** | The surface or material on or from which an organism lives, grows or obtains its nourishment. |
| **Surplus** | The quantity of material left over once requirements have been met, or an excess of production or supply. |
| **Transmissible spongiform encephalopathies (TSEs)** | A group of fatal and rare degenerative brain and nervous system disorders. TSEs are known to be transmissible from livestock to humans via the consumption of contaminated meat and result from ruminants consuming ruminant material. |
| **Waste** | Any substance or object which the holder discards, intends to, or is required to discard and further defined in Article 3 of Directive 2008/98/EC. |

# EXECUTIVE SUMMARY

56–82%

PROTEIN CONTENT ATTAINABLE IN INSECT MEAL

## BACKGROUND

Livestock play a crucial role in the food system, contributing to our livelihoods, cultural richness, and dietary nutrition worldwide. Through converting plants and other raw materials into food for people in the form of animal protein, livestock are able to make use of materials which humans might not be able to consume directly, like grasses and certain agricultural by-products.

However, worldwide there are a colossal 80 billion animals reared and slaughtered each year. All of these farmed animals require their own sustenance in the form of animal feed for growth and metabolism. Growing this feed requires precious resources like land and water. The production of soy in particular, 75% of which is used in animal feed, is fuelling climate change through deforestation and habitat conversion in critical ecosystems like the Brazilian Cerrado, Argentine Gran Chaco and the Northern Great Plains in the US. Despite the risk we are putting our planet and climate at to produce feed and livestock, in European diets, the consumption of animal protein far exceeds dietary requirements and future demand for meat and dairy remains relentless.

We are facing an urgent triple challenge to prevent catastrophic climate change while restoring nature, and ensuring that healthy and sustainable diets are accessible to a growing population. It will be crucial to examine meat and dairy production and consumption to address these challenges, and in the UK there is increasing dialogue on how 'less and better' meat and dairy might be adopted. Coined by the Eating Better Alliance, this term refers to reducing the consumption of meat and dairy in 'less', and ensuring that any meat and dairy produced comes from animals reared within healthy ecosystems, on more natural diets where ingredients are from sustainable sources, and on farms that deliver high standards of animal welfare in reference to 'better'. This emphasis on natural diets from sustainable sources demonstrates that the way our livestock are fed is a critical contributor to 'better' meat.

Better feed production refers to that which protects forests and high-value ecosystems, prioritises land to grow food for people, reduces toxicity and eutrophication, and ensures that water is sourced from areas of sustainable water management. If produced in accordance with these principles, alternative feed proteins provide a lever to tip the feed system towards improved efficiency and environmental protection. One such alternative feed protein could be derived from insects, which contain a defatted protein content between 56 and 82%, reaching up to double the protein content of soybeans (40% protein) and in excess of the protein content of hi-pro soymeal (up to 50% protein).

In natural ecosystems, insects play a variety of roles, functioning as pollinators, predators and prey for a whole spectrum of other organisms which live alongside them. Importantly, many insects are biological waste processors, helping to recycle and decompose material within ecosystems. This means that, when farmed, insects can be reared from a vast range of feedstocks, or substrates, converting this material into high-protein body mass. Insect farming therefore presents the opportunity to produce a high-protein feed ingredient which can displace proportions of soymeal and fishmeal while also processing quantities of food surplus, food by-products and other raw materials which cannot be consumed directly by people and might otherwise go to 'waste'.



While insect protein is commercially available as bird and pet food, and is present in low quantities in some aquafeeds, it is yet to penetrate the livestock feed sector due to several constraints (Chapters 2 and 3). For insect protein, and indeed other novel proteins, to transition from niche products to commonly used feed ingredients, routes to greater volumes and markets are required. This study examines how the production of insect meal might scale up in UK pig, poultry and salmon feeds, with focus on the black soldier fly, and what this could mean for the UK's future soy and fishmeal footprint.

540,000 TONNES

POTENTIAL ANNUAL DEMAND FROM UK PIG, POULTRY AND SALMON SECTORS BY 2050

### Report findings

We project that the total demand for insect meal from the UK's pig, poultry and salmon sectors could reach the region of 540,000 tonnes a year by 2050. Of this, around 240,000 tonnes of insect meal per year could be sourced from UK insect farms. In doing so, UK insect farms would convert 3.4 million tonnes of feedstock substrate material, which might otherwise go to waste, into a high-protein feed ingredient (Chapter 4).

If total demand for insect meal from UK agriculture is met, either through further, more ambitious scaling up of insect farming in the UK, or through the procurement of insect meal from other geographies, annually around 16,000 tonnes of fishmeal and 524,000 tonnes of soy could be displaced in UK feed. This is equivalent to one fifth of the UK's projected 2050 soy import volumes, or Tesco UK's entire 2018 soy footprint. To produce this quantity of soy annually, at least 150,000 hectares of land would be required, almost the size of Greater London. These figures are based on conservative estimates where insect meal constitutes 12% of the diet of salmon, 6% of the diet of poultry and 5% of the diet of pigs (Chapter 4).

20%

THE REDUCTION IN SOY IMPORTS POSSIBLE IF THE USE OF INSECTS IN UK FEEDS CAN SCALE UP

Our calculations suggest that the cost of production of insect meal could fall between the current market prices of soymeal and fishmeal, with costs falling over time with economies of scale. Thus, in the near term, insect meal could be cost competitive with fishmeal and, in the longer term, with soy too.

To secure this future vision for a more diversified and circular UK feed system, and to reach the volumes and price points for insect meal demonstrated as possible by our study, action is required from UK industry and policymakers. The volumes of UK-reared insect meal are currently too low to enable uptake by feed manufacturers. Even though the use of insect meal is currently permitted within aquaculture, volumes cannot increase in the absence of investment, increased demand and enabling policy conditions. Collaboration is therefore required to accelerate growth and realise the potential of the industry.

## RECOMMENDATIONS TO STAKEHOLDERS

### UK GOVERNMENT

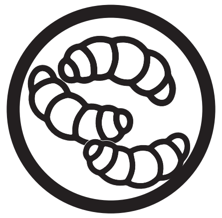
Existing legislation is placing a stranglehold on insect farming, restricting what materials insects can be reared from and preventing insect meal from being used in pig and poultry feed. The UK government must introduce legislation permitting the use of insect meal in pig and poultry feed and, subject to the appropriate research, broaden the range of feedstocks which can be used to farm insects.

### AQUACULTURE AND RETAIL SECTORS

As the use of insect meal is already permitted in aquaculture, aquaculture suppliers and retailers should work together to increase demand within this sector. This could be through commitments to using specific volumes or through the development of customer-facing marketing to encourage consumption of insect-fed fish, given that insects are natural components of many fish diets.

### PIG, POULTRY AND RETAIL SECTORS

The pork and poultry sectors should work with retailers, civil society and other industry stakeholders to advocate for the introduction of legislation permitting the use of insect meal in pig and poultry feed. This will create enabling conditions to displace the greatest quantity of soy from the UK footprint.



### INSECT FARMERS

UK insect farmers should develop an industry standard or code of conduct outlining core principles for production and minimum standards. This will provide retailers and their pork, poultry and aquaculture suppliers assurance that the insect meal they are sourcing is safe to use, nutritious and sustainably produced.

### FINANCIERS

Financiers should build a platform or mechanism to support collaboration and investment, geared towards increasing the confidence of private investors to fund the commercialisation of insect production on a larger scale.

### RESEARCHERS

Researchers should increase publicly available scientific evidence on how insects can most effectively be used in animal feed. Critically, this should include standardised life cycle assessments to determine how insect farming can yield optimal sustainability outcomes. The risks associated with different insect feedstocks and how these risks can be mitigated should also be researched.

### CRITICAL CONSIDERATIONS

In addition to supporting the development of insect farming, feed buyers should also invest in other potential sustainable novel feed proteins in order to shift towards a more diverse and circular feed system. However, novel feed proteins are just one of many levers to shift the food system. Crucially, ending deforestation and habitat conversion for soy continues to be a priority, along with reducing the consumption of animal proteins.

# THE ROADMAP HOW WE CAN SCALE UP THE USE OF INSECTS IN UK FEEDS

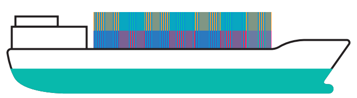
TOTAL UK DEMAND

| | 2021 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| Total UK demand | 21,000 TONNES/YR | 460,000 TONNES/YR | 510,000 TONNES/YR | 540,000 TONNES/YR |
| Insect meal from UK farms | <6,000 TONNES/YR INSECT MEAL FROM UK FARMS | 60,000 TONNES/YR INSECT MEAL FROM UK FARMS | 160,000 TONNES INSECT MEAL FROM UK FARMS | 240,000 TONNES INSECT MEAL FROM UK FARMS |
| Substrate | <90,000 TONNES SUBSTRATE PROCESSED/YR | 820,000 TONNES SUBSTRATE PROCESSED/YR | 2,270,000 TONNES SUBSTRATE PROCESSED/YR | 3,410,000 TONNES SUBSTRATE PROCESSED/YR |
| Facilities | 0 LARGE, 0 MEDIUM, 0 SMALL, <10 MICRO | 0 LARGE, 1-5 MEDIUM, 5-10 SMALL, 10-15 MICRO | 1-3 LARGE, 6-10 MEDIUM, 10-15 SMALL, 15-20 MICRO | 3-5 LARGE, 10-15 MEDIUM, 15-20 SMALL, 20-25 MICRO |
| | <10 UK PRODUCTION FACILITIES | UP TO 30 UK PRODUCTION FACILITIES | UP TO 48 UK PRODUCTION FACILITIES | UP TO 65 UK PRODUCTION FACILITIES |

TOTAL UK DEMAND

## WHERE WE COULD BE BY 2050

**If total demand for insect meal in UK feeds is met, 524,000 tonnes of soy could be displaced from future soy imports**



**This quantity of soy would require at least 150,000 hectares of land each year to produce, an area almost equivalent to the size of Greater London.**

## HOW TO GET THERE:

**UK GOVERNMENT** must introduce legislation which permits the use of insect meal in pig and poultry feed, and broadens the range of feedstocks which can be used to farm insects.

**PIG AND POULTRY SECTORS** must advocate for the legislative changes required.

**AQUACULTURE SECTOR** must increase demand for insect meal in aquafeeds.

**RETAILERS** must support suppliers by encouraging the use of insect meal in supply chains, starting with aquafeeds.

**INSECT PRODUCERS** must develop an industry standard or code of conduct to assure customers of the minimum safety, sustainability, quality and welfare standards that will be met.


# CHAPTER 1 > INTRODUCTION

## THE ROLE OF FEED IN 'LESS AND BETTER' MEAT

**40%**

**PROPORTION OF GLOBAL ARABLE LAND USED TO PRODUCE ANIMAL FEED**

Farmed animals play a crucial role in the food system, contributing to livelihoods worldwide and shaping our rich cultural landscapes. Crucially, farmed animals provide protein and other essential nutrients by converting plant and other raw materials which might otherwise go to waste into food products which can be consumed by people.

However, an insatiable global appetite for meat and dairy means that, each year, approximately 80 billion farmed animals are reared and slaughtered (Ritchie and Roser, 2019). Producing quantities of animal feed sufficient to nourish this colossal number of farmed animals places pressure on our entire agricultural system, in which approximately 40% of global arable land is used to produce feed for livestock (WWF, 2020a). Demand for meat and seafood continues to increase, and therefore so too does demand for feed ingredients high in protein, such as soy and fishmeal, that fuel animal growth. In Europe, however, our actual consumption of animal protein far exceeds dietary requirements and, despite this overconsumption of meat and dairy, the majority of our calories and proteins are still actually supplied by plants (Ritchie, 2019).

Currently, the feed system is dominated by a few terrestrial crops which could be consumed directly by people, including soy, maize, wheat and barley, along with other critical ingredients like fishmeal and fish oil. While soy and fishmeal offer high protein levels and can be produced sustainably, over time we must reduce our dependency on the use of these in feed – our planet has finite land resources which cannot be exploited indefinitely. While there are significant quantities of previously converted land available in Brazil for soy expansion in the short term (Soterroni et al., 2019), in the longer term we must rebalance diets if we are to stay within our planetary boundaries for food production (WWF, 2020a). We must use our precious land resources to grow less feed for animals and more food for people.

If we are to meet the triple challenge of preventing catastrophic climate change, while also restoring nature and ensuring that healthy and sustainable diets are accessible to a growing population, we must move towards consumption of 'less and better' meat. This term, coined by the Eating Better Alliance of over 60 civil society organisations, is defined by two key components set out in the 'Sourcing Better' framework (Eating Better, 2021):

(1) less meat: reducing consumption of meat and dairy in the UK by 50% by 2030; and

(2) better meat: ensuring that any meat and dairy products that are consumed come from the best possible production methods. Therefore, 'better' meat comes from animals reared within healthy ecosystems, favouring more natural diets where ingredients are from sustainable sources, and on farms that are well managed to deliver high standards of animal welfare.

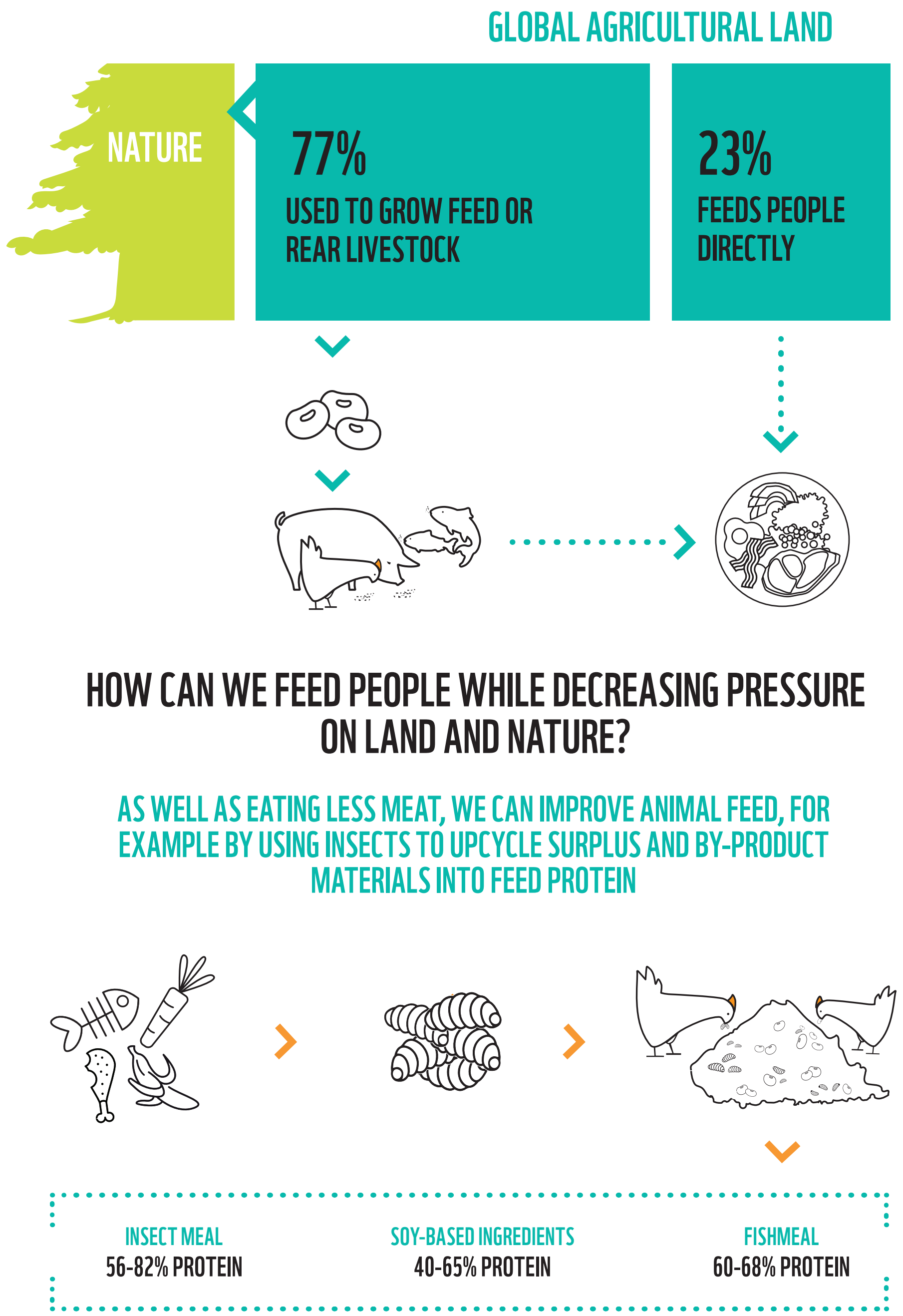
While there are a broad range of criteria attributed to 'better' meat, there is clear emphasis on livestock diets and the need to improve feed to reduce the overall environmental impact of meat production. There are several requirements that relate specifically to animal feed:

- land use change: protecting forests and other high value ecosystems like grasslands from land use change. This includes: (1) no deforestation or habitat conversion in the supply chain, (2) reducing reliance on imported feeds, (3) eliminating any soy and palm kernel meal without physical certification.

