

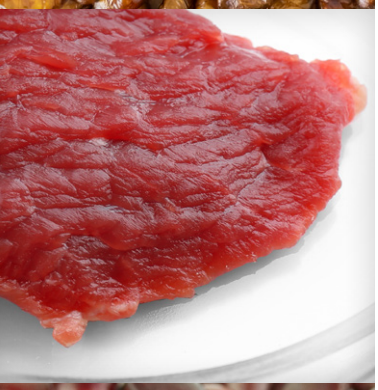


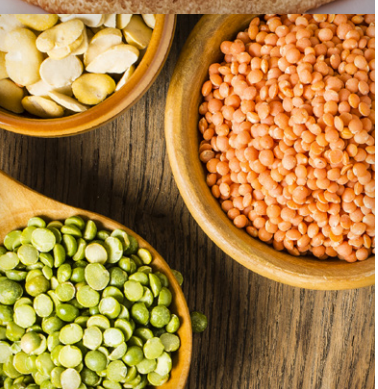

Alternative Proteins: Identifying UK priorities

A roadmap for the future of the alternative protein sector in the UK

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GROWING KENT & MEDWAY

UKRI Innovate UK

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Foreword

Our food system has been experiencing recent shocks that are affecting both the availability and cost of many staple food products. The need to increase agricultural productivity to meet the requirements of a global population, predicted to reach c.10 billion by 2050, is well documented. Recent stresses, including Brexit, the COVID-19 pandemic and conflict in Europe, also highlight both the need and opportunity to increase domestic food production to mitigate against future supply chain challenges.

Within this context there is a growing demand for protein sources for both human and animal consumption. Consumers are also increasingly looking for alternatives to traditional meat and dairy products for a variety of lifestyle choices, driving significant global market opportunities in this space. As a result, the alternative protein sector is predicted to reach $27 billion by 2027, and the UK is well placed to access this global market through our world-leading science-base and industry capability across the agri-food supply chain. Opportunities also exist to develop new domestic protein sources to displace reliance on global commodities like soya- and fishmeal in the animal feed and aquaculture sectors, which also have the benefit of helping to reduce the environmental impact of food production.

The publication of the National Food Strategy highlighted the potential in the alternative protein industry, with recommendations describing actions to support the creation of a competitive domestic marketplace. To better understand our current position and capability within this exciting new space, a cross-sector workshop was held in February to identify opportunities and challenges to establishing a competitive UK industry over the short, medium and long term. The workshop was taken forward by UKRI's Transforming Food Production (TFP) programme and the Growing Kent & Medway Strength in Places Strategic Priorities Fund.

A series of roadmaps have been developed as an output from the workshop which identify key priorities for the sector towards 2030. The TFP programme is already supporting a number of projects developing novel technologies and innovations to establish new industries across this sector, from insect and algal proteins, to advanced fermentations for single-cell proteins, and lab-cultured meat. This report provides an initial blueprint for how the sector can come together and work collaboratively for mutual benefit, helping to unlock the global market opportunities that are emerging across the alternative protein sector.

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Innovate UK

Executive summary

The UKRI Transforming Food Production (TFP) team and Growing Kent & Medway both recognise the emerging opportunity in the alternative protein sector, and have come together to explore the UK priorities for industry, academia, regulatory bodies and funders. This was achieved through the development of a focussed workshop to provide a series of roadmaps for key categories of alternative proteins. The workshop brought together relevant stakeholder experts to determine the UK capabilities and capacity in the alternative protein sector, and where future investments can be targeted to maximise impact.

The workshop objectives were to:

- Provide a catalyst to **build effective consortia**
- Identify **project concepts** for forthcoming competitions
- Provide a consolidated view of **opportunities and barriers** in the sector
- **Prioritise Technological, Commercial, Regulatory and Consumer actions** required across short- (1-2 yrs.), medium- (2-5 yrs.), long- (5-10 yrs.) and very long- (10 yrs.+) term timescales to realise a competitive UK alternative protein sector.

This activity builds upon a previous 'Alternative Proteins Roadmapping Workshop' held on 23rd March 2021, the aim of which was to develop a conversation between the TFP programme, participating funded companies and a selection of stakeholders to create a shared vision and preliminary roadmap for the UK alternative protein sector. A link to the report and roadmap can be found here: **(https://www.ukri.org/wp-content/uploads/2021/08/UKRI-060821-AlternativeProteinsRoadmapSummaryReport.pdf)**.

This latest online workshop, held on 22nd February 2022, brought together 30 attendees, all experts from this specialised sector – including senior managers and technical professionals from both UK SMEs, and large businesses in each of the priority sectors listed below. In addition, leading researchers from Higher Education Institutions (HEIs) and representatives from UKRI, Defra, industry bodies, regulators and policy makers associated with alternative protein food products were invited.

The priority sectors for workshop participants were:

- **Plant proteins** – pulses, extracts from other plants, agri-food side streams etc
- **Fermentation** – proteins from fermentation-based systems (based on algae, bacteria, fungi or gas-/energy-based systems), and cell culture technologies that are primarily developing lab meat products
- **Novel systems** – new aquaculture, insect proteins

The workshop produced a series of roadmaps, one for each priority sector, with expert insight into the current status of the sector, the size of the opportunity and the barriers, and detailed information on the following aspects: Technical; Commercial; Regulatory; Consumer insight.

The alternative protein sector is evolving rapidly, and this report is a snapshot in time. Some of the key recommendations were shared across the priority sectors, and included:

- Development of an implementation and action plan to coordinate interdisciplinarity, integrating research into the production, novel processing and the potential for onward product development;
- Provide sustainable sources of funding to explore disruptive research and innovation ideas;
- Strengthen capability in the UK to deliver purposeful technology solutions;
- Assessment of the UK landscape to facilitate early engagement and consortia building with suitable industry and academic partners;
- Develop mechanisms to successfully speed up pioneering innovations through the UK market, including access to finance for scale-up;
- Develop a core team for coordinating and building the UK ecosystem, providing a centralised resource accessible to all UK stakeholders; and
- Distribute pump-priming funds for onward discovery science and collaborative R&D.

The Alternative Proteins 'UK Priorities' Workshop delivered a deeper and more up to date understanding of the landscape and potential opportunities for the UK in the global alternative protein sector, providing insights and recommendations for maximising impact from future public and private investment.

Introduction

Global food systems currently have a high emissions profile, which is projected to grow as a proportion of total emissions due to other sectors decarbonising, a lack of resilience to weather extremes and elements of resource inefficiency with high externality costs [1]. Shifting to sustainable, alternative proteins can, in part, help with the transformation of our food system to become more climate smart. For the UK and Europe, this means improving protein self-sufficiency, deconstructing unsustainable supply chains, and increasing diversity both in sources of protein and end user products.

The definition considered here for alternative proteins are proteins which are produced from sources that have low environmental impact in order to augment livestock protein sources or offer an alternative to meat and dairy protein sources which directly or indirectly address 13 out of 17 UN Sustainable Development Goals (SDGs), and provide promising innovation opportunities.