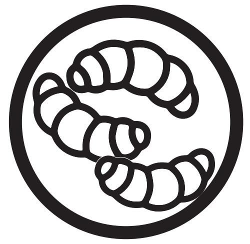
- land use change: reducing the use of land suitable to grow human-edible foods, like legumes and cereals, for animal feed.
- lowering the pollution footprint: reducing the amount and toxicity of pesticides used to grow feed crops and reducing eutrophication.
- water scarcity: sourcing from areas with sustainable water management and minimising the use of irrigated crops for animal feed.

In line with reducing reliance on imported feed and eliminating deforestation and habitat conversion for feed production, a key measure of better feed is the percentage of feed coming from alternatives to soy. If produced using raw materials which cannot be consumed directly by people, or indeed livestock, alternative feed ingredients provide a lever to tip the feed system towards improved efficiency while also offering pathways to reduce materials that might otherwise go to waste. But to realise these benefits, more must be understood about alternative feed ingredients and their route to scale.

Figure 1. Reducing the land footprint for feed.





**56-82%**

**PROTEIN CONTENT ATTAINABLE IN INSECT MEAL**

## NOVEL FEED PROTEINS

There have been a range of novel feed proteins in development over the past decades, however, few have penetrated the market. To be competitive with and thus displace conventional feed proteins, novel proteins must offer either comparable or better cost advantages and/or functional advantages. The environmental impact of their production must also be favourable to soy and fishmeal, and favourable to other processes typically used to process any unused raw materials which might be used as inputs or feedstocks.

Among algal, yeast and bacterial derived proteins, insect-derived protein offers promising potential. The natural diets of many animals, both farmed and wild, include insects. If allowed to do so within the production environment, farmed freshwater fish, poultry and pigs would consume insects as part of their natural behaviour. As well as containing healthy fats and oils, insects can yield 56–82% protein content following defatting, offering good nutritional content for feed (Makkar et al., 2014). Given the role that insects play in natural ecosystems as biological waste processors and decomposers, they can be reared from a vast range of feedstock substrate materials. This ability to convert substrates into a high-protein product positions insects as one of several potential novel feed ingredients that could displace proportions of soybean meal and fishmeal in feed.

While insect protein is commercially available as bird and pet food, and is present in low quantities in aquafeed, it is yet to penetrate the livestock feed sector. Like all novel feed proteins, to transition from a niche product to a commonly used feed ingredient, routes to greater volumes and markets are required. This study explores how supply chain food by-products and surpluses could guide growth in insect protein production, using the UK as an example geography. We then propose actions that might be taken by UK stakeholders to realise such growth. We focus on the rearing of black soldier fly, as a commonly farmed insect species, and how it could displace proportions of soymeal and fishmeal in UK salmon, pork and poultry feed, and therefore contribute towards the reduction in UK footprint in these commodities.

## CONVENTIONAL HIGH-PROTEIN FEED INGREDIENTS: SOYBEAN AND FISHMEAL

Animals require essential amino acids to develop and grow, as well as a number of other key nutrients. The protein level required in diets varies among livestock species, with fish, chicken and monogastric animals, such as pigs, requiring higher dietary protein relative to ruminant species.

**48%**

**PROTEIN CONTENT OF SOYMEAL**

### Soybean – a high protein plant

Soybean (*Glycine max*) is a species of legume widely grown for its edible bean. Soy produces more protein per hectare than any other major crop (WWF, 2014), and has a higher percentage of protein than many animal products: dried soybean contains 35.9g protein per 100g, compared to 34.2g for cheese and 21.1g for pork (Hoste and Bolhuis, 2010; cited in WWF, 2014).

Of all soy cultivated, 85% is destined for animal feed, with only 15% going to other uses, including biofuel, industrial processes, and direct consumption by people, such as in tofu or burgers (Voora et al., 2020). The major soybean products used in feed are whole soybeans, soy oil, soy meal (crushed and defatted soybean) and soy protein concentrate (crushed, defatted, purified and dehydrated soy protein). Whole soybeans contain approximately 40% protein (Heuzé and Tran, 2016), while extracted or hi-pro soymeal contains approximately 48% protein (Heuzé et al., 2020). The soy protein concentrate typically used in aquaculture contains approximately 65% protein. Other soy protein isolates exist which can consist of more than 90% protein (Lusas and Riaz, 1995). Soymeal prices have seen a slight decline and stabilisation over recent years, although since 2018 the price of Brazilian soy has increased due to demand from China shifting from US to South American soy (Fuchs et al., 2019).

The UK has a significant soy footprint, on average importing 3.6 million tonnes each year (WWF and RSPB, 2020). In the regions which the UK sources soy from, Argentina, Brazil, Paraguay and the US, soy production comes with a high risk of deforestation and habitat conversion (WWF and RSPB, 2017). In these regions are precious habitats like the Amazon rainforest, the Cerrado savannah, the Gran Chaco woodlands and the Northern Great Plains grassland, which collectively contain an immense variety of plant, animal and cultural diversity.

Unfortunately, land conversion for soy is ongoing, especially where environmental regulation is weak or poorly enforced. In addition to habitat loss and the severe impacts on biodiversity that come with it, soil erosion on vast plantations and loss of carbon to the atmosphere through land use change are also significant issues, alongside exploitation of land and labour rights (WWF, 2021; WWF and RSPB, 2020). While soy that is certified to be deforestation- and conversion-free is available under the Roundtable on Sustainable Soy (2021) scheme and others, the majority of the world's soy is not cultivated to an environmental standard (Voora et al., 2020).

**360 MILLION TONNES**

**SOY PRODUCED GLOBALLY IN 2020**

Great strides have been made in the responsible production of soy, for example, through biome-wide solutions such as the Amazon soy moratorium and joint calls from civil society and the private sector such as the Cerrado Manifesto and Statement of Support Group (IDH, 2020). There has also been recent and significant action within the salmon industry, as salmon producers will now only purchase soy protein concentrate from soy traders and suppliers that have a company-wide policy not to source soy from the Cerrado biome that has come from land converted after August 2020 (Mano, 2021). Verified deforestation, conversion and exploitation free soy, produced in alignment with the guidelines set out in the Accountability Framework Initiative (2021), must become mainstream, and efforts seeking to achieve this must continue to be supported.

Alongside improving production, we must recognise that predicted future demand for soy is alarming, with some estimates projecting 2050 soy production to be as high as 515 million tonnes (WWF, 2014), a significant growth from the 360 million tonnes produced in 2020 (USDA, 2021). While there is scope for soy expansion in the short term (Soterroni et al., 2019), ultimately our land resources are finite. Therefore, long-term strategies to reduce soy demand are required if we are to reduce pressure on the biodiverse landscapes where soy is currently produced. In line with 'less and better', reduced consumption of meat alongside scaling up the use of novel feed proteins are both levers towards this end, with insect protein potentially playing a key role in displacing proportions of soy used.

**60–68%**

**PROTEIN CONTENT OF FISHMEAL**

### Fishmeal

In 2018, 12% of global fish production was used for non-food purposes, with the majority of this used for the production of fishmeal and fish oil (FAO, 2020). There are three main sources of fishmeal: fish stocks harvested specifically for the purpose, known as forage fish, for example, small, bony and oily fish such as anchovy, herring and pollock; by-catches from other fisheries; and trimmings and offal left over from fish processed for human consumption that is unpalatable or fast spoiling (Heuzé et al., 2015). Fishmeal has a protein content of 60–68% as fed (Heuzé et al., 2015), and offers essential omega-3 DHA and EPA oils. Fishmeal price can vary significantly due to fluctuations in global supply and demand linked to decreasing fish stocks and global weather phenomena such as El Niño (Heuzé et al., 2015), but it typically fetches a price that is at least triple that of soybean meal. There are concerns around the over-exploitation of wild-caught forage fish for the production of fishmeal, and the consequences of this on the stocks of other wild caught fish, along with the wider marine ecosystem due to overfishing and by-catch (WWF, 2020b). As with feed ingredients produced on land, we should be using our marine resources to feed people directly as far as possible.

© NNATTALLI / SHUTTERSTOCK / WWF

© NAPAT / SHUTTERSTOCK / WWF

## COULD INSECTS BE A SOURCE OF FEED PROTEIN?

The natural diets of many animals, both farmed and wild, include insects. If allowed to do so within the production environment, fish, poultry and pigs would consume insects as part of their natural behaviour. Commonly farmed insect species include the banded cricket (*Gryllodes sigillatus*), Jamaican field cricket (*Gryllus assimilis*), house cricket (*Acheta domesticus*), mealworm (*Tenebrio molitor*), house fly (*Musca domestica*) and the focus of this study, the black soldier fly (*Hermetia illucens*).

Insects can be farmed in a range of locations, climatic conditions and production scales. There are examples of both industrial-scale automised production facilities and smaller-scale, on-farm units (FAO, 2013). Generally, insects are reared, euthanised humanely and then processed by crushing to separate the protein and oil content, both of which are considered high-value products. This process leaves a concentrated and dry meal containing 56–82% protein (Makkar et al., 2014), up to double the protein content of soybean and in excess of the protein content found in hi-pro soymeal. Insect meal can be added to animal feed rations, often as pellets or part of compound feeds.

The amino acid profile and digestibility of meals is also important in feed formulation. Some studies suggest that insect meals could have competitive amino acid profiles to fishmeal, including a range of essential or indispensable amino acids, however, composition and digestibility vary by insect species, life stage, feedstock diet and rearing system (Nogales-Mérida et al., 2018; IPIFF, 2020).

Available evidence suggests that insect-based feeds are comparable with fishmeal and soy-based feed formulae in terms of protein and nutritional properties (IPIFF, 2020), with the exception of fish oils, which cannot be sourced from insects but are required in aquafeed (Belghit et al., 2019).

A key by-product from insect biomass production is the insects' excrement, known as frass, which is high in nitrogen and can be applied to soil as a fertiliser, offering an additional income stream and thus contributing towards the commercial viability of insect farming businesses. A second and potentially high value by-product is chitin, found in exoskeleton skin sheddings, and with potential use in pharmaceuticals, textiles industries and agriculture (PROteINSECT, 2016).

### THE PRODUCTS OF INSECT FARMING:

## PROTEIN, OIL, FRASS & CHITIN

ADULT

LARVAE

CIRCULAR IMAGES: © SHUTTERSTOCK / WWF



## REVIEW OF LITERATURE ON THE ENVIRONMENTAL IMPACT OF INSECT PRODUCTION

Insect farming and processing requires a feedstock substrate and energy, water and land to operate the farming facility. The extent of the environmental impact will therefore depend on the insect species (see Supporting Technical Report, Section 2.1.1, Table 1), substrate(s) used, the use of by-products from insect production, and the power and heat source for the insect rearing facility. Impacts can also vary by geography and location of the insect farm.

A literature review completed for this study, taking into account a range of environmental factors, suggests that the overall environmental impact of insect production is lower than those of the production of soybean and fishmeal (Table 1). While this review included both grey and academic literature, it is important to note that there is limited literature available and further research is required to quantify the environmental impact of different insect production systems and to determine the rearing conditions required for optimal environmental outcomes. The literature suggests that the greatest reductions in impact will be in land use (compared to soy production) and biodiversity (compared to both soy and fishmeal production). This is due to the high risk of habitat conversion for soybean production and the reduction of fish stocks for providing fishmeal for use in aquaculture. For further information on the methods used to compare environmental impacts, see **Supporting Technical Report Section 2.2.**

**Table 1. Summary of literature on the environmental impact of insect farming relative to soy and fishmeal production.**

Indicative high-level summary of existing literature comparing the relative impact of soymeal, fishmeal and insect meal production on the environment, considering both state indicators and pressure indicators. This summary is based on interpretation of the scientific evidence-base reviewed in this study, however, further research is required. The impact of soy and fishmeal production is based on uncertified material. The impact of insect meal production is based only on European insect farms.

**■ high impact; ■ moderate impact; ■ low impact; blank for negligible or unknown impact**

| ENVIRONMENTAL IMPACT | | SOYBEAN MEAL | FISHMEAL | INSECT MEAL |
|---|---|---|---|---|
| **State indicators (i.e. changes to the state of nature)** | | | | |
| Land use change | | High conversion risk | No impact | No land use change at scale |
| Soil condition | | Intensive agriculture | No impact | No impact |
| Climate impact | | Conversion | Relatively low emissions from shipping | Operation of facility |
| Water removed | | If irrigated | Low impact | Operation of facility and substrate moisture adaptation |
| Nitrogen | | If NPK applied to soy or to crops in rotation | No impact | Nitrogen accumulation in frass |
| Biodiversity | | Conversion and intensive agriculture | Reduced fish stocks, by-catch | Low ecological impact |
| Pollution | | Pesticide use and eutrophication | Effluent discharge | Limited evidence |
| Waste | | Limited evidence | Limited evidence | By-products chitin and frass have uses |
| **Pressure indicators (i.e. environmental footprint assessments)** | | | | |
| Land use footprint | | Large area required | Small area used | Small area used |
| Carbon footprint | Direct | Cultivation and shipping | Fishing vessels | Heating requirement |
| | Indirect | Land use change | Low indirect footprint | Substrate dependent |
| Water footprint | | High water use | Limited evidence | Low water use |

# CHAPTER 2 > CURRENT STATUS OF INSECT FARMING IN THE UK

## INSECT FARMING IN THE UK IN JANUARY 2021

The insect farming industry in the UK is relatively new and unestablished, consisting of just a few micro- and small-scale facilities, including but not limited to AgriGrub, Beta Bugs, Better Origin, Entocycle, InsPro, and Monkfield Nutrition. These facilities are researching, developing technology and producing insect-derived products for a range of end uses, such as feed for birds, reptiles and hedgehogs. In addition, small volumes are being used in feeds, including processed insect protein for use in aquaculture and pet foods, and live insect feed for livestock on pilot farms (e.g. on poultry farms).

**THE UK'S FIRST INDUSTRIAL SIZED FACILITY IS IN CONSTRUCTION, THE FIRST STEP TOWARDS SCALING UP UK OPERATIONS**

The UK insect farming industry is growing, with the construction of the first industrial-sized facility in the UK approved following the award of government grant funding in 2020 (UKRI, 2020). The new facility has also received support from wider industry (Holland, 2020), and will rear black soldier fly on former foodstuffs and food surplus substrates to create insect protein for aquaculture feed and pet food. There are also a number of other smaller-scale insect farming businesses entering the market.

The Insect Industries UK Secretariat, formerly the Insect Biomass Task & Finish Group, represents UK insect farmers and others across industries with an interest in advancing insects as feed. The group's purpose is to foster industry collaboration to promote insect farming in the UK.

While there are examples of insect production in the UK and new facilities are under construction, the growth of the industry is lagging behind other regions, such as mainland Europe and North America. In these regions, considerable public and private investment has encouraged the development of large industrial-scale facilities, which are already operational and supplying processed insect protein to aquaculture.

## TAKING STOCK: PERCEIVED BARRIERS TO SCALE-UP AND OPPORTUNITIES TO BE UNLOCKED IN THE UK

Setting out a future vision for insect farming in the UK requires an understanding of the current barriers preventing growth of this industry at full speed. Stakeholder consultations were carried out to gather perspectives from across the feed industry and the insect production value chain. Over 80 organisations contributed via either telephone interview or online survey, including insect producers, insect technologists, researchers, feed manufacturers, processors and manufacturers, farmers, retailers and regulators. While the majority of respondents were based within the UK, insights were also received from organisations based in other European nations, the US, Africa, Asia and Brazil.

While responses were welcomed from any stakeholder that wished to participate, the networks and forums used to circulate surveys typically favoured stakeholders who may already have an interest in the insect value chain. See **Supporting Technical Report section 3** for further information on methods used.


Example of a UK black soldier fly farm in Cambridgeshire

# BARRIERS TO SCALE-UP

## LEGISLATION

Existing legislation was considered by stakeholders to be the greatest barrier to scaling up insect farming in the UK. It is severely limiting the markets in which insect protein can be sold. In light of this, Chapter 3 provides a detailed overview of existing legislation and how it is limiting.

## FINANCE AND INVESTMENT

Start-up costs for new entrants into insect farming remain high, and support is initially required for operational costs, especially for industrial-sized facilities. These costs are not insurmountable but do require investment. However, access to adequate funding was considered the next greatest barrier after existing legislation. Key areas of concern remain:

- Private investors require confidence in the growth of the sector, but existing legislation is preventing this and obscuring likely future returns.
- There is a lack of government support for insect farming, such as through subsidies or support schemes that are available to other agricultural producers in the UK. Relative to other European nations, public investment in insect farming in the UK has been low.
- As there is currently a limited set of feedstock substrates permitted for use in insect rearing, insect farmers are in competition with subsidised industries such as anaerobic digestion for access to these substrates. This reduces security of supply of substrate and therefore security of supply of insect meal, which is required for investor confidence.

## RETAILER REQUIREMENTS

Through product specifications, retailers influence the production methods for meat and seafood in their supply chains, including the composition of feeds used to rear animals. Feed producers and farmers are required to meet these specifications and produce to any standards mentioned within them as a condition of supply. While these are designed to protect the reputation of the industry and ensure that consumer quality expectations and safety needs are met, these do limit the degree of flexibility feed producers have to incorporate alternative ingredients in feed. The key areas of concern cited by stakeholders related to:

- In most cases, existing agricultural standards do not apply to insect farming. These require adaptions or exceptions in reference to insect-derived protein as a feed ingredient to enable insect meal to be used more widely in feed products.
- Alternatively, an insect-specific standard or code of conduct could be established, but as yet does not exist.
- This lack of standardisation and assurance contributes to a lack of encouragement from retailers to support suppliers in using insect meal over alternative feed proteins, despite existing interest. This potentially suppresses demand.

## CONSUMER ACCEPTANCE

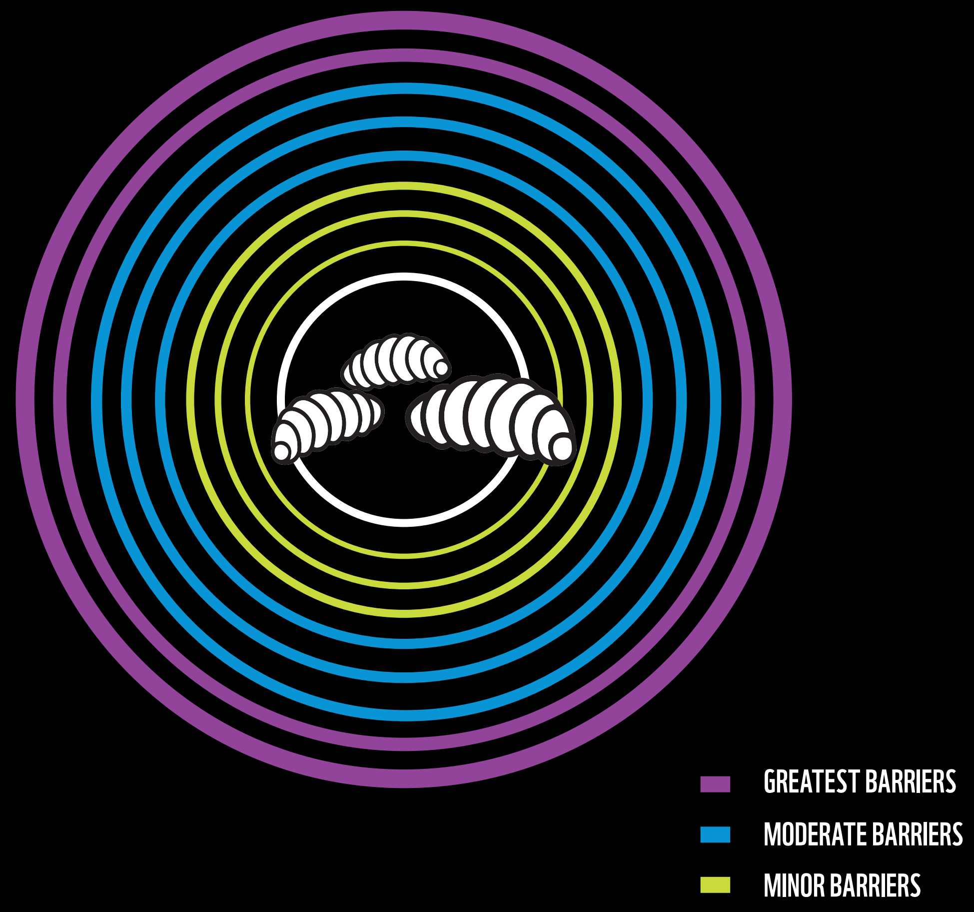
Stakeholders raised concerns around the reputational and commercial risk to industry if consumers do not accept insect-fed meat products as a concept, and the extent to which consumers might drive demand for insect-fed meat given that these would likely be premium products during initial stages of growth. The key areas of concern cited by stakeholders related to whether consumers would

- accept that insects would be fed to livestock and/or fish;
- have concerns around the animal welfare of the insect species being reared, including the diet of the insects, given that they would ideally be reared from a range of substrates which might otherwise go to waste; or
- be concerned that the substrates used to feed insects might result in adverse health impacts for people or for livestock, for example, through contamination by toxins or through disease transmission (for example, TSE).

## RESEARCH AND DEVELOPMENT

The evidence base demonstrating the positive environmental impact of insect farming relative to soy and fishmeal production, along with the nutritional impact of substituting these for insect meal, is limited to a relatively small number of studies largely based on examples in other nations (see Supporting Technical Report Section 2.2 for further information). The key research gaps identified by stakeholders related to

- the potential feed conversion ratios and production yields for different combinations of insect species and rearing substrate(s). This would help to guide economic viability of different production methods.
- the safety and viability of using additional streams of food surplus, food by-products and other non-food raw materials beyond those currently permitted for use in insect rearing. It is particularly necessary and urgent to identify whether insects can contract and/or transmit TSE if reared on animal by-products.
- the environmental impacts of different insect production systems against (a) the production of conventional feed proteins, (b) the production of alternative novel proteins, and (c) alternative methods of substrate disposal and processing.




**LEGISLATION RESTRICTING WHAT CAN BE FED TO INSECTS**

A limited number of feeding substrates are authorised for rearing insects which are intended to be used in animal feed.

**LEGISLATION ON PERMITTED USES OF INSECT MEAL**

Insect meal is classified as processed animal protein. There are tight restrictions on how this can be used in feed.

**FINANCE / INVESTMENT**

Lack of private and/or government funding to support the industry.

**RETAILER REQUIREMENTS**

Feed producers are required to abide by retailer specifications. These specifications influence demand for feed ingredients and limit the flexibility feed producers have to use alternative ingredients.

**RESEARCH AND DEVELOPMENT NEEDS**

There is limited understanding of the risk of contaminants flowing up the food chain via substrates used for rearing.

**CONSUMER PERCEPTION**

Risk of methods used in insect farming and insect-fed animal products being unacceptable to consumers.

**INSECT FARMING AND PROCESSING TECHNOLOGY**

There is limited access to low-cost technology, this would contribute towards reducing start-up costs for insect farmers.

**USE OF INSECT BY-PRODUCTS**

Restrictions around the disposal and/or application of insect by-products, such as insect frass as a fertiliser, prevent all potential revenue streams from being optimised.

**Figure 2. Barriers restricting the scale-up of insect farming in the UK**

These were identified through consultation in 2020 and represent the views of the participants. Please note this list is not exhaustive; please see page 20 for further detail on the methods used to collect responses.

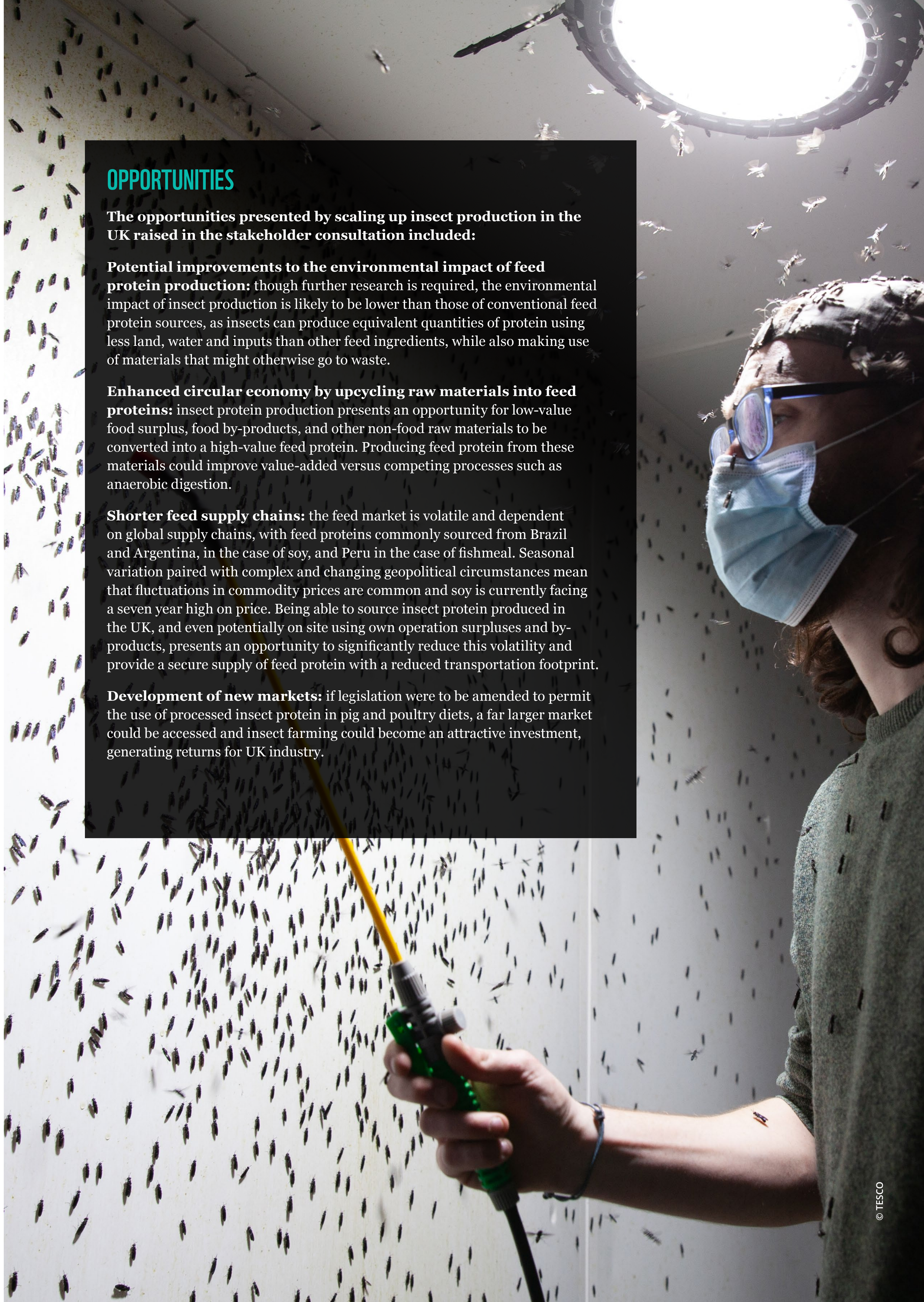
## INSECT FARMERS IN THE UK ARE OPERATING UNDER CONSIDERABLE CONSTRAINTS

### INSECT FARMING OPERATIONAL CONSTRAINTS AND USE OF BY-PRODUCTS

As insect farming in the UK is in the early stages of development, stakeholders stated that the volumes of insect protein currently available are insufficient for bulk buying in the quantity needed to mix into feed at the industrial scales required. In addition, stakeholders cited the cost of insect protein as a barrier to use. Low volumes and high prices are symptomatic of the current context in which insect farmers are attempting to operate and are placing considerable constraints on their ability to reduce costs. This includes but is not limited to:

- Legislation limiting the markets in which insect meal can be sold obscures assessments of potential future growth and returns and challenges access to investment.
- Legislation limiting the feedstock substrates which can be used to rear insects. This is limiting insect farmers to using higher-value substrates and putting insect farmers in competition with subsidised industries like anaerobic digestion. Ideally, insect farming should use raw materials which cannot be consumed directly by livestock or people, which would also be more cost effective to procure. Research is required to identify the feedstock substrates with the greatest potential for use, which meet product safety and quality needs while also minimising environmental impact.
- There are restrictions around the sales and uses of the by-products that result from insect farming, such as frass and chitin, which prevent all potential revenue streams from being maximised. While protein remains the highest value output of insect farming, frass (i.e. insect manure) is the largest output by weight and is a valuable fertiliser and soil enhancer. Evidence from other countries shows that a strong domestic market for frass in agriculture and horticulture provides an important secondary revenue stream within the overall insect farming business model.
- Start-up costs are high and reducing operational costs can often be dependent on being able to procure and maintain high-cost technology. A lack of investment opportunities for new entrants curtails growth in volumes and economies of scale.
- These conditions mean that it is probable that UK-produced insect meal would be outcompeted by insect meal produced in other regions, especially where warmer climates result in reduced energy costs for temperature regulation and where there is increased availability of and permission to use low-cost rearing substrates.