In the UK, the land footprint and dietary Green House Gas (GHG) emissions per capita for animal protein production and consumption is approximately twice that of plant protein production and consumption [2][3]. The independent UK Committee on Climate Change reported the requirement of 20% reduction in the consumption of meat (particularly red and processed) and dairy products to achieve net-zero carbon emissions by 2050 [4], and to contribute to food security, healthy diet, biodiversity, and resilience.

Here lies an opportunity for UK-led disruptive innovation. One of the UK's ambitions should be to foster connections within the UK research community in the alternative protein-based food area, and work in tandem with domestic and international industry partners to deliver global innovation impact.

Nutritious protein sources from plants, seaweeds, or via non-animal cell culture/ fermentation (e.g. fungi and microalgae) or cultured meat, can provide an alternative to more traditional protein sources.

Alternative protein-based foods in Europe and UK are projected to grow to £6.8 billion by 2025 [5]. For the EU and UK, the current meat alternatives (£1.3 billion) and dairy alternatives (£2.7 billion) represent only 0.7% and 3% of total meat and dairy market share respectively [5], which indicates a huge opportunity for further market growth. Investment will be required at the production, processing and product level for the UK to capitalise on the cutting-edge research and innovation potential across the alternative protein sector.

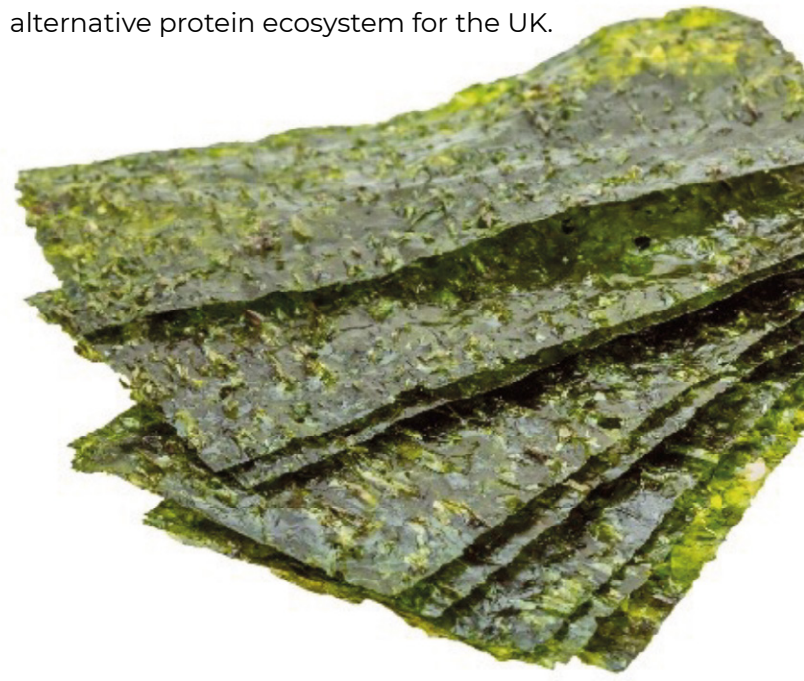
Growing Kent & Medway

Developed through the UKRI Strength in Places Fund, Growing Kent & Medway is a world-class research, innovation and enterprise cluster supporting growth in technology-driven horticulture, fresh produce packaging, food and drink processing and its supply chains. Growing Kent & Medway is a diverse and dynamic collaboration that brings together innovative growers and processors, scientists, technologists, and entrepreneurs to deliver a shared goal of improving productivity and sustainability in the sector.

We are building on Kent and Medway's established reputation and industry base to make this region one of the most dynamic, competitive and successful horticultural and agri-tech locations in the world. Our unique geography means we are home to most of the UK's high-value horticultural production, packaging and processing, and a major gateway to global markets.

Growing Kent & Medway has created a Special Focus Group to support the opportunity for UK-led, disruptive innovation in alternative protein-based products. Plant-based food is the fastest growing trend in the UK food sector. According to Nielsen MarketTrack report the sales value in the UK grew by 73% during 2018-2020, with plant-based milk and cheese showing triple digit sales growth over this period. In the UK, sales are predicted to be £1.1 billion for meat alternatives in 2024 and £565 million for dairy alternatives in 2025.

Building on the expertise, research capabilities and resources across its research organisations (see annex 3), Growing Kent & Medway is coordinating an interdisciplinary approach; one that will develop and support a new innovation-led, alternative protein ecosystem for the UK.



Roadmaps

An online workshop was attended by 30 delegates (see annex 1) in February 2022 to identify the key challenges and opportunities facing the UK alternative protein sector.

Participants were invited to register for the workshop through Growing Kent & Medway. The attendees were then selected to ensure there was a broad range of expertise in plant-based, fermentation (lab-cultured meat and mycoprotein) and novel (new aquaculture or insect) proteins. There were representatives from UK-based academia, industry and policy makers.

The discussion groups considered the challenges and opportunities around the technical, commercial, regulatory and consumer factors impacting the alternative proteins sub-sectors.

In advance of the workshop, 26 respondents completed a questionnaire to identify the highest priority challenges and opportunities facing their sub-sector, and indicated the likely timeframes to realise or overcome those barriers. The survey responses guided the workshop discussion (see annex 2).

The knowledge and information collected from both the workshop and questionnaire have informed the following roadmaps by sub-sector.

Plant-based

OBJECTIVE

Understanding drivers and barriers to develop globally competitive plant and algal protein sector in the UK to help deliver the sustainable protein-based diet shift.

Current Status

Technical

The plant-based protein sector is dominated by imported materials, largely soya. New processing facilities are upcoming in the UK for plant-based food, including:

- A new facility in Lincolnshire by Naylor Farms for plant protein extraction
- Europe's largest plant-based factory (Plant & Bean by Griffith Foods and Gushen) at Boston, Lincolnshire
- A £6 million UK potato protein extraction facility at the Branston site
- Substantial improvement in taste and texture of plant protein-based products

Commercial

There is an estimated £1 billion market for plant-based alternatives in the UK, with a huge potential to grow; predicted market growth (year-to-year growth in %) for meat alternatives (30%), dairy free milk (48%) and cheese alternative (38%). This will be mainly driven through the expansion of start-ups.

Regulatory

Workshop discussion centred around how to use post-Brexit UK regulation to drive innovation and further accelerate market. There is great potential to leverage algae harvest in the UK by exploiting the coastline.

Consumer

Plant-based food is the fastest growing consumer trend.

Size of opportunity

Technical

The technical opportunities discussed included:

- Develop improved varieties and introduce new crops as protein sources
- Impart circularity within the plant protein value chain (e.g. upcycled proteins)
- Eco-innovative technology for plant protein extraction and scale up
- Develop sustainable process – shift to bio-processing
- Deliver better taste and texture for plant-based products

Commercial

In order to realise these opportunities, there is a need for the sector to adapt to growing consumer demand. Commercial opportunities include co-product market development to impart circularity at reduced cost and nutritional labelling.

Regulatory

There is a Post-Brexit opportunity to utilise novel technology like gene editing. Discussion also focussed on addressing agronomy at the primary production stage by identifying new crop protection approaches.

Consumer

There is a growing demand for novel protein products as the consumer is aware of the climate benefit of this form of protein over animal-based alternatives.