For further information on barriers and opportunities please see **Supporting Technical Report sections 3.4 and 3.5.**



© TESCO

### OPPORTUNITIES

**The opportunities presented by scaling up insect production in the UK raised in the stakeholder consultation included:**

**Potential improvements to the environmental impact of feed protein production:** though further research is required, the environmental impact of insect production is likely to be lower than those of conventional feed protein sources, as insects can produce equivalent quantities of protein using less land, water and inputs than other feed ingredients, while also making use of materials that might otherwise go to waste.

**Enhanced circular economy by upcycling raw materials into feed proteins:** insect protein production presents an opportunity for low-value food surplus, food by-products, and other non-food raw materials to be converted into a high-value feed protein. Producing feed protein from these materials could improve value-added versus competing processes such as anaerobic digestion.

**Shorter feed supply chains:** the feed market is volatile and dependent on global supply chains, with feed proteins commonly sourced from Brazil and Argentina, in the case of soy, and Peru in the case of fishmeal. Seasonal variation paired with complex and changing geopolitical circumstances mean that fluctuations in commodity prices are common and soy is currently facing a seven year high on price. Being able to source insect protein produced in the UK, and even potentially on site using own operation surpluses and by-products, presents an opportunity to significantly reduce this volatility and provide a secure supply of feed protein with a reduced transportation footprint.

**Development of new markets:** if legislation were to be amended to permit the use of processed insect protein in pig and poultry diets, a far larger market could be accessed and insect farming could become an attractive investment, generating returns for UK industry.

# CHAPTER 3 > LEGISLATION – THE CURRENT SITUATION

Through a series of stakeholder consultations, legislation surrounding the production of insect protein was identified as the greatest barrier to the scale-up of insect production in the UK. This summary chapter explores how and why this is the case. There is a full legislative review in **Section 4** of the **Supporting Technical Report**.

**PRESSURE IS MOUNTING TO DEVELOP NEW UK LEGISLATION TO ACCOUNT FOR THE ROLE OF INSECT FARMING AS AN INNOVATIVE AGRICULTURAL PRACTICE**

## HOW IS LEGISLATION LIMITING SCALE-UP?

Historically, agricultural practices and feed law have not reflected the role insects play in natural food chains as converters of waste to protein. Given that legislation plays a central role in shaping the commercialisation of food production, it is essential that regulation continues to protect human and animal health without unnecessarily restricting the development of the insect sector in the UK.

The rules regulating the use of insects in animal feed are predominantly contained in EU regulations and directives. Following the UK's exit from the European Union on 31 December 2020, these form part of the body of 'retained EU law' and continue to apply in the UK market.[1]

The 'overriding principle' informing European food and feed law is the **protection of human life and health, animal health and welfare, the environment and consumers' interests**. This is reflected in **EU Regulation 178/2002** (known as the 'General Food Law') and, in particular, in the 'general objectives'[2] and 'precautionary principle'[3] set out therein.

The General Food Law lays down the principles governing food and food safety, and more significantly feed[4] and feed safety. It applies to all those producing insects for feed across various stages of the production and supply chain and must be adhered to.

Previously, European legislation governing the composition of feed for farmed animals (including fish) intended for human consumption strictly prohibited the utilisation of insects as a source of protein in farmed animal feed. The categorisation of insects as 'farmed animals' has the consequence of bringing insects produced for use in animal feed within the scope of legislation governing the use of animal by-products and processed animal protein (PAP).

The principal reason for restricting the use of animal by-products, particularly PAP, as feed for farmed animals, is the risk arising from the transmission of Transmissible Spongiform Encephalopathies (TSEs). There are strict controls regarding what may be fed to livestock (including insects) aimed at preventing the spread of TSEs. The European feed ban rules[5] (also known as the 'TSE Regulations') contain the predominant protective measures laid down against TSEs.

Unlike any other livestock production process, the regulations governing animal feed bite at two stages in the feed chain, if introducing insect protein:

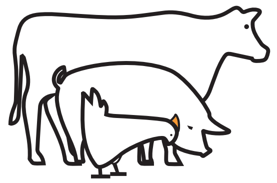
- **first,** in determining what may be fed to insects; and
- **second,** in determining what insects may be fed to.

As the market for insect protein has developed, there has been mounting pressure to develop new legislation to take account of the emerging role of insects in the feed market.

[1] European Union (Withdrawal) Act 2018
[2] Article 5(1), EU Regulation 178/2002
[3] Article 7(1), EU Regulation 178/2002
[4] Article 3(4), EU Regulation 178/2002
[5] EC Regulation 999/2001 (the 'Feed Ban Rules/TSE Regulations')



## THE USE OF INSECTS IN ANIMAL FEED – WHAT FARMED ANIMALS MAY INSECTS BE FED TO?



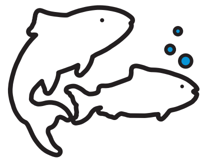
### Restrictions around pigs, poultry and other farmed animals

The feed-ban provisions of the TSE Regulations do not permit PAP, including that derived from insects, to be fed to farmed animals. The current position is that processed insect protein cannot be fed to any farmed livestock intended for human consumption, including pigs, poultry and cattle.

It is anticipated that a proposal to amend EU legislation to permit the use of processed insect protein in pig and poultry feed will be approved. Such an amendment would provide authority to introduce a similar amendment to UK regulations. An appropriate and robust risk assessment in line with the precautionary principle is an essential prerequisite to any change in feed law.

Insect-derived fats (lipids) and insect-derived hydrolysed proteins are permitted in feed for farmed animals.[6,7] Hydrolysed proteins from non-ruminants (including insects) are not treated as PAPs and are permitted under the TSE Regulations. There are currently no plants approved to make hydrolysed protein in Great Britain.[8]

It is considered that live insects are permitted to be used in animal feed[9] and that practice is already taking place with live insects being fed to chickens producing eggs.



### The aquaculture exception

In a significant development in the use of insect protein in animal feed, specific species of insects are now permitted to be used in aquaculture feed. This is due to an exception to the general feed ban on PAP that came into force in 2017[10] and authorised the use of PAP from non-ruminant animals for use in aquaculture. PAP derived from the following seven species of insect is now authorised for use in aquaculture feed: black soldier fly; common housefly; yellow mealworm; lesser mealworm; house cricket; banded cricket; and field cricket.

### Pet food

Insects and their derived products are authorised for use as feed in pet food.[11]

A summary of the current permitted and prohibited uses of insect protein in animal feed, as of January 2021, is outlined in Table 2.

**Table 2. Current permitted and prohibited uses of insect protein in UK animal feed.**

Information correct as of January 2021. Further information can be found in the **Supporting Technical Report Section 4.**

Insect PAP – All Species = except invasive alien species

| | INSECT PAP – ALL SPECIES | INSECT PAP – FROM THE 7 SPECIES | INSECT LIPIDS AND HYDROLYSED PROTEIN | LIVE INSECTS |
|---|---|---|---|---|
| Ruminants | ✗ | ✗ | ✔ | N/A |
| Poultry | ✗ | ✗ | ✔ | ✔ |
| Pigs | ✗ | ✗ | ✔ | ✔ |
| Fish | ✗ | ✔ | ✔ | ✔ |
| Pet food | ✔ | ✔ | ✔ | ✔ |
| Fur animals | ✔ | ✔ | ✔ | ✔ |

[6] Defra and APHA Guidance "Supplying and using Animal By Products as animal feed or in animal feed and how to get your site authorised" 14 Jan 2019. Article 10 of Regulation (EC) No 1069/2009. Article 14(d)(i) of Regulation (EC) No 1069/2009. Annex X, Chapter II, Section 3 of Regulation (EU) No 142/2011. Catalogue of Feed Materials Part C, 9.2.1, Annex to Regulation (EU) No 2017/2017. Requires compliance with Article 15 of Regulation (EC) No 178/2002, Article 4 of Regulation (EC) No 767/2009 and Regulation (EC) No 767/2009
[7] Article 7(3) EC Regulation 999/2001
[8] Defra and APHA Guidance "Supplying and using Animal by Products as farm animal feed or in animal feed and how to get your site authorised" 14 Jan 2019
[9] Catalogue of Feed Materials in EU Regulation 2017/1017 at 9.16.1. Requires compliance with EU Regulations 1069/2009 and 142/2011, EC Regulation 999/2001 and Regulation (EC) No 767/2009. Page 43, IPIFF Guide on Good Hygiene Practices, December 2019
[10] Articles 1 and 2, EU Regulation 2017/893
[11] Article 14(d)(iii), Regulation (EC) 1069/2009 and Article 35, Regulation (EC) 1069/2009. Regulation (EC) 1069/2009. Requires compliance with Article 15, Regulation (EC) 178/2002

## SUBSTRATES IN INSECT FARMING – WHAT MATERIALS CAN BE FED TO INSECTS?

The inclusion of invertebrates in the definition of 'farmed animals' not only prescribes what animals insects may be fed to, but also the permitted substrates which insects may be reared on. Insects kept or bred for use in animal feed must currently be treated as farmed animals and consequently fed in accordance with general animal feed law.

The TSE Regulations prohibit feeding certain materials to insects. The broad effect is that meat products and similar proteins derived from (i.e. the bodies of) animals (other than permitted materials) cannot be used as an insect substrate. In addition, there is a mandatory 'unauthorised' list of materials which are prohibited from being placed on the market as animal feed. This list includes certain materials which are generally discarded as waste (e.g. animal and human excrement, wastewater, solid urban household waste and food packaging). Currently, under no circumstances can these unauthorised materials be used as a substrate in animal feed, even if treated.

**LEGISLATION SEVERELY LIMITS THE MATERIALS WHICH CAN BE USED TO REAR INSECTS**

### Permitted feedstocks, or substrates

Permitted insect substrates include vegetal matter, such as cereal grains, legume seeds, roots, fruits, forages and algae, and non-animal-containing industry by-products, such as by-products from bakery, breakfast cereal and confectionery industries, and from processing fruit and vegetables.

The TSE Regulations do permit the use of certain animal by-products as substrates, including milk, cooked eggs, fats, rennet and non-ruminant gelatine, provided that the substrates have undergone processing such as pasteurising, cooking or baking under the hygiene regulations.

Substrates must not have been mixed with any prohibited material and must otherwise comply with General Food Law requirements around feed safety.

There is a 'Community Catalogue of feed materials'[12] (the 'Catalogue'), which comprehensively lists permitted animal feed materials.

### What about 'waste'?

It is crucial that any material considered for use as an insect substrate is not classified as (or does not inadvertently become) waste[13] or mixed with waste. Once material falls under the definition of 'waste' (by being discarded or intended to be discarded) it is subject to strict regulations regarding handling and disposal and is not permitted for use as insect substrate. The EU 'Waste Framework Directive'[14] sets out a 'waste hierarchy'[15] and the criteria animal feed (including insect) producers must meet to ensure that the material is not classified as 'waste'. WRAP's 'Food and drink material hierarchy',[16] which sets out steps for preventing surplus food and drink materials becoming waste, identifies 'sending to animal feed' as the final measure before such material becomes waste under the waste hierarchy.

A 'New EU Waste Directive'[17] came into force in 2018 but was not implemented by the UK. Instead, the 'gaps' between the Waste Directive Framework and the New EU Waste Directive have been bridged under separate UK law.[18] This ensures continued alignment with EU legislation around the treatment of 'waste'. Significantly, it removes a burden that existed under the Waste Framework Directive, so that materials destined for use as feed materials (that do not contain animal by-products) are no longer within the scope of the EU Waste Directive.

[12] Annex to Regulation (EU) 2017/1017
[13] Waste is defined under the Waste Framework Directive as "any substance or object which the holder discards or intends or is required to discard" Article 3(1) of Directive 2008/98/EC
[14] Directive 2008/98/EC
[15] Article 4 of Directive 2008/98/EC
[16] See: Food waste in England - Environment, Food and Rural Affairs Committee - House of Commons (parliament.uk)
[17] Directive (EU) 2018/851
[18] Waste (Circular Economy) (Amendment) Regulations 2020

# CHAPTER 4 > THE FUTURE VISION OF UK INSECT FARMING

INSECT FARMING SHOULD IDEALLY USE RAW MATERIALS WHICH CANNOT BE CONSUMED DIRECTLY BY LIVESTOCK OR PEOPLE

This chapter sets out a scenario in which insect production in the UK might scale up, between now and 2050, using only supply chain food surplus and by-products, and based on projected demand for feed protein in salmon, pig and poultry diets.

Salmon, pig and poultry feeds were selected as target feeds because the diets of these animals require large volumes of protein (Schreiber et al., 2019; WWF, 2017) and thus are likely to represent the future market for insect protein, which is positioned to displace soymeal and/or fishmeal. These animals would also feed on insects as part of their natural behaviour (FAO, 2013), and insect meal is already permitted for use in aquaculture, offering a route to larger volumes. In this exercise we assume that the consumption of salmon, pork and poultry in UK diets will increase as projected under ‘Business as usual’.

While the principles of the vision set out in this paper may be relevant to a range of insect species and end markets, we have focused on the production of black soldier fly (*Hermetia illucens*), one of the most commonly farmed species worldwide. The larvae of the black soldier fly, for which the species is farmed, are nutritionally comparable to fishmeal and soymeal (IPIFF, 2020), and have an insatiable appetite, able to consume large amounts of organic waste from both plants and animals, including wet waste. Neither the larval or adult forms of black soldier fly are considered pests, and there is low risk of black soldier fly becoming an invasive species relative to some other insect species (Bessa et al., 2020). Black soldier fly is also one of seven insect species already authorised for use in aquaculture feed in the European Union and in the UK.

## OUR APPROACH TO DEVELOPING THE FUTURE VISION FOR INSECT PRODUCTION IN THE UK FOLLOWED THREE CORE STEPS:

**1. Assessment of feedstock substrates available in the UK.** A set of 10 criteria was used to assess the suitability of 22 potential feedstocks for insect rearing. These were mostly food surplus or food by-products. For the purposes of this exercise, substrates currently outside of the list of materials permitted for use in animal feed were considered, so that legislation was not restrictive. This identified 10 substrates to be carried forward to step 2, in which potential insect protein production volumes were modelled based on the quantity of feedstocks available.

**2. What could the industry look like in 2050? Prediction of the volumes of insect protein that could be produced in the UK using the quantities of suitable substrates available.** Three scenarios for scale-up were considered: ‘Business as usual’, ‘Achievable’, and ‘Aspirational’. We present here the results for the ‘Achievable’ scenario.

**3. Recommendations to reach the potential growth set out in the ‘Achievable’ scenario.** We then explored the conditions and actions required from UK stakeholders to enable the growth that we demonstrated is possible in the UK.

Here, we present a summary of our approach and the key findings. A detailed explanation of methods and results can be found in the **Supporting Technical Report sections 4 and 5.**



## ASSESSMENT OF FEEDSTOCKS, OR SUBSTRATES, AVAILABLE IN THE UK FOR INSECT REARING

In this section we identify substrates available in the UK and use semi-quantitative methods to assess each against their potential suitability for insect rearing, using black soldier fly as an example species. We also offer a snapshot of permissions surrounding each substrate, in relation to the law around feed safety (e.g. the General Food Law[19]), thus putting the use of each substrate into context with existing legislation.

In total, 22 streams of food and non-food materials were identified as possible substrates for black soldier fly rearing, spanning supply chain food surplus, manufacturing by-products, animal by-products and others (Table 3). These were assessed against 10 core criteria, using a red, amber, green analysis, which was informed by a literature review and a series of stakeholder interviews with subject matter experts. The criteria which each substrate was assessed against included:

**1. Risk of contamination.** This covered both risk of harmful materials within the substrate and the degree of traceability back to the substrates’ original source.

**2. Risk to retailers.** The degree to which retailers would accept the substrate in their feed supply chain, including whether they perceive the substrate to be acceptable to consumers.

**3. Feed manufacturers’ perspective – aquaculture.** The degree to which feed manufacturers would accept the substrate in their aquaculture feed supply chains, given that many freshwater fish would feed on insects as part of their natural behaviour.

**4. Feed manufacturers’ perspective – livestock.** The degree to which feed manufacturers would accept the substrate in their livestock feed supply chains, with a focus on pigs and poultry.

**5. The total volume of substrate produced each year in the UK,** and thus overall quantity available.

**6. The surplus volume of substrate available,** following the most common form of processing, and thus the ‘excess’ or ‘surplus’ volumes available. This is in recognition that there is existing competition for substrates.

**7. The security of supply of the substrate over time.** The degree to which the substrate is consistently available over seasons and/or any production cycles which might exist for that substrate.

**8. The affordability of the substrate.** The cost of procuring a tonne of untreated substrate.

**9. Estimated nutritional profile of the substrate.** Estimations of the protein, fat, carbohydrate, and water content of the substrate.

**10. Compatibility with black soldier fly specific needs and rearing system.** The degree to which the substrate might offer the nutritional profile required by black soldier fly, the ease of introducing the substrate to the rearing environment and the degree of risk of insect mortality.


[19] Regulation (EC) No 178/2002

**IN PRACTICE, MANY BLACK SOLDIER FLY FARMERS USE BLENDED SUBSTRATES. HOWEVER, WE WERE UNABLE TO CONSIDER HOW BLENDED SUBSTRATE STREAMS MIGHT PERFORM IN OUR CRITERIA**

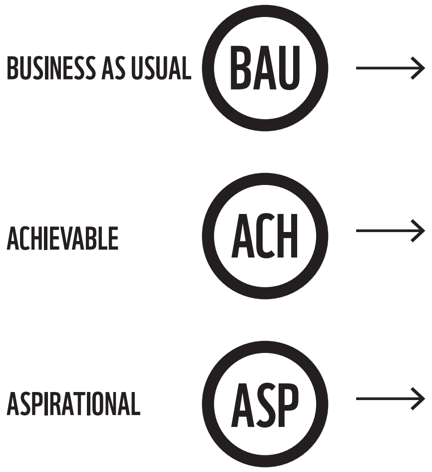
The criteria did not consider any current legislative or regulatory barriers, as we wanted to consider each substrate outside of the current restrictions. There is a lack of publicly available research on how different substrates perform in black soldier fly rearing, along with a lack of research on the resultant nutritional profile of the black soldier fly. The criteria used therefore intend to offer an approximation, based on expert consultation, of how the efficiency of production and the nutritional quality of the black soldier fly meal might vary with the substrate(s) used. In practice, many black soldier fly farmers use blended substrates. However, we were unable to consider how blended substrate streams might perform in our criteria.

Further information on the methods used to assess substrates can be found in the **Supporting Technical Report Section 5.3**.



## RESULTS OF THE ASSESSMENT

Ten substrates were shortlisted based on good overall performance across the criteria scored (Table 3) and were then divided into three categories:




**substrates currently allowed for use in insect rearing under UK legislation:** (**1**) vegetable by-products, (**2**) bakery by-products, (**3**) beverage industry brewers' grains, and (**4**) dairy by-products;

**substrates not currently authorised for use, but have high near-term potential according to the assessment method used in this study:** (**5**) food surplus from manufacturing, (**6**) bakery mixed with animal by-products, and (**7**) food surplus from retail; and

**non-food substrates that are not currently authorised for use, and require caution, but have relatively high volumes available and thus offer potential for use in insect rearing in the longer term:** (**8**) low quality finfish by-products that remain following processing into fishmeal that would otherwise go to waste, (**9**) AD food-based digestate, and (**10**) poultry manure (layers).

**Figure 3. What feedstock substrates could farmed insects be fed?**

Our assessment identifies six additional feedstock substrates that could be suitable for insect farming in the UK. This list is not exhaustive and further research is critical to identify how any risks associated with using additional substrates could be mitigated.

Numbers refer to quantity of feedstock substrate available (thousand tonnes/year). Correct as of 2020 data.

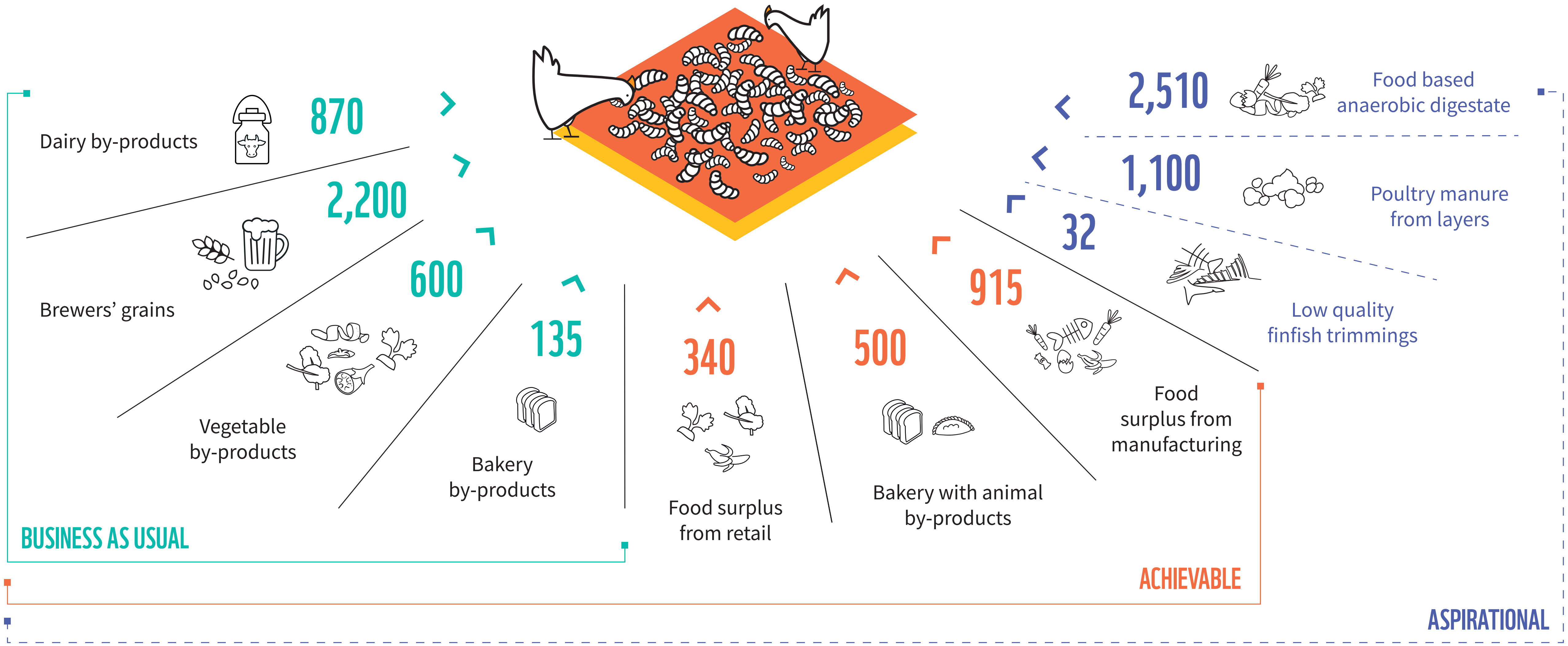


**Table 3. Assessment of substrates that may be suitable for use in black soldier fly farming, subject to further research.**

This assessment is based on information from literature, a series of external stakeholder consultations, and expert opinion from within the project team. Substrates were scored against criteria using a traffic light system.
An overall summary score was allocated to each substrate and used to inform whether the substrate was taken forward for consideration in the 'Achievable' (ACH) or 'Aspirational' (ASP) scaling scenarios. Substrates currently permitted for use in insect farming in the UK are marked 'Business as usual' (BAU). ABP = animal by-products, AD = anaerobic digestate.

**red ■ = low potential, amber ■ = moderate potential and green ■ = high potential**

| CATEGORY | SUBSTRATE | DEFINITION | 1. Risk of contamination | 2. Risk to retailers | 3. Feed manufacturer perspective – aquaculture | 4. Feed manufacturer perspective – livestock | 5. Total UK volumes available | 6. Surplus UK volumes available | 7. Security of supply | 8. Affordability (untreated) | 9. Estimated nutritional profile | 10. Compatibility with black soldier fly systems | Overall score | Taken forward for scale-up scenarios * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mixed Food | Food surplus – household | Non-segregated mixed food surplus from households that includes animal by-products and is likely to be mixed with other non-food materials. | red | amber | red | red | green | green | green | green | amber | green | red | – |
| | Food surplus – hospitality and food service | Non-segregated mixed food surplus from hospitality and food service that includes animal by-products and is likely to be mixed with other non-food materials. | red | amber | red | red | red | red | red | green | amber | green | red | – |
| | Food surplus – retail, de-packaged | Non-segregated mixed food surplus from retail that has been de-packaged and includes animal by-products. | amber | green | amber | amber | red | red | green | green | amber | green | amber | ACH |
| | Food surplus – manufacturing | Non-segregated mixed food surplus from manufacturing that includes animal by-products. | green | green | green | green | amber | red | green | green | amber | green | green | ACH |
| Vegetable | Vegetable by-products | Segregated vegetable and fruit surplus from manufacturing and processing units. | amber | green | green | green | green | amber | green | green | red | amber | green | BAU |
| Bakery | Bakery surplus | Segregated bakery surplus from manufacturing (e.g. bread, cakes, pastry and biscuits, pasta, chocolate, sweets and similar products such as breakfast cereals). | green | green | green | green | amber | red | green | red | red | amber | green | BAU |
| | Bakery mixed with ABP | Non-segregated bakery surplus from manufacturing that contains animal by-products (e.g. raw eggs, meat, fish, and products or preparations derived from or incorporating meat or fish). | amber | amber | amber | red | red | red | green | green | green | green | amber | ACH |
| ABP – animal parts | Abattoir surplus | Slaughterhouse animal by-products, including blood, meat and bone meal etc. | amber | red | amber | red | green | green | green | amber | green | green | amber | – |
| | Finfish trimmings – high quality | Fish trimmings or other fish processing by-products of good quality that are typically used in the production of fishmeal (e.g. trimmings, skins, heads, frames, bones with attached flesh, viscera and blood). | amber | amber | green | amber | amber | red | green | red | green | green | red | – |
| | Finfish trimmings – low quality | Fish trimmings or other fish processing by-products that remain following processing into fishmeal that would otherwise go to waste (e.g. remains of trimmings, skins, heads, frames, bones with attached flesh, viscera and blood). | amber | amber | green | amber | amber | amber | green | amber | green | green | amber | ASP |
| | Shellfish by-products | Shellfish by-products including discarded shellfish (e.g. defect mussels) and parts of the shellfish not intended for human consumption (e.g. shell, viscera, head, legs etc.). | amber | amber | green | amber | red | amber | green | green | amber | amber | red | – |
| ABP – manure | Poultry manure – broilers | Poultry litter from floor-raised birds (broilers, turkeys, broiler breeder pullets) consisting primarily of droppings and bedding (usually wood shavings or sawdust). Feathers and waste feed make up the remaining litter components. | amber | red | red | red | green | red | green | red | green | amber | red | – |
| | Poultry manure – layers | Poultry manure consisting of only faecal droppings associated with caged layers and broiler breeders. | amber | red | red | red | green | green | green | green | green | amber | amber | ASP |
| | Cattle manure | Manure from cattle in the form of slurry or farmyard manure; primarily made from dung, urine, waste grass, and other dairy waste. | amber | red | red | red | green | amber | green | green | red | red | red | – |
| | Pig manure | Manure from pigs in the form of slurry, typically made of a mix of urine, faeces and waste water, and pig muck from straw-based sheds. | amber | red | red | red | green | green | green | green | red | red | red | – |

| CATEGORY | SUBSTRATE | DEFINITION | 1. Risk of contamination | 2. Risk to retailers | 3. Feed manufacturer perspective – aquaculture | 4. Feed manufacturer perspective – livestock | 5. Total UK volumes available | 6. Surplus UK volumes available | 7. Security of supply | 8. Affordability (untreated) | 9. Estimated nutritional profile | 10. Compatibility with black soldier fly systems | Overall score | Taken forward for scale-up scenarios* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Anaerobic digestate** | AD digestate fibre | Fibre fractions that have been separated from whole digestate produced by anaerobic digestion. | amber | amber | amber | amber | red | red | amber | amber | red | red | red | – |
| | AD food-based digestate | Digestate produced by anaerobic digestion that contains source segregated biodegradable materials such as left-over food, livestock slurries or crops such as maize and grass silage. | amber | green | amber | amber | green | green | green | amber | red | red | amber | ASP |
| | AD non-source segregated | Digestate produced by anaerobic digestion that contains a range of non-source segregated food and non-food materials. | red | red | red | red | red | red | amber | amber | red | red | red | – |
| **Sewage** | Sewage biosolids/ sludge | A residual, semi-solid material that is produced as a by-product during sewage treatment of industrial or municipal wastewater. | red | red | red | red | green | green | green | green | red | red | red | – |
| **Other by-products and co-products** | Brewers' grains | A solid residue left after the processing of germinated and dried cereal grains (malt) for the production of beer and other malt products (malt extracts and malt vinegar). | green | green | green | green | green | red | green | red | green | green | amber | BAU |
| | Dairy by-products | Surplus material from the processing and manufacturing of milk products (e.g. butter, buttermilk powder, cheese, lactose, whey powder, surplus whey). | green | green | amber | red | amber | red | green | green | green | green | amber | BAU |
| | Fats and oils | Used cooking oils and fats that have been used for cooking or frying in the food processing industry, restaurants, fast foods etc. | green | green | green | amber | red | red | green | red | red | red | amber | * |
| | Drinking water treatment cake | Dewatered sludge cake produced from drinking water treatment plants. | amber | amber | amber | amber | red | amber | amber | green | red | red | red | – |
| | Paper sludges | Paper sludge consisting of fibres that are discarded in the pulping process. | red | amber | amber | amber | green | green | green | green | red | red | red | – |

**red ■ = low potential, amber ■ = moderate potential and green ■ = high potential**

*Fats and oils are currently permitted for use in insect rearing, however this substrate was not taken forward in the 'Business as usual' modelling scenario due to poor compatibility with black solider fly rearing systems.