Barriers and/or trade offs

Technical

Numerous challenges were identified at a technical level which need to be addressed to realise a competitive UK plant-based alternative protein sector, including:

- Lack of diverse protein sources to develop innovative ingredients
- Lack of tools (varieties, crop protection, agronomy) to maximise sustainable domestic production
- Need for technology to make plant protein extraction more sustainable and efficient
- How to impart circularity within the plant protein value chain (e.g. minimising waste from upstream protein production)
- How to improve and adapt the functionality (emulsification, taste and texture) of plant-based products
- Lack of understanding for bioavailability of macro and micronutrients from alternative plant protein sources

Commercial

Commercial barriers which need to be overcome include the need to reduce the cost of the raw materials and products, scaling up processing facilities and investment in infrastructure.

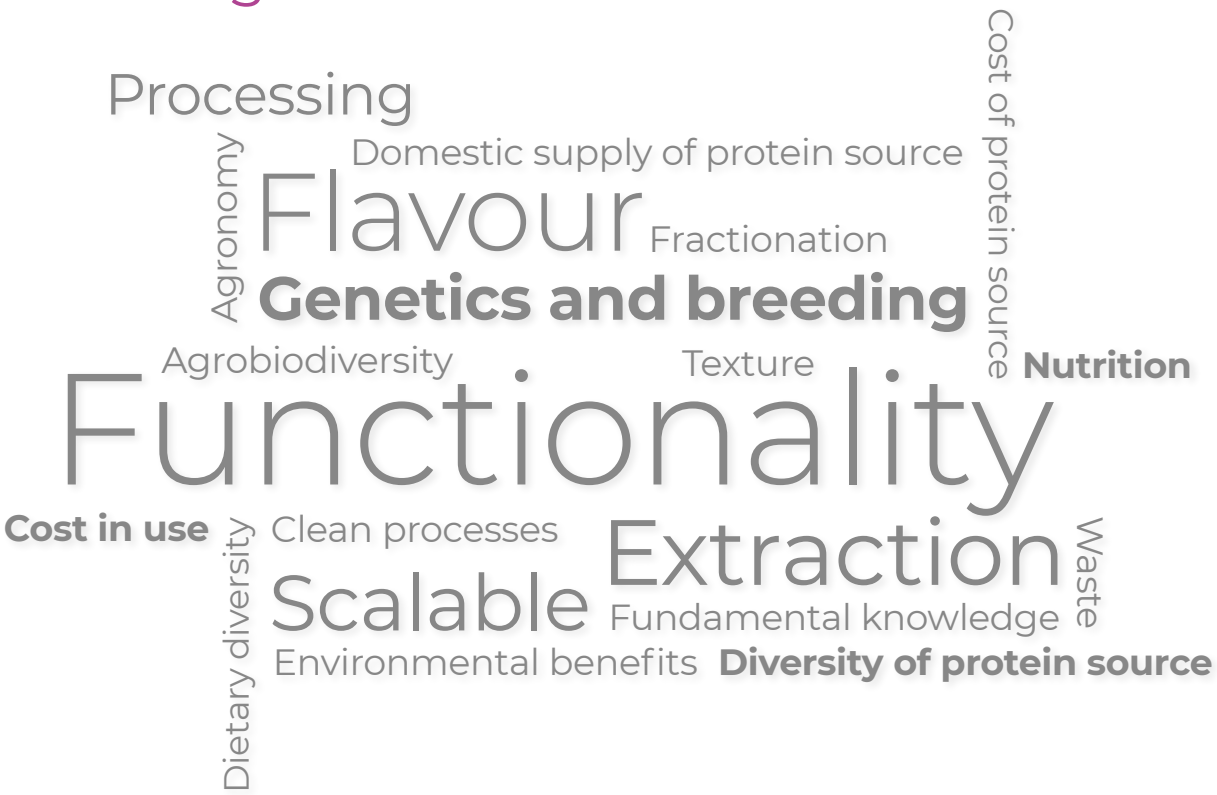
Regulatory

Regulatory barriers that need to be addressed include the regulation around novel crop production, lack of robustness of product claims within the plant-based food sector, impact of novel food legislation (resulting in longer time to market) and high salt, sugar and chemically modified starch in meat and dairy alternatives.

Consumer

From a consumer perspective of plant-based alternative proteins there is a lower acceptance in terms of naturalness and clean label compared to traditional products. There is a negative connotation with 'ultra-processing' which needs to be addressed through educating the consumer and transparency. Another consumer barrier is the willingness to try new products. For repeat purchase affordability of alternative protein sources versus animal-based alternatives is also key.

Challenges: **Technical**



	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Functionality		• mimic animal derived proteins • improve and adapt		
Diet				• nutritional comparison to animal-based equivalence
Extraction			• small pilot scale research facilities • scalability of novel/sustainable technologies	
Flavour	• mimic animal derived products/ remove flavour taints			
Genetics and Breeding		• lack of transformation technologies		• lack of suitable varieties
Processing	• scalable facilities			
Production		• establish "new" crops in rotations • Crop protection products	• grower investment • yield stability	
Supply Chains		• resilience • import/export		

Functionality	Within the medium term the taste and functionality of plant-based protein products will increasingly mimic the animal derived proteins, although some believe that benchmarking against animal derived products may not be useful. In order to improve and adapt the functionality of the plant-based products there is a need for better and more diverse raw materials to develop innovative ingredients for the food industry.
Diet	There is a focus on crude protein content in the alternative protein market but the animal-based offer is providing more than just protein (e.g. micro- and macronutrients) and these additional nutrients are bioavailable and well studied. There is a need for more research to identify the nutritional equivalence of alternative protein sources vs. the animal derived proteins. Are the comparisons correct? i.e. 1KG of meat vs. 1KG of plant-based – need to look beyond protein alone.
Extraction	In the longer term there is a need for technology development to make protein extraction processes more sustainable, more efficient and less costly. The cost of protein raw material production is still high and there is a lack of efficient scaling – for example there is no pilot scale extraction facility in the UK for fava bean. Moreover, there is a sustainability challenge to address the waste/side-streams generated following the protein extraction process. This presents a co-product development opportunity which will lead to an increase in the sustainability of products via valorisation of the waste streams (see opportunities section). To address the sustainability challenge there is also an opportunity to integrate energy, water and waste utilisation into these manufacturing processes.
Flavour	In the short to medium term there is the challenge to improve the flavour quality of plant-based protein ingredients and products through the masking/elimination of off-flavours (e.g. beany and earthy flavours of certain crops like legumes) and to mimic animal derived products (for example fat profiles often overlooked but it is the fat profile of meat, cream and butter etc which is perceived by many to taste good).
Genetics and Breeding	There is a lack of diversity of species and varieties of legumes suited to the UK climate. Over the medium term there is a challenge to develop and deploy transformation technologies to improve variety availability. In the very long term the challenge will be to breed varieties suitable for UK conditions – currently most breeders are based overseas and not actively breeding in the UK/for the UK. There are no commercial UK plant breeders focussing on these crops.
Processing	There is currently little investment in processing facilities in the UK beyond extrusion. In the short to medium term this challenge needs to be addressed by scaling facilities and adding diversity in the processing capabilities (e.g. 3D printing, shear cell, electrospinning). There is a lack of funding to de-risk scale up of processing. There is a need for efficient processing to minimise side-streams/ loss in order to become more sustainable.
Production	There is a need to improve production for these "new" crops. In the medium term we need to develop more technical knowledge and agronomy about where and how to grow the crops in the UK climate with good rotations giving the potential to support pulse cropped area 4-5 times larger than present. Also in the medium-term the lack of available crop protection chemistry needs to be addressed for these relatively minor crops. Currently the ROI for beans is low to none most years but if yield stability can be improved they can give high returns – "beans are a wish crop meaning growers wish they put more in the ground on a good year and less in the ground in a bad year". There is a need to improve yield stability in the long term in order to ensure grower investment to grow these crops. Large investment is required to diversify a farms crop portfolio (i.e. crop specific machinery and developing the knowledge base within a farmers business).
Supply Chains	There is a medium term challenge to ensure that the domestic plant-based protein sources (= lower food miles) achieve climate resilience, dietary diversity and agri/biodiversity. Supply closer to point of manufacture is ideal however local is not always possible (as it can sometimes be less efficient both in cost and environmentally). Multiple sourcing options across a wider range of locations (including local) would increase supply chain resilience. Currently most raw ingredients are coming from North and South America with limited availability from Europe – this situation is unlikely to change as the demand increases unless there is a marked increase in the production capacity within Europe.

Challenges: **Commercial**

	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Economically viable supply chain			• high cost of raw materials • profitability of farming sector • government subsidies	
Investment		• infrastructure investments – farmer • infrastructure investments – processor	• ROI to Farmer • R&D	
Flavour taints		• high costs of masking flavours	• reduce and/or eliminate beany/ earthy flavours	
Clean label		• products with added ingredients		
Sustainable supply chain		• access to UK sustainable protein sources		
Business sector structure		• fragmented – lots of SMEs		

Economically viable supply chain	A key supply chain challenge to address in the longer term is the cost of raw material (per unit protein). For animal feed the challenge is finding an economically viable alternative to replace soymeal. If soya is to be replaced by domestic sources there is a need to address the capacity and locality of mills in relation to the point of consumption. For food as opposed to feed, the cost of raw material can be a significant barrier as manufacturers are reluctant to pass this on to consumer. The lack of futures trading, like for other major crops, means processors cannot hedge against future purchases. Certain sources of plant-based protein are prohibitively expensive e.g. hemp is 3-4x the cost of soya/pea. If compared to animal derived protein plant-based raw materials can be inline or cheaper.
Investment	The sector is currently experiencing market failure due to the volume driven supply chain which is a typical characteristic of our commodity market; growers won't commit until market guaranteed; breeders won't invest until grower demand exists. In the short/medium term there is a need to invest in infrastructure at the primary producer and processor level. Primary producer investment is needed to start to grow novel crops (i.e. crop specific machinery) and this requires a critical mass in order for processors to invest in processing capabilities. Processor investment could start with a pilot production plant in UK for pea or faba. Volume is an issue for processors – e.g. Lupins for feed – need a critical mass grown locally to warrant the millers investing and/or adapting their equipment for diversifying their product range. R&D investment in bigger research programmes to develop long term alliances through out the supply chain from breeder to processor is required to address the challenges leading to market failure. In the longer term this will help deliver an ROI to the farmer ensuring a UK supply within the global supply mix.
Flavour taints	Not a priority for animal feed (where cost point and nutrition are more of a priority). In specific food products, optimal flavour profile remains an issue but is a competitive area of active inhouse R&D. Currently off-flavour (of plant protein like legumes) are masked by masking agent (supplied by flavour companies) but these can add to costs and contribute to complex labelling and go against the consumer perception of naturalness. In the longer term the market perhaps needs time to evolve “a consumer journey” e.g. we keep masking flavours but the consumer should be given the chance to adapt to the actual flavour (of ingredients).
Clean label	The clean label challenge is a priority which will be addressed in the medium term.
Sustainable supply chain	There is a medium term challenge to address the sustainability of the sources of raw ingredients and a risk that we will move from an unfair/unsustainable animal-based diet to an unfair/unsustainable plant-based one. There is a need to grow more from less in both the UK and globally to ensure sustainable supply chains beyond the medium term.
Business sector structure	The plant-based alternative protein sector was described as an unusual business sector which was very fragmented with lots of SMEs – this also creates an opportunity as the sector matures.

Challenges: **Regulatory**

Hemp
Agrochemicals
Uncertainty
Trade
GM
Allergenicity
Novel food legislation
Negative impacts on health
Genetics and breeding
Labelling
Protein digestibility

	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Novel food legislation		• EFSA approvals for emerging plant proteins • uncertainty relating to novel foods	• labelled as "novel foods" but consumed elsewhere	
Standards of identity (naming of products)		• food labelling using old concepts	• e.g. milk vs mylk or ice cream vs frozen dessert	
Labelling		• natural classification • nutrition	• sustainability metrics	
Production		• new crops • crop protection products		

Novel food legislation	Although novel food legislation is perceived to be less of a problem for plant-based alternative protein compared to other alternative protein sectors it is still a challenge in the medium term as emerging plant proteins and different fractionated derivatives from established and novel crops could trigger novel food status (and also raise standards of identity issues). Beyond the medium term there is confidence that the legislation around novel foods will catch up on granting food safety etc and that regulators will soon have more efficient processes in place to deal with crops which haven't had the long history of consumption which other staples have. If introducing novel ingredients be aware these might become allergens of the future.
Standards of identity (naming of products)	Standards of Identity (SOI) is not a high priority issue for the plant-based alternative protein companies represented at the workshop as they can deal with this challenge through marketing. The challenge of SOI is that it is confusing the consumer – to address this in the medium term there just needs to be transparency in how the product is described to the consumer.
Labelling	There is a need for the labelling of the products to be consumer driven (consumer relevance and interpretation). The product has to be adequately described so that labelling can help the consumer understand unfamiliar sources of raw ingredients and ensure the robustness of product claims. In the longer term, labelling could be used to report on sustainability metrics and to make nutritional claims more robust.
Production	Regulatory barriers are preventing a tool kit for novel crop production in the UK to be developed and utilised to its full effect (e.g. use of breeding techniques, variety diversification, crop protection options, Integrated Pest Management (IPM) optimisation in the field). In the short term, as its own regulator for crop protection and IPM regulation, UK government and devolved administrations can support the sector by facilitating regulation for minor crops (e.g. research to develop agronomic solutions and crop protection product approval (e.g. through EAMUs – Extensions of Authorisation for Minor Uses)). In the longer term, breeding novel crops will help support the sector, however there are challenges which need addressing including the prohibitively large regulatory burden of getting new/minor crops registered particularly for smaller companies (see Defra under utilised crop review). Plant breeders therefore need significant seed sales guaranteed to justify investment in breeding programmes for these crops. There is a need to reduce cost of market entry for breeders in order to address this challenge. Promising changes in gene editing regulation may help address the availability of new varieties and crops better adapted to the UK climate in the medium term.