© KANAWA_STUDIO / ISTOCK / WWF

## WHAT COULD THE INDUSTRY LOOK LIKE IN 2050?

Three scenarios for upscaling the production and use of insect protein were modelled, using black soldier fly as an example species and the UK as an example geography, for inclusion in the feed of salmon, pigs and chicken. The insect feedstocks, or substrates, used in the modelling were informed by the results of the assessment of substrates outlined in the previous section of this report.

We considered 'scaling up' in this study to be the actions of increasing (a) the use of insect protein in feed in the UK's salmon, pork and poultry sectors, and (b) the farming of insects in the UK, using UK-sourced substrate material.

WE MODEL AN 'ACHIEVABLE' SCENARIO FOR SCALING UP THE USE OF INSECTS IN UK FEEDS

To improve volumes of insect protein produced within the UK, we do not favour only large factories but take into account a range of production facilities to allow for the breadth of systems that will likely be needed to help the industry grow. To set out a vision for black soldier fly production in the UK in 2050, we address:

1. **What are the potential scenarios for scaling up the supply and use of insect protein from 2021 to 2050?** What are the legislative changes required to support growth? What subset of substrates could be used to rear insects?
2. **Estimating supply and demand:** What quantity of suitable substrate(s) is available in the UK, and from this, what volume of insect protein could be produced from UK insect farms? What combination of UK-based insect farming facilities might be required to meet these projected volumes? How far could volumes of UK-produced insect meal meet the total projected demand across UK poultry, pig and salmon farms?
3. **Competition with conventional feed proteins – cost of production of insect protein relative to the market value of soy and fishmeal:** How economically feasible is insect farming in the UK – how far can insect meal compete with soy meal and fishmeal on price?

### Modelling scenarios for scaling up insect protein production and use in the UK

Three scenarios were considered which varied according to a) legislative permissions and b) the combination of substrates used as insect rearing feedstocks, based on the substrate assessment carried out in the previous chapter. All three scenarios took into consideration those substrates already permitted for use. The three scenarios considered were:

1. **'Business as usual':** No legislative change, based on the four substrates currently approved for use in the UK (vegetable by-products, bakery without animal by-products, beverage industry brewers' grains, and dairy by-products).
2. **'Achievable':** Legislative change within five years, permitting processed insect protein to be used in the feed of pigs and poultry intended for human consumption, and permitting the use of three additional insect feedstock substrates (food surplus from manufacturing, food surplus from retail, and bakery mixed with animal by-products).
3. **'Aspirational':** Legislative change within five years, permitting processed insect protein to be used in the feed of pigs and poultry intended for human consumption, and permitting the use of six additional insect feedstock substrates (food surplus from manufacturing, food surplus from retail, bakery mixed with animal by-products, low quality finfish, food-based anaerobic digestate and poultry manure from layers).



This section presents the results for the modelling of Scenario 2: 'Achievable'. This scenario was selected on the basis that it offers an ambitious but realistic pathway for the scale-up of insect production in the coming years, using a broader range of supply chain surpluses and by-products as feedstock than currently permitted, thus enabling the production of greater volumes of insect meal and oil.

For results of the modelling of Scenario 1: 'Business As Usual' and Scenario 3: 'Aspirational', along with further information on methods used, please see **Supporting Technical Report Section 6**.

**3.4 MILLION**

TONNES OF UK-SOURCED MATERIAL THAT, EVERY YEAR, COULD BE CONVERTED INTO A HIGH-PROTEIN FEED INGREDIENT

## RESULTS OF MODELLING 'ACHIEVABLE' SCENARIO

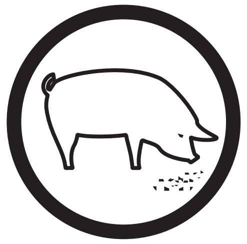
**Supply of UK-farmed insect protein**

We project that, by 2050, the quantity of substrate converted into feed protein by insects each year could reach up to 3.41 million tonnes. From this quantity of substrate, 237,000 tonnes of insect meal could be produced per year from UK insect farms via a combination of micro-, small-, medium- and large-scale facilities (Table 4). As per the conditions set out in the 'Achievable' modelling scenario, this is dependent upon regulatory change permitting the use of additional rearing substrates.

The quantity of substrate reported available for use in insect farming is based on forecasted UK population growth and consumption, using data sourced from the Agriculture and Horticulture Development Board (AHDB), Department for Environment Food & Rural Affairs (Defra), Food Standards Agency (FSA), Office for National Statistics, Organisation for Economic Co-operation and Development (OECD) commodity statistics, Seafish Authority and Waste & Resources Action Programme (WRAP), and the following assumptions:

1) Waste reduction targets under the Courtauld Agreement will be met.
2) The percentage of each substrate directed to insect rearing will grow from 2% in 2021, to 50% in 2050, but not exceed this. This is in recognition that there will be competition for these materials as we increasingly improve our ability to reduce surplus and repurpose materials in other industrial symbioses.

Feed conversion ratios for substrate to insect have been sourced from academic literature. See the **Supporting Technical Report Section 6.3** for further detail on methods used.



**IF TOTAL DEMAND FOR INSECT PROTEIN IN FEED IS MET, THE UK'S 2050 SOY FOOTPRINT WOULD FALL BY 524,000 TONNES AND FISHMEAL FOOTPRINT BY 16,000 TONNES**

### Total demand for insect protein from UK poultry, pork and salmon sectors

We project that total demand for insect meal from UK pig, poultry and salmon sectors could reach 540,000 tonnes per year by 2050. This calculation is based on predicted increases in demand for soy and fishmeal and the following substitutions:

#### Salmon feed

A reduction in fishmeal use by **25%**, and a reduction in soy protein use by **50%**, to displace **38,000 tonnes** of soy protein and/or fishmeal per year by 2050. The resulting diet would consist of **15%** fishmeal, **7%** soy protein and **12%** insect meal.

#### Pig feed

A reduction in soymeal use by **30%**, to displace **98,000 tonnes** of soy per year by 2050, resulting in an overall diet consisting of **12%** soymeal and **5%** insect meal.

#### Poultry feed

A reduction in soymeal use by **30%** to displace **404,000** tonnes of soymeal per year by 2050, resulting in an overall diet consisting of **14%** soymeal and **6%** insect meal.

We assume that consumption of pork, poultry and salmon in the UK will continue as per current trends, calculated using data from AHDB, Defra and OECD commodity statistics. We assume that 1kg of soy and/or fishmeal is replaced with 1kg of insect meal, and that legislative changes will permit the use of processed insect protein in the feed of pigs and poultry, along with the use of additional insect rearing feedstock substrates.

If the estimated total demand for insect protein in the UK of 540,000 tonnes is met in 2050, and these equivalent volumes of soy and fishmeal were to be displaced across the salmon, pig, and poultry sectors, the UK's 2050 soy footprint would fall by approximately 524,000 tonnes and fishmeal by approximately 16,000 tonnes each year.

Our projections suggest that, with limited changes to the permitted insect rearing feedstocks, 44% of this demand could be met using insect meal produced in the UK. If a broader range of substrates are permitted for use, for example, those in our 'Aspirational' scenario, UK insect farming may be able to produce even greater volumes than this. The remaining 60% of demand could be met via imported insect meal produced to equivalent safety, quality and sustainability standards.

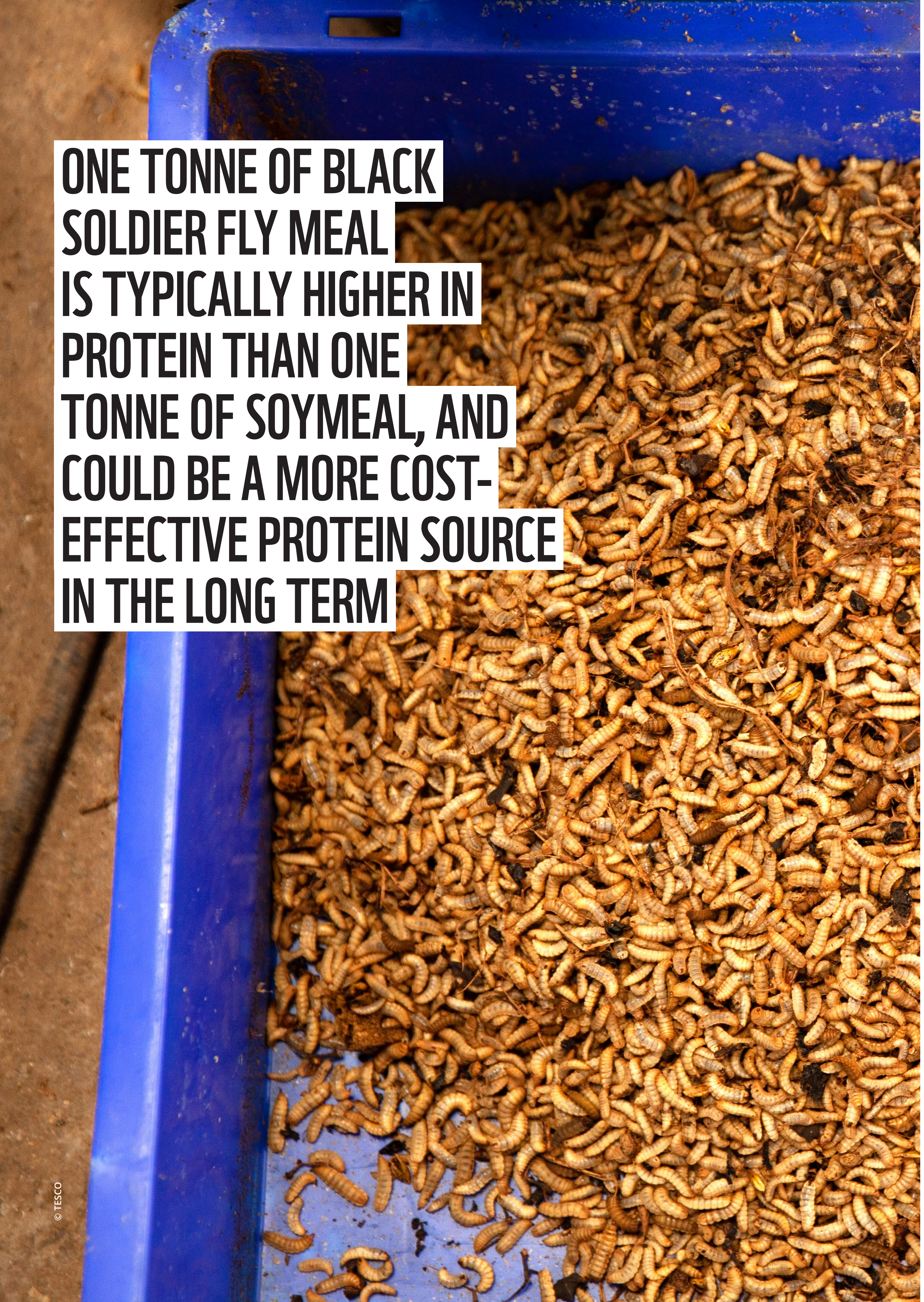
See **Technical Report Section 6.3.4** for further information.

## MODELLED COST OF PRODUCTION OF INSECT PROTEIN IN THE UK

A financial viability assessment of four different categorisations of black soldier fly production systems was carried out, covering micro-, small-, medium- and large-scale facilities. The assessment takes into account joint revenue from the production of protein, oil and frass. The assessment was developed to show predicted cash flows, profits and net present values over the timescale 2021–2050 and was informed by data from existing black soldier fly production facilities in operation, the stakeholder consultation phase of this study and grey and academic literature.

The results of the financial viability assessment indicate that all four insect production facilities generate a net profit after depreciation and interest. These results are based on assumptions related to Scenario 2: 'Achievable', in which legislative change would take place within five years that permits processed insect protein to be used in pig and poultry feed and permits the use of three additional substrates for insect rearing. They also assume equivalent prices to fishmeal are received for insect meal.

© PETER CATON / WWF-UK



## ONE TONNE OF BLACK SOLDIER FLY MEAL IS TYPICALLY HIGHER IN PROTEIN THAN ONE TONNE OF SOYMEAL, AND COULD BE A MORE COST-EFFECTIVE PROTEIN SOURCE IN THE LONG TERM

© TESCO

The costs of production of a tonne of dry insect meal and a tonne of insect oil in a medium sized facility were estimated for the example year 2030. This used the following assumptions:

- **Legislative change within five years of 2020 permitting:** a) the use of processed insect protein in the feed of pigs and poultry intended for human consumption, and b) the use of three additional substrates permitted (food surplus from manufacturing, food surplus from retail, and bakery mixed with animal by-products, as per the waste stream assessment carried out in this study);
- **Capital expenditure** estimated at £10 million to construct the medium-sized facility in 2021. This estimate includes construction of facility, machinery and production equipment, contingencies, start-up and technical costs.
- **Operational costs** in first year of operation (2022) estimated at £2,578,000. This estimate includes but is not limited to administration, licences, legal, IT, communications, research and development, maintenance and repairs, general supplies, heating and electricity, water and salary costs. This estimate also included £300,000 for access to substrates, plus £56,400 for transport of substrate to facility, where cost of access to brewers' grains is estimated at £40/tonne, and bakery by-products £30/tonne. Cost of access of the remaining substrates was assumed to be £0/tonne, on the basis that there is a gate fee for disposal of these substrates (vegetable by-products, dairy by-products, bakery with animal by-products, food surplus from retail, food surplus from manufacturing). We considered a scenario in which supply of substrates to insect producers was accounted for as a revenue stream, however, WWF does not support a scenario where creation of surplus and excess by-product is incentivised.
- **Conversion of substrate to insect:** A conservative larvae conversion factor of 0.6 is applied across all substrate types for the production of protein meal, and a conversion factor of 0.2 for the production of oil.
- **Protein content:** Protein content and quality of black soldier fly meal is assumed superior to soy meal but equal to fishmeal, based on existing literature (IPIFF, 2020). In calculations, 1kg of soy and/or fishmeal is replaced with 1kg of insect meal.
- **Sale price for insect oil:** at £586–£655 per tonne based on econometric modelling of price data for soy oil and fish oil equivalence sourced from the IndexMundi (2020) data portal.
- **Nominal sale price of frass:** at £5 per tonne, similar to the cost that might be achieved for other agricultural fertilisers such as manure.