Challenges: **Consumer**

	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Perceived as ultra-processed		• misinformation	• change consumer mindset	
Consumer acceptance		• willingness of consumers to try new products	• ROI to Farmer • R&D	
Consumer behaviour		• improving engagement and education • drive demand for healthier and sustainable option		
Sensory acceptability			• simulate organoleptic properties	
Affordability and availability		• sourcing/supply chains • price of final product	• mismatch between sustainability and affordability	

Perceived as ultra-processed	There is a perception that ultra-processed food is always unhealthy. "Sympathetic processing" is the processing of foods which can promote the release of more nutrients. There is a need in the medium term to bring narrative back to the evidence base and open the dialogue across the stakeholders (industry, farmers, government, knowledge partners (scientists and engineers) and consumers) to achieve this. Once the misinformation is neutralised by evidence, in the longer term there is a need to change the consumer mindset about the need of processing. After all, most processing is good – it helps to extend the shelf life of products so they can be mass marketed, safe, convenient and affordable. Many crops can't be eaten in their raw form or are not palatable. New processes are being used for 1) protein production (using solvents, water and energy), 2) processing steps of modifying raw protein for better function such as extrusion and 3) formulating new products (NPDs) which need to be defined and communicated transparently to the consumer.
Consumer acceptance	In the medium term there is a need to address the willingness of consumers to try new products through marketing and accessing different segments of the market. The alternative protein product market is exciting where consumers have a lot of choice so once they have tried once they are likely to try more. There is a need to conduct research in to what the consumers see as important sensory attributes for alternative protein products to achieve wider acceptance of plant-based in the longer term. Currently, sensory research is benchmarked against animal protein sources – this may change as current diet habits shift and sensory perception evolves in consumers. In the longer term there is a need to provide awareness of deficiencies e.g. calcium and iron as diet habits shift away from animal-based sources of protein.
Consumer behaviour	In the medium term there is a need to improve engagement and education of the consumer – this could be achieved through story telling e.g. around reducing your carbon footprint and health benefits when compared to certain animal-based alternatives. In turn this will drive demand for a healthier and more sustainable option.
Sensory acceptability	In the longer term there is a need to simulate organoleptic properties (texture, flavour, colour, taste, smell, etc) of animal-based alternatives.
Affordability and availability	Health and climate are important consumer drivers for certain markets but locally produced, sustainable food can come at a higher cost. Affordability is the primary driver for food choice to many households and it is the households with poorer diets that would benefit most from incorporating healthier and more sustainable plant-based proteins into their diets. In the US a survey (conducted by McKinsey) which investigated the drivers for first time purchase of alternative protein products found that sustainability, nutrition and safety were top but repeat purchase was about cost. The mismatch between sustainability and affordability needs to be addressed in the longer term.

Opportunities: **Technical**

	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Genetics and breeding			• gene editing • breed varieties with enhanced protein/nutrition • breed varieties with climate resilience/ adapted to new locations • breed varieties with enhanced health properties • genome sequencing of crops	
Circular economy		• co-product market development • engineering design • utilising waste and underutilised resources		
Differentiated characteristics		• nutrition • functionality		
Diversify protein source			• different sources of proteins	
Efficient extraction and processing methods			• lower environmental impact • higher extraction yields using sustainable process	
Agronomy		• alternative control		
Labelling		• nutrition		

Genetics and breeding	There are a number of opportunities to breed varieties with new/enhanced traits including increased protein content/quality, enhanced nutrition/ health properties (e.g., biofortification), varieties with climate resilience/adapted to new locations. These are all opportunities which will be realised in the long term (5-10 years) because of breeding cycles however, there is an opportunity to expediate this for some traits through gene editing and genome sequencing of legume crops. Some of the issues, raised in the challenges section, which could be addressed through genetics and breeding were; “right crops, wrong places” (breeding and trialling of different crops in new territories) and; the inefficiency of pulling apart proteins/starches/fibres into separate streams and then combining during processing may be addressed through breeding varieties that are more amenable to processing. The development of more functionalised legumes with higher protein content will lead to the availability of better raw materials..
Circular economy	In the medium term there is an opportunity to develop co-products as observed in the more mature soya/wheat sector. If an increase in protein content is realised through genetics and breeding (see above) then this will provide an opportunity to reduce waste/side streams. Either way, circularity needs to be integrated into the supply chain in order to improve sustainability credentials versus other protein sources. There is also an opportunity to utilise waste streams from other processes (e.g. brewer's spent grain) and other underutilised resources for plant-based protein extraction. Circularity was covered in further detail in the challenges section.
Differentiated characteristics	In the medium term the plant-based alternative protein sector has an opportunity to deliver competitive advantages by developing differentiated characteristics including improved nutrition and better functionality. On nutrition, there is an opportunity to develop targets with nutritionist to determine what the nutritional characteristics would be optimal. There is an opportunity to develop tailor-made protein ingredients with enhanced functions and/or targeted for specific applications. Cost-benefit wise, any new products must deliver at/ above soya/wheat to compete in the market place (these are the benchmarks). On functionality a better fat profile will deliver better product quality (e.g. meat alternatives).
Diversify protein source	Alternate sources, e.g. hemp and buckwheat, are interesting for more marginal land e.g. much of Scotland. There are extensive opportunities in the long term to trial and assess plant-based proteins from different sources across a broad range of applications.
Efficient extraction and processing methods	In the long term there is an opportunity to develop novel methods of extraction which have a lower environmental impact, higher extraction yields and at reduced costs. More research will be required to address this challenge to understand how to generate better protein fraction (= improved quality via downstream process). On processing, a systematic understanding of the process-function relationship for wider varieties of plant/algal proteins (i.e. a link to fundamental research is required). Also, to sustainably deliver the desired protein functions, the effect of non-thermal processing on the inter-relationship between (micro)structure and function (e.g. solubility, emulsification or texture) needs to be further studied.
Agronomy	In the medium term there is an opportunity to address agronomy at the primary production stage by identifying new crop protection approaches. Integrating legume crops into the rotation which will offer potential benefits in soil and net-zero.
Labelling	There is an opportunity for labelling products to inform the consumer of nutritional benefits beyond the protein content/level, which may include fibre and phytonutrients. Like animal sources of protein, nutrient profile of plant proteins will be highly variable depending on the source (species/variety choice) and the processing system. Therefore it is important to communicate this to the consumers. Protein is easily measurable and the consumer has a good understanding of what it means. Opportunity could focus on other micro- and macronutrients which are often harder to estimate in complex food matrices and difficult to communicate to the consumer. There is also a need to understand how much is lost during processing (e.g. vitamins).

Opportunities: **Commercial**

	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Circular economy		• co-product market development • use of agri-food waste		
Sustainability		• sustainable alternatives to animal derived foods		
Consumer demand		• increased consumer interest – 15% CAGR globally		
Net-zero		• opportunity to fix N and reduce artificial N input		• help achieve climate targets
Dietary shift	• shift toward vegan/vegetarian diets			
Labelling		• naturalness/ Eco labelling • marketing • nutritional labelling		

Circular economy	In the medium to long term there is a commercial opportunity to develop co products and identify opportunities for waste streams developed within the manufacturing process but also to utilise waste streams from outside (i.e. extract protein from brewer's spent grain). There is also an opportunity to partner with other alternative protein sub sectors e.g. use of the waste streams from plant-based protein manufacturing process could be utilised by the precision fermentation subsector. This sector is very amenable to circular economy models.
Sustainability	Eco labelling initiatives is an opportunity in the medium term which will be required to communicate environmental benefits to consumer (see labelling below).
Consumer demand	There is a growing consumer demand for novel protein products as evidenced by most consultancy reports which gives high Compound Annual Growth Rate (CAGR) for plant-based protein sector and a Food Standards Agency (FSA) commissioned survey looking at consumer perceptions of alternative, or novel, sources of protein (https://www.food.gov.uk/research/behaviour-and-perception/survey-of-consumer-perceptions-of-alternative-or-novel-sources-of-protein).
Net-zero	Plant-based proteins make a strong net-zero case and this is measurable making policy easier to implement to support the sector. In the medium term, with increasing fertiliser costs, there is an opportunity to fix Nitrogen and reduce artificial Nitrogen input in primary production. In the very long term as alternative proteins displace animal-based alternatives there is an opportunity to help achieve climate targets.
Dietary shift	There is a clear commercial opportunity in the short term as there is an increasing shift in the UK population towards vegan and vegetarian diets which is being realised by the sector. With this momentum there is an opportunity to address some of the issues in our current food landscape. The public health, nutrition and food security aspects of alternative proteins are all positive messages. Should the government use the opportunity presented by the Eat Well Guide and National Food Strategy documents to revise the dietary guidelines (led by department of health) in light of the increase in the diversity of protein sources available to the consumer? A need was recognised by the group to focus commercial messaging on balanced diet i.e. needn't be a 100% plant-based = small shift e.g. AHDB Eat Balanced campaign. Is there an opportunity for some social science research here (building on the FSA consumer perceptions survey cited above)?
Labelling	There is an opportunity in the medium term to communicate the environmental benefits to the consumer through eco labelling initiatives allowing the sector to communicate the product to the consumer transparently e.g. crops that are unfamiliar to them. Pea and faba offer positive story (low footprint, biodiversity, pollinators). As expanded upon in the technical opportunity section, there is a commercial opportunity to highlight the nutrients plants do bring e.g. dietary fibre. More work could be undertaken in this area to understand what dietary properties are available from the plant-based diets and where these could be used to address issues in our current food landscape. Perception that plant-based = healthier, greener but needs fortification.

Opportunities: **Regulatory**

GM Standardise food safety methodology

Genetics and breeding

Trade

Health claims

Reduced allergenicity

Regulatory standards

UKRI Innovate UK
GROWING KENT & MEDWAY

	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Genetics and breeding			• gene editing	• genetic modification
Reduced allergenicity			• food ingredients with reduced or no allergenicity	
Regulatory evolution	• develop robust evidence for regulators	• post-Brexit opportunities • standard of identity		

Genetics and breeding	There is an opportunity to educate the consumer about the use of breeding techniques such as gene editing (GE) and genetic modification (GM) to give them the information required to inform there position on these technologies. There is a role here for 'knowledge partners' (i.e. Universities and Research Organisations) to educate the consumer (might seem to the consumer that the food manufacturer is conflicted). This can be achieved through openness and transparency and active engagement with the consumer.
Reduced allergenicity	There is an opportunity here to offer alternatives to allergy causing animal-based products (e.g. lactose) but an associated challenge may see increased prevalence of different allergies as diets shift e.g. to pea allergens.
Regulatory evolution	Post-Brexit, the UK is its own regulator for crop protection products and GM/GE regulation. This is an opportunity for this sector, however, it will require a coordinated precompetitive space to accelerate regulatory approval = Scientific community develop robust independent evidence that is communicated to the regulator and subsequently to the consumer – but this will need funding. On standards of identity (SOI), post-Brexit, UK regulators have the opportunity to change SOI regulation with just the one regulator rather than the multiple regulators which make up the EU position = easier for industry to navigate.

Opportunities: **Consumer**

	Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Sustainability	• increased awareness	• climate benefits associated with plant-based diets		
Lifestyle shift		• increased awareness of healthy lifestyle • improved nutrition		
Dietary shift	• wider product range is inclusive of consumer diets	• shift towards plant-based/ flexitarian diets		
New product development		• satisfy new dietary trends • targeting different sectors of the population • utilise plant functionality to enhance consumer experience		
Affordability			• cost reduction of raw material	

Sustainability	According to FSA survey (cited above) consumers are choosing plant-based proteins over animal-based protein primarily (44%) due to perception of food safety ahead of perception that it is healthier and more sustainable – this finding presents a potential opportunity to pursue through further research into the safety aspects of plant-based proteins. Agricultural sector are good at promoting the sustainability issue – needs to translate to end product (see labelling opportunities above).
Lifestyle shift	Wealthy individuals can shift their lifestyles around sustainability and nutrition however affordability is preventing those people who we most want to see shift their dietary choices for a healthier and more sustainable society. In the medium term policy and government guidelines should incentivise industry to address this by making products that they want to eat affordable so the shift is an easy one e.g. plant-based protein supplemented chicken nuggets.
Dietary shift	The consumer opportunity is clear and already evident around society's dietary shift however there is a need for industry, research organisations (ROs) and Government to address some of the short term challenges around consumer education. The consumer needs to be informed about health and sustainability of their food preferably by universities, ROs and the third sector, crucially with buy in from all the stakeholders. There is an opportunity to have a hybrid approach to products with reduced meat substituted with plant-based protein which will promote consumer acceptance (nutrition, appearance etc). The latter needs strong messaging (from the food industry/retailer).
New product development	There are many consumer opportunities which can be realised by this sector in the medium term through new product development including satisfying new dietary trends, targeting different sectors of the population and utilising plant functionality to enhance consumer experience. The group discussed that these new products needn't just mimic animal-based products – if consumers are given the opportunity to get used to it, new flavours and textures can be a positive (e.g. plant-based milk drinks).
Affordability	There is an opportunity to address affordability through research into increasing production of the raw ingredients right through the supply chain from breeder> primary producer> processor> consumer. This should be realised over the next 5-10 years.