**OUR CALCULATIONS SUGGEST THAT WITH ECONOMIES OF SCALE, THE COST OF PRODUCTION OF INSECT MEAL COULD REACH £490 IN 2030**

Under these assumptions, modelling indicated costs of production to be:

**£540 per tonne of dry black soldier fly larvae** (whole larvae)

**£490 per tonne of dry black soldier fly larvae** concentrated protein meal (following defatting and processing), nutritionally superior to soy meal and equivalent to fishmeal based on protein content.

This places the cost of production of black soldier fly meal above the market value of soymeal (as used in pork and poultry feeds, at approximately £380–£430/tonne) and below the market value of soy protein concentrate and fishmeal (as used in salmon feeds, at approximately £800–£1,000/tonne and £1,000–£1,300/tonne, respectively). One tonne of black soldier fly meal is typically higher in protein than one tonne of soymeal and could potentially be a more cost-effective protein source in the long term. When considering protein content alone, black soldier fly meal can be equivalent to both soy protein concentrate and fishmeal.

Furthermore, it was found that there are significant gains to be made by increasing black soldier fly production scale over time, corresponding to declining costs of production for insect protein meal and oil.

See **Supporting Technical Report section 6.4** for further information.

**Table 4. Key metrics and indicators for scaling up the use of insects in UK feeds.**

Metrics and indicators are based on Scenario 2: 'Achievable' roadmap to scale-up and relate only to the use of insect protein in UK salmon, pig and poultry feeds

| | | BASELINE (2020) | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| Estimated demand for insect meal (tonnes) in animal feed and rate of inclusion (%)[1] | Salmon feed at 11.7% inclusion | 21,000 | 34,000 | 35,000 | 36,000 | 38,000 |
| | Poultry feed at 6.1% inclusion | Not authorised | 336,000 | 340,000 | 378,000 | 404,000 |
| | Pig feed at 5.1% inclusion | Not authorised | 82,000 | 83,000 | 92,000 | 98,000 |
| | Total | 21,000 | 452,000 | 458,000 | 506,000 | 540,000 |
| Quantity of food surplus or food by-product that could be available in the UK for processing by insects | Number of substrates authorised for use [3] | 4 | 7 | 7 | 7 | 7 |
| | Total volume of substrate available (wet weight, tonnes) | 3,810,000 | 5,700,000 | 5,940,000 | 6,170,000 | 6,830,000 |
| | Proportion processed by insects (%) | 0.5% to 2% | 5% | 14% | 37% | 50% |
| | Total volume of substrate available for processing by insects (wet weight, tonnes) | <90,000 | 300,000 | 820,000 | 2,270,00 | 3,410,000 |
| Volume of insects that could be produced in the UK based on food surplus and by-products available | Volume of insect oil co-product (tonnes) | <2,000 | 7,000 | 19,000 | 52,000 | 79,000 |
| | Volume of frass by-product (tonnes) | <17,000 | 56,000 | 151,000 | 420,000 | 631,000 |
| | Volume of insect meal produced (tonnes) | <6,000 | 21,000 | 57,000 | 157,000 | 237,000 |
| | Estimate of total demand met by supply of UK-farmed insect meal (%) | 5% | 5% | 12% | 13% | 44% |
| Number of operational facilities required to meet projected volumes of insect products[2] | Micro scale | <10 | 5–10 | 10–15 | 15–20 | 20–25 |
| | Small scale | 0 | 1–5 | 5–10 | 10–15 | 15–20 |
| | Medium scale | 0 | 0 | 1–5 | 6–10 | 10–15 |
| | Large scale | 0 | 0 | 0 | 1–3 | 3–5 |
| Cost of production | Cost for dry matter larvae (£/tonne) | N/A | £550 | £540 | £510 | £500 |


[1] Estimated total demand for insect meal within animal feeds based on the current proportion of fishmeal and soybean meal that is used by these sectors. The inclusion rates are indicative only and may be higher or lower in some species feed depending on age, growth stage, diet composition etc.

[2] Number of micro-scale (~1,300 tonnes/year insect meal), small-scale (~1,700 tonnes/year insect meal), medium-scale (~4,200 tonnes/year insect meal) and large-scale (~22,000 tonnes/year insect meal) facilities that are operational in the UK. There are no known facilities larger than micro-scale that were operational in the UK in 2020.

[3] Substrates include vegetable by-products, bakery by-products, brewers' grains and dairy by-products in 2020, and then the addition of bakery mixed with animal by-products, food surplus from retail (non-packaged) and food surplus from manufacturing from 2025 onwards, presuming legislation changes that allow substrates to be used.

237,000

TONNES OF INSECT PROTEIN THAT UK INSECT FARMS COULD SUPPLY TO UK AGRICULTURE EACH YEAR BY 2050

## SUMMARY OF RESULTS

Insect farming provides the opportunity to convert materials which might otherwise go to waste disposal or energy recovery into a high-value feed protein. Insect meal could offer up to double the protein content of soy, and equivalent protein levels to fishmeal, while also reducing our land footprint for feed production.

We project that, by 2050, UK insect farms could provide 237,000 tonnes of insect protein to UK agriculture each year. This would involve the upcycling of 3.4 million tonnes of UK-sourced food surplus and food by-products into high value feed protein. The total demand for insect meal from the UK's pig, poultry and salmon sectors could, however, far exceed 237,000 tonnes, reaching 540,000 tonnes a year by 2050. This demand could be met through more ambitious scale-up in the UK, by enabling a broader range of feedstock substrates to be used (subject to legislative change) or through the procurement of insect meal from other geographies. This could have a significant impact on the UK's future commodity footprint, resulting in the annual displacement of 16,000 tonnes of fishmeal and 524,000 tonnes of soy from UK feed by 2050. This is equivalent to one fifth of the UK's projected 2050 direct soy imports. To produce this volume of soy protein, at least 150,000 hectares of land would be required annually (USDA), almost the size of Greater London.

Further, our study finds that, with economies of scale and sufficient investment, the cost of production of insect protein in the UK could be equivalent to the market value of soy and below the market value of fishmeal. This suggests that, with time, insect meal could compete with these conventional feed proteins on price.

It is important to note that our calculations apply only to the UK poultry, pig and salmon sectors. If a 12% inclusion in salmon feed and a 5–6% inclusion of insect meal in pig and poultry feed were to be adopted across Europe, where there are far greater volumes of substrate available for use, even greater volumes of soy and fishmeal could be displaced. Our study considers only black soldier fly production and the use of the protein product. There could be further opportunities using other insect species, along with other insect co-products, including insect oil, chitin and frass, all of which provide additional opportunities for the insect production sector to diversify and expand. See **Supporting Technical Report Section 7.3** for further information.

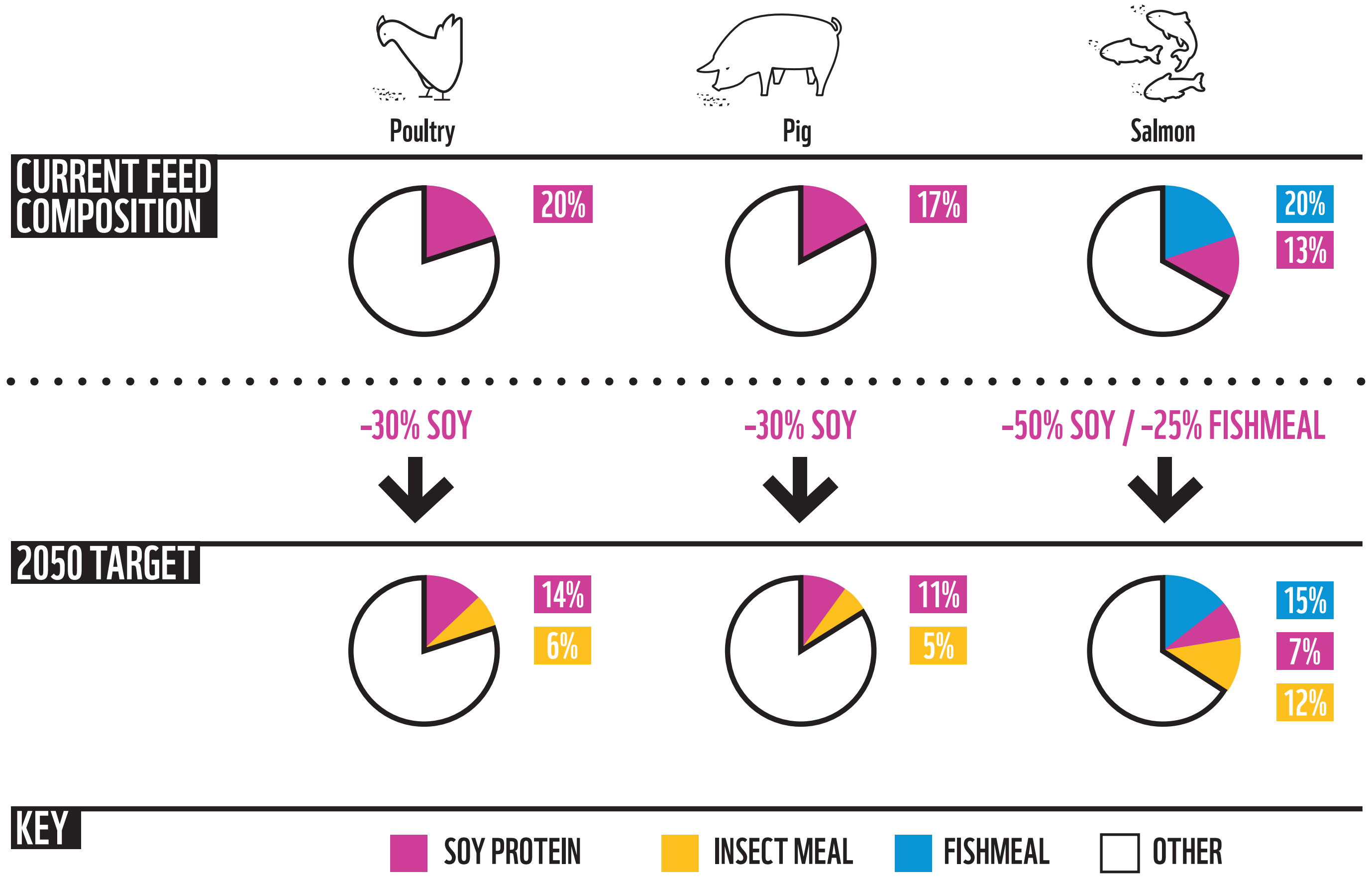
### CRITICAL CONSIDERATIONS

Supporting sustainable soy production that is free of conversion, deforestation and exploitation remains critical. In addition to supporting the development of insect protein as a feed ingredient, soy buyers should also invest in the development of other potential sustainable novel feed proteins in order to shift towards a more diverse and efficient feed system. While novel feed proteins are one of many levers to shift the feed system towards reduced environmental impact, crucially we must consume less meat and dairy.

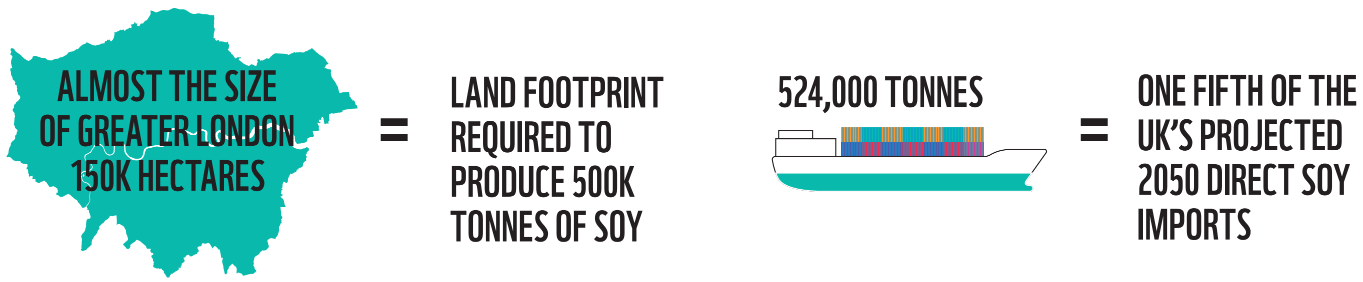


To secure this future vision for insect protein in the UK and reach the volumes and price points demonstrated as possible in our study, industry and policymakers must collaborate to break out of the volumes deadlock currently preventing UK insect farming from growing at full speed. The volumes of UK-reared insect protein are currently too low to enable uptake by feed manufacturers, and notably within aquafeed where the use of processed insect protein is currently permitted. Yet, volumes cannot increase in the absence of investment, increased demand, and enabling policy conditions which permit the use of insect meal in pig and poultry feed, and enable the use of a broader range of low-cost rearing substrates. A number of actions are required from UK stakeholders to realise the potential of this industry. These actions and recommendations have been developed following a series of consultations with UK stakeholders across the feed value chain and subject matter experts. For further detail on all recommendations and the rationale behind them, see **Supporting Technical Report Section 8**.

Figure 4. The use of insect protein could reduce the UK's future soy imports by one fifth.




### 2050 TARGET - REDUCING THE UK SOY FOOTPRINT BY 524K TONNES



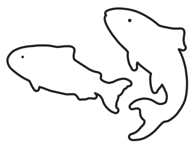
## SCALING UP THE USE OF INSECTS IN UK FEEDS: RECOMMENDATIONS FOR EACH STAKEHOLDER IN PRIORITY ORDER

Existing legislation is placing a stranglehold on the use of insects in feed in the UK.

### UK GOVERNMENT

1. **Amend legislation** so that the use of processed insect protein is permitted in the feed of pigs and poultry intended for human consumption.
2. **Mandate the Food Standards Agency to urgently research the risks associated with different insect feedstocks and how these risks can be mitigated.** Thereafter and where appropriate, introduce legislation widening the categories of feedstock substrates permitted for use in insect production. Substrate availability will quickly become limiting once insect meal can be used in pig and poultry feed, and challenge the ability of UK-produced insect meal to compete with imported insect meal.
3. **Develop incentives to support innovative farming methods,** such as agricultural funding or subsidies that cater to the rearing of insects for use in feed. This should include recognition that the farming of insects for animal feed is an agricultural activity. The new Environmental Land Management Scheme for England under the Agriculture Act provides an opportunity to address this for rural insect farming, but to an extent that is insufficient. The opportunity for urban insect farms will also need to be addressed, as well as schemes for other regions in the UK (i.e. Wales, Scotland and Northern Ireland). Further standalone funding schemes therefore need to be considered.
4. **Develop a formal body to represent the interests of the insect farming sector in the UK.** This should provide clear guidance to government on the needs of the industry and should serve the needs of UK policymakers, industry stakeholders, and citizens to establish confidence in UK insect farming. For example, develop a UK equivalent of the International Platform of Insects for Food and Feed (IPIFF), which promotes the use of insects for human consumption and in animal feed in Europe, acting as a conduit between research, industry and policymakers.
5. **Work across civil society, academia, industry and citizens to develop and deliver a cross-departmental food and farming strategy.** This should explicitly cover protein requirements in feed for animals and in food for people. This should also contain a commitment to less and better meat and dairy consumption aligned with the Eating Better Alliance recommendations (Eating Better, 2019). For examples of such strategies, see the Dutch Ministry of Agriculture's National Protein Strategy and further examples (Clark and Lenaghan, 2020).