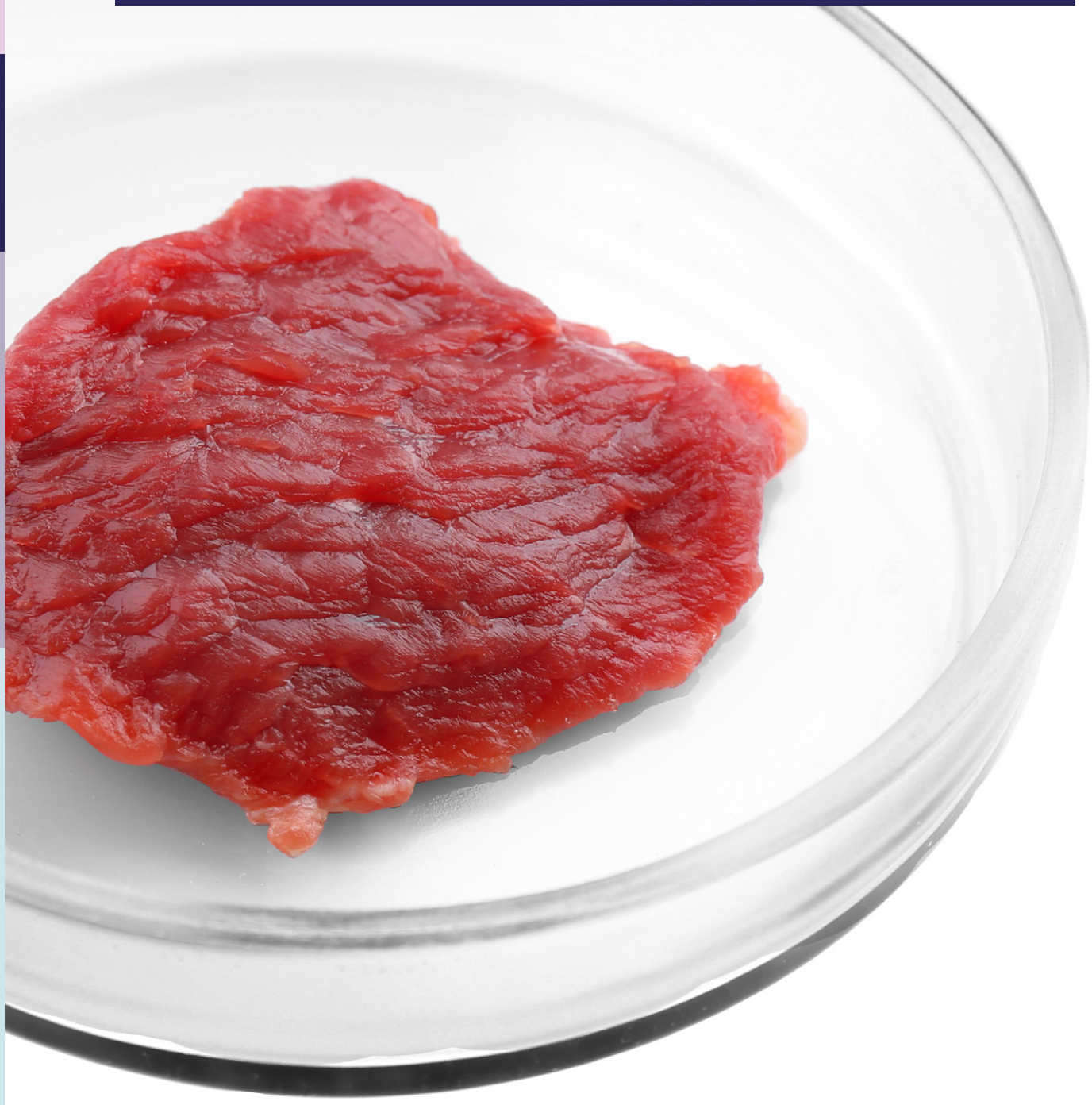
Fermentation

OBJECTIVE

Mycoproteins: Grow mycoprotein market to provide a sustainable and affordable protein alternative to replace meat and dairy products.

Lab-cultured meat: Provide consumers with an ethical and sustainable lab-cultured meat option at a cost equivalent to meat.

Mycoproteins and lab-cultured meat: Further improve sustainability of fermentation products.



Current Status

Technical

Mycoproteins

The UK is the world leader in mycoprotein fermentation, meaning production is well established at a national level. Nonetheless, the demand for mycoprotein products exceeds current supply capacities.

Lab-cultured meat

There are multiple small companies investigating the potential of lab meat cultivation. Cultures cannot currently be produced easily at scale. As such, this alternative protein industry is at an early stage of its development.

Commercial

Mycoproteins

The alternative protein space is highly competitive with the plant-based and mycoprotein sectors competing for market share.

Lab-cultured meat

Not yet commercially available in the UK.

Regulatory

Mycoproteins and lab-cultured meat

The regulatory framework for fermentation products is complex and difficult to navigate. For example, extensive food testing is required to bring lab-cultured meat to the market and extensive testing is also required to register novel mycoproteins as a food source. Brexit is an opportunity for UK regulatory bodies to streamline these processes.

Consumer

Mycoproteins

Even a well-informed audience can be under the impression that mycoproteins are highly processed and that they contain many other ingredients, but this is not true. Education of the consumer is required to ensure they are aware that these products are not heavily processed, and that consuming them is associated with health benefits.

Lab-cultured meat

Due to the nascent nature of the cultured meat sector, it is not currently known whether consumers will accept lab-cultured meat as a surrogate for farmed meat.

Size of opportunity

Technical

Mycoproteins

During the identification and development of *Fusarium venenatum*, extensive numbers of alternative fungal species were screened for their potential use in mycoprotein production. There is an opportunity to build upon this data in order to determine additional alternative species for mycoprotein production. The implementation of gene editing will allow the improvement of fungal strains/species to increase their potential for commercialisation.

Lab-cultured meat

Producing custom-built fermenters and development of food-specific growth regulators will help to optimise the production of cellular fermentation products. Developing an open-access model for the production of facility blueprints will enable technical advances.

Commercial

Mycoproteins

Harnessing fermentation products as a major food has the potential to provide a more sustainable protein source when compared to animal-based products. The conscientious consumer is increasingly aware of the environmental impact of food production. Thus, tapping into this market could be achieved through communicating the environmental sustainability of these products.

Lab-cultured meat

Extensive optimisation of lab-cultured meat generation has the potential to provide a sustainable alternative to animal farming. Such optimisation may provide an affordable meat product with a low carbon footprint.

Regulatory

Mycoproteins and lab-cultured meat

The participants felt a carbon footprint tax would help level the playing field within the wider protein food market. Such a strategy would ensure that the production of environmentally sustainable food sources is incentivised. Better training to navigate the regulatory process could help companies understand the steps that need to be taken in order to achieve the freedom to operate. In particular it may be useful if UKRI/KTN could develop a training package to support the navigation of this complex area (specifically to help small companies/start-ups).

Brexit provides a potential opportunity to make the regulatory process more agile, providing a quicker route to market for new and novel products. This could help UK companies to expediate the development of nutricious and sustainble alternative proteins.

Consumer

Mycoproteins and lab-cultured meat

Often curiosity will drive a consumer to try a new product, but the real challenge is to get people to make a second or third purchase. The cost of the product remains the primary factor that influences the likelihood of a repeat purchase.

Barriers and/or trade offs

Technical

Mycoproteins

Scaling up production to meet demand is proving the largest technical challenge for mycoprotein production.

Lab-cultured meat

Recreating a comparable taste and eating experience to that of meat is important for repeat purchase. Lab-cultured meat companies are in need of precompetitive research on optimising the bio-processes of cultivated meat development. Currently, there is no body of literature detailing optimised production protocols, thus companies must each optimise processes independently. This lack of collaboration has impeded progression within the area.

Commercial

Mycoproteins and lab-cultured meat

Financial incentives for environmentally positive solutions will level the playing field where alternative protein companies are competing with the established meat industry.

Regulatory

Mycoproteins and lab-cultured meat

There are extensive regulatory procedures that must be followed in order to get a novel food product onto the market. The industry would like the process to be streamlined and felt regulators should look to expedite the regulation process, particularly where strain improvement and selection has led to products that are safer for human consumption.