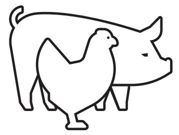
### AQUACULTURE SECTOR



1. **As it is currently possible to use insect meal in aquaculture in the UK, aquaculture suppliers and retailers should work together to increase demand.** For example, this could begin with using low volumes, such as 1 or 2% inclusion rates, building to greater volumes in the future. Another example could be working together to develop customer-facing marketing to encourage the consumption of insect-fed fish.
2. **If you are already using insect meal successfully in aquaculture feeds, communicate this within the industry and with academic third parties.** This will increase evidence, published or otherwise, of the use of insects in aquafeed, offering greater confidence to investors and peers.



### PORK AND POULTRY SECTORS

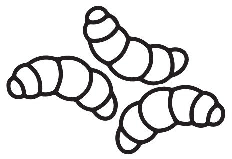


1. **Work with the retail sector to advocate for the introduction of legislation which permits the use of insect meal in pork and poultry feed.** For example, via active participation in the Insect Industries UK Secretariat (formerly the Insect Biomass Task & Finish Group).
2. **Support on-farm trials to demonstrate and validate the benefits of using insect meal in the diets of pigs and chickens.** For example, support trials that test a variety of production systems, insect species, insect feeding substrate and insect meal dietary inclusion rates.
3. **Work with the aquaculture and retail sectors to develop customer-facing marketing which encourages the consumption of insect-fed pork and poultry products once regulation allows this.** For example, support the development of point-of-sale information, colleague training and on-pack messaging.

### RETAILERS

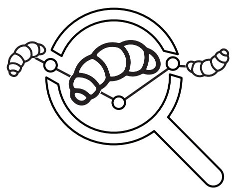
1. **Encourage the use of insect meal in feed within your supply chain.** For example, publish a public statement of intent to signal future demand to the wider industry. Starting with aquaculture, where use is currently permitted, commit to using insect meal in feed, so that 1% of the total diet is insect based by 2025.
2. **Work with the aquaculture, pork and poultry sectors to develop customer-facing marketing which encourages the consumption of insect-fed fish and, when regulation allows, other animal products.** For example, develop point-of-sale information, colleague training and on-pack messaging.
3. **Work with the pork and poultry sectors to advocate for the introduction of legalisation which permits the use of insect meal in pork and poultry feed.** For example, via active participation in the Insect Industries UK Secretariat (formerly the Insect Biomass Task & Finish Group).

### INSECT FARMERS



1. **Develop minimum standards for the production of insect meal, oil, frass and chitin to assure customers of the safety, quality, sustainability and consistency of material entering feed and other supply chains.** For example, develop and abide by an industry code-of-conduct or an industry standard, such as a Publicly Available Specification. These minimum standards should include the welfare standards for the insects being farmed and approved slaughter methods for farmed animals as prescribed by Defra and FSA.
2. **Work with the pork and poultry sectors to carry out on-farm trials to demonstrate and validate the benefits of using insect meal in the diets of pigs and chickens.** For example, trials across a variety of production systems, insect species, insect feeding substrates and insect meal dietary inclusion rates should be tested.
3. **Work with retailers, aquaculture and pork and poultry sectors to develop customer-facing marketing which encourages the consumption of insect-fed fish and, when regulation allows, other animal products.** For example, support the development of point-of-sale information, colleague training and on-pack messaging.

## RESEARCHERS



A research agenda that increases publicly available scientific evidence on how insects can be most effectively used in animal feed is required. Priority research areas include:

1. **Standardised life cycle assessments are required to identify to the conditions under which insect farming yields optimal sustainability outcomes.** Assessments should be relative to soy and fishmeal production and/or to competing substrate processing and disposal methods, such as anaerobic digestion, energy recovery and landfill.
2. **Urgently research the risks associated with different insect feedstocks and how these risks can be mitigated.** Robust evidence is a prerequisite for any legislative change widening the substrates permitted for use in rearing insects. Substrate availability will quickly become limiting once insect meal can be used in pig and poultry feed, and will challenge the ability of UK-produced insect meal to compete with imported insect meal.
3. **Carry out on-farm trials** to identify the optimal rearing conditions across a range of production scales, insect species and dietary inclusion rates in feed.
4. **Develop an insect farming technology roadmap** that outlines how advances in production equipment, processing and facilities can be made and rolled out to increase capacity and efficiency, and drive down overall costs.

## PRIVATE FINANCIERS

1. **With participation from wider industry, develop a platform or mechanism** to promote collaboration and investment which aims to increase confidence in private investors to fund the commercialisation of insect farming on a larger scale.
2. **Consider short-term fiscal incentives** to enable insect protein to be cost-competitive.

## ADDITIONAL ACTIONS IDENTIFIED

The following recommendations were also identified as vital to support the upscaling of insect production in the UK:

- Review whether existing financial and regulatory structures to support anaerobic digestion result in unfair competition for feedstock with higher value uses, such as insect farming.
- Implement a legislative amendment to permit food business operators to supply permitted materials into the feed chain (dual registration option).



# REFERENCES


**Accountability Framework (2021)** Accountability Framework Initiative, website. Available at: accountability-framework.org/ [Accessed 18 May 2021]

**Belghit, I., Liland, N.S., Gjesdal, P., Biancarosa, I., Menchetti, E., Li, Y., Waagbø, R., Krogdahl, A. and Lock, E. (2019)** Black soldier fly larvae meal can replace fish meal in diets of sea-water phase Atlantic salmon (*Salmo salar*). Aquaculture, Vol. 503, 609–619. Available at: doi.org/10.1016/j.aquaculture.2018.12.032 [Accessed 23 June 2021]

**Bessa, L.W., Pieterse, E., Marais, J. and Hoffman, L.C. (2020)** Why for feed and not for human consumption? The black soldier fly larvae. Comprehensive Reviews in Food Science and Food Safety. Volume 19, Issue 5, Pages 2747–2763. Available at: doi.org/10.1111/1541-4337.12609 [Accessed 23 June 2021]

**Clark, W. and Lenaghan, M. (2020)** The Future of Food: Sustainable protein strategies around the world. Available at: zerowastescotland.org.uk/sites/default/files/ZWS1508%20The%20Future%20of%20Food%20%5BProtein%5D%20FINAL%20June%2030%2020202.pdf [Accessed 23 June 2021]

**Eating Better (2021)** Sourcing Better: 8 steps for retailers and restaurants to buy better meat and dairy, 16 February 2021. Available at: eating-better.org/blog/8-steps-to-sourcing-better-meat-and-dairy [Accessed 18 May 2021]

**Eating Better (2019)** Better by half: A roadmap to less and better meat and dairy, 24 Jul. 2019. Available at: eating-better.org/betterbyhalf [Accessed 18 May 2021]

**FAO (2013)** Edible insects: Future prospects for food and feed security. Available at: fao.org/3/i3253e/i3253e.pdf [Accessed 23 June 2021]

**FAO (2020)** The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. Available at: doi.org/10.4060/ca9229en [Accessed 23 June 2021]

**Ffoulkes, C., Illman, H., O'Connor, R., Lemon, F., Behrendt, K., Wynn, S., Wright, P., Godber, O., Ramsden, M., Adams, J., Metcalfe, P., Walker, L., Gittins, J., Wickland, K., Nanua, S. and Sharples, B. (2021)** Development of a roadmap to scale up insect protein production in the UK for use in animal feed. Technical Report for WWF-UK and Tesco.

**Fuchs, R., Alexander, P., Brown, C., Cossar, F., Henry, R. and Rounsevell, M. (2019)** Why the US–China trade war spells disaster for the Amazon. Nature. 567, 451–454, Available at: doi.org/10.1038/d41586-019-00896-2 [Accessed 30 September 2020]

**Heuzé, V., Tran, G. and Kaushik, S. (2015)** Fish meal. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. Last updated on 11 May 2015, 14:32. Available at: feedipedia.org/node/208 [Accessed 8 January 2021]

**Heuzé, V. and Tran, G. (2016)** Soybean (general). Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. Last updated on 3 August 2016, 10:37. Available at: feedipedia.org/node/753 [Accessed 8 January 2021]

**Heuzé, V., Tran, G. and Kaushik S. (2020)** Soybean meal. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. Last updated on 4 March 2020, 18:25. Available at: feedipedia.org/node/674 [Accessed 8 January 2021]

**Holland, J. (2020)** UK aquaculture hopeful as millions allocated to first large insect farm, 8 October 2020. Available at: seafoodsource.com/news/aquaculture/uk-aquaculture-hopeful-as-millions-allocated-to-first-large-insect-farm [Accessed 27 May 2021]

**IDH, The Sustainable Trade Initiative (2020)** European Soy Monitor: Insights on European responsible and deforestation-free soy consumption in 2018. Available at: idhsustainabletrade.com/uploaded/2020/05/IDH-European-Soy-Monitor-v2.pdf [Accessed 23 June 2021]

**IndexMundi (2020)** Detailed country statistics. Available at: indexmundi.com/ [Accessed 10 February 2021]

**IPIFF (2020)** Nutritional benefits of insects in animal feed. Available at: ipiff.org/wp-content/uploads/2020/02/IPIFF-Nutritional-benefits-of-insects-in-animal-feed.pdf [Accessed 23 June 2021]

**KPMG (2013)** Sustainable Insight, A roadmap to responsible soy: Approaches to increase certification and reduce risk. Available at: idhsustainabletrade.com/uploaded/2016/11/KPMG-Roadmap-to-responsible-soy-2013.pdf [Accessed 23 June 2021]

**Lusas, E.W. and Riaz, M.N. (1995)** Soy protein products: processing and use. The Journal of Nutrition, Volume 125, Issue suppl_3, Pages 573S–580S. Available at: pubmed.ncbi.nlm.nih.gov/7884536/ [Accessed 23 June 2021]

**Makkar, H., Tran, G., Heuze, V. and Ankers, P. (2014)** State-of-the-art on use of insects as animal feed. Animal Feed Science and Technology, Volume 197, 1–33. Available at: doi.org/10.1016/j.anifeedsci.2014.07.008 [Accessed 23 June 2021]

**Mano, A. (2021)** Brazil soy firms commit to zero deforestation from 2020, 15 January 2021. Published online at Reuters.com. Available at: reuters.com/article/us-brazil-soy-sustainability/brazil-soy-firms-commit-to-zero-deforestation-from-2020-idUKKBN29K2RA [Accessed 18 May 2021]

**Nogales-Mérida, S., Gobbi, P., Józefiak, D., Mazurkiewicz, J., Dudek, K., Rawski, M., Kierończyk, B. and Józefiak, A. (2018)** Insect meals in fish nutrition. Reviews in Aquaculture, Vol. 11, Issue 4, 1080–1103. Available at: doi.org/10.1111/raq.12281 [Accessed 23 June 2021]

**PROteINSECT (2016)** Enabling the exploitation of Insects as a Sustainable Source of Protein for Animal Feed and Human Nutrition, Reporting, Last updated 16 November 2016. Available at: cordis.europa.eu/project/id/312084/reporting [Accessed 18 May 2021]

**Ritchie, H. (2019)** "Half of the world's habitable land is used for agriculture". Published online at OurWorldInData.org. Available at: ourworldindata.org/global-land-for-agriculture [Accessed 18 May 2021]

**Ritchie, H. and Roser, M. (2019)** "Meat and Dairy Production". Published online at OurWorldInData.org. Available at: ourworldindata.org/meat-production [Accessed 18 May 2021]

**Roundtable on Sustainable Soy (2021)** Roundtable for Responsible Soy, website. Available at: responsiblesoy.org/?lang=en [Accessed 18 May 2021]

**Schreiber, W., Garcia, X.V. and Allen, A. (2019)** Moving to deforestation free animal feed: 2018 Retail Soy Initiative. Available at: www.3keel.com/wp-content/uploads/2019/10/3keel_soy_report_2019.pdf [Accessed 23 June 2021]

**Soterroni, A.C., Ramos, F.M., Mosnier, A., Fargione, J., Andrade, P.R., Baumgarten, L., Pirker, J., Obersteiner, M., Kraxner, F., Câmara, G., Carvalho, A. and Polasky, S. (2019)** Expanding the Soy Moratorium to Brazil's Cerrado. Science Advances 17 Jul. 2019, Vol. 5, no. 7, eaav7336. Available at: advances.sciencemag.org/content/5/7/eaav7336 [Accessed 23 June 2021]

**UKRI (2020)** Using insects to convert food waste into sustainable animal feed, 14 October 2020. Available at: ukri.org/news/using-insects-to-convert-food-waste-into-sustainable-animal-feed/ [Accessed 27 May 2021]

**USDA (2021)** Foreign Agricultural Service Market and Trade Data (PSD Online): Custom Query. Available at: apps.fas.usda.gov/psdonline/app/index.html#/app/advQuery [Accessed 18 May 2021]

**USDA (Not Dated)** Foreign Agricultural Service, International Production Assessment Division (IPAD Crop Explorer – Production Briefs – Brazil. Available at: ipad.fas.usda.gov/cropexplorer/pecad_stories.aspx?regionid=br&ftype=prodbriefs [Accessed 18 May 2021]

**Voora, V., Larrea, C. and Bermudez S. (2020)** International Institute for Sustainable Development, State of Sustainability Initiatives. Global Market Report: Soybeans. Available at: iisd.org/system/files/2020-10/ssi-global-market-report-soybean.pdf [Accessed 23 June 2021]

**WWF (2014)** The Growth of Soy: Impacts and Solutions. WWF International, Gland, Switzerland. Available at: panda.org/?214091/The-Growth-of-Soy-Impacts-and-Solutions [Accessed 23 June 2021]

**WWF (2017)** Appetite for Destruction. Available at: wwf.org.uk/updates/appetitefordestruction [Accessed 23 June 2021]

**WWF (2020a)** Bending the Curve: The Restorative Power of Planet-Based Diets. Loken, B. et al. WWF, Gland, Switzerland. Available at: planetbaseddiets.panda.org/ [Accessed 23 June 2021]

**WWF (2020b)** Living Planet Report 2020 – Bending the curve of biodiversity loss. Almond, R.E.A., Grooten M. and Petersen, T. (Eds). WWF, Gland, Switzerland. Available at: zsl.org/sites/default/files/LPR%202020%20Full%20report.pdf [Accessed 23 June 2021]

**WWF (2021)** Plan for at-risk landscapes. Available at: wwf.org.uk/sites/default/files/2021-05/WWF_UK_2021_Plan_at_risk%20Landscapes.pdf [Accessed 23 June 2021]

**WWF and RSPB (2017)** Risky Business: Understanding the UK's overseas footprint for deforestation-risk commodities. Available at: wwf.org.uk/sites/default/files/2017-10/WWF%20and%20RSPB%20-%20Risky%20Business%20Report%20-%20October%202017.pdf [Accessed 23 June 2021]

**WWF and RSPB (2020)** Riskier Business: The UK's Overseas Land Footprint. Available at: wwf.org.uk/sites/default/files/2020-07/RiskierBusiness_July2020_V7_0.pdf [Accessed 23 June 2021]

# WWF AND TESCO ARE WORKING IN PARTNERSHIP TO HALVE THE ENVIRONMENTAL IMPACT OF THE AVERAGE UK SHOPPING BASKET



© JIRI HREBICEK / SHUTTERSTOCK / WWF