Consumer

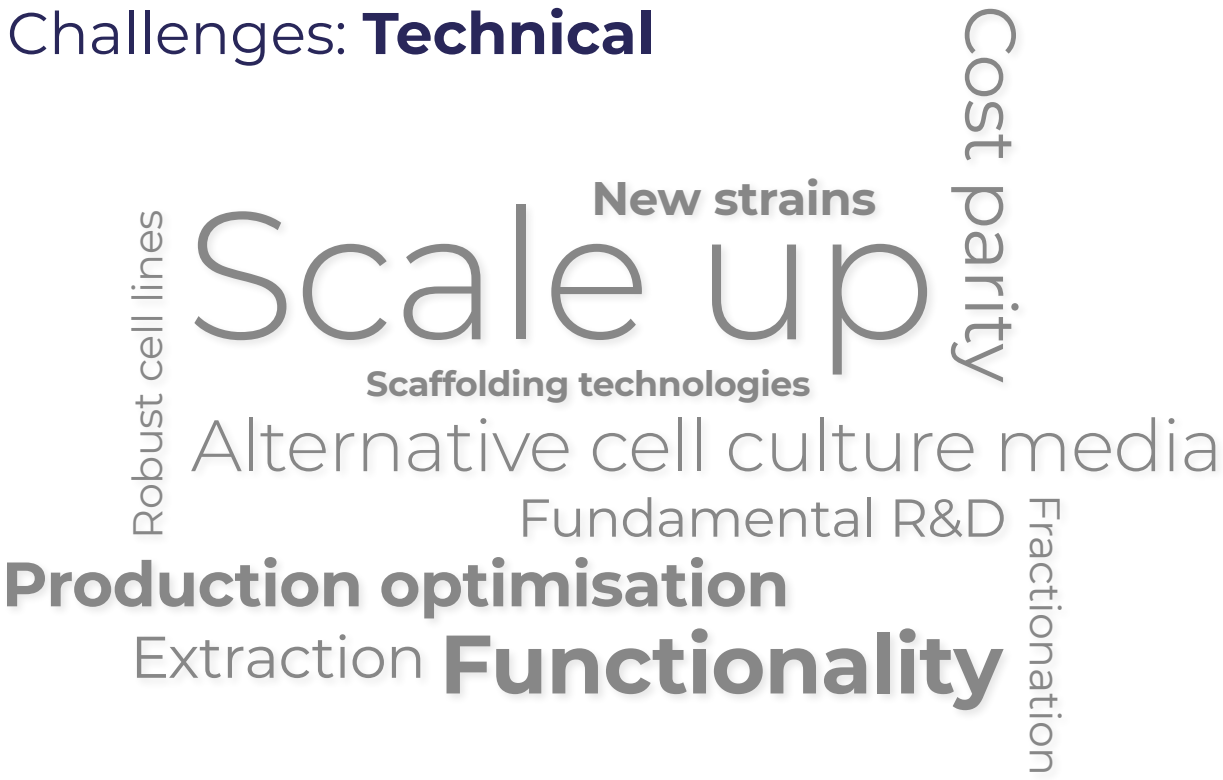
Mycoproteins

There are many opportunities outside of meat equivalents within the alternative protein sector. Indeed, the fermentation sector are not exploiting dairy and egg alternatives to the extent that the plant-based sector have.

Lab-cultured meat

Achieving consumer acceptance for lab-cultured meat is one of the major barriers that must be overcome in order for these products to become established in the market. It is anticipated that consumer acceptance can be achieved through the use of celebrity endorsement and media campaigns. The cultivated meat sector is working towards the development of a new product which is a hybrid of alternative protein sources. In particular, they are interested in the potential to integrate plant-based and fermentation products. This offers a potential route to market via tapping into an existing market base.

Challenges: **Technical**



		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat	**Scale up**		• scalable bioreactors • bioprocesses		
	Alternative cell culture media		• expensive • not sustainable		
	Cost parity		• delivering price parity to traditional meat		
Mycoprotein	**Scale up and investment**		• expansion of fermentation capacity • economical extraction of protein	• integrated biorefineries for algae, fungi etc. • overcoming the 'valley of death'	
	Production optimisation		• productivity • building of robust production processes • How to control cell structure/ metabolism during fermentation		

Lab-cultured meat	**Scale up**	In the medium term there will be a need for the sector to scale up from market access to industrial scale. This will require several fold increase in the cell quantities produced which can be achieved by developing robust bioprocesses in scalable bioreactors. Bioreactors are typically optimised for pharmaceutical production – the optimal bioreactor for meat culture may look different. As this is a very nascent area of research there are many opportunities to custom design purpose built bioreactors with greater efficiency. This could be achieved through scaling down activities in order to determine optimum conditions. The tissue being generated is very complex, with a large number of cells (10^{12}) needed to achieve 1 kg of product, these cells are mostly stem cells – in order to achieve the required density of stem cells there is a need to optimise bioprocesses.
	Alternative cell culture media	Cell culture media is currently optimised for human or mouse and not for livestock. There is a need within the medium term, as this sector scales, to develop alternative cell culture media which is optimised to livestock cells and also addresses the cost and sustainability of current options. For example, there is a need to replace animal components (i.e. serum-free) whilst still being cost effective. Also need to find alternatives for other expensive components (e.g. growth factors).
	Cost parity	Achieving cost parity with traditional meat is critical for the economic feasibility of cultivated meat products and there is a need within the medium term, as this sector scales, to address this challenge e.g. through scaling up and reducing costs of inputs as described above. Reducing the cost of production was considered in the workshop as one of the sector's highest priorities to address and ranked over taste or production challenge.
Mycoprotein	**Scale up and investment**	In the medium-term there is a need to increase fermentation capacity (and efficiency; see case study) and also develop efficient and economical extraction procedures for proteins from algae, fungi and bacterial fermentations. Case study: A market leading mycoprotein producer, present at the workshop, has demonstrated commercial viability and so is now focussed on scaling up productivity through the expansion of fermentation capacity however the number of fermenters that are required to meet demand is significant with each fermenter ordered requiring a long time to appreciate an ROI – this company would want to investigate optimising/innovation in the processes of fermentation of mycoprotein.
	Production optimisation	Production optimisation needs to be addressed within the medium term including improving productivity, building of robust production processes and investigating specific challenges such as how does cell structure/metabolism determine processing to meat-like texture and how to control this during fermentation.

Challenges: **Commercial**

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat	**Cost parity with alternatives**		• efficiency/economies of scale		
	Scale up			• lack of capacity for demo-scale and mid-scale co-manufacturing • lack of model production facility blueprints • lack of data sharing to inform process improvement	
Mycoprotein	**Competition**		• new alternative protein sources	• lack of B2B options	
	Scale up			• capital investment for commercial-scale facilities • needs economies of scale to hit mainstream	

Lab-cultured meat	**Cost parity with alternatives**	A commercial challenge addressed with technical solutions as discussed above. As the cultivated meat sector scales, efficiency and the economics of production will improve. Some of the commercial suggestions made by workshop participants were cultivated meat co-product valorisation and techno-economic models to inform product and process development.
	Scale up	There is a lack of discussion between businesses in the cultivated meat sector around common/shared technical issues due to competitive concerns. Indeed there is a notable lack of data sharing. Currently there is no extensive body of literature available in this area and companies are extremely keen for precompetitive research to be undertaken in this space to inform and optimise cultivated meat development. Precompetitive research would also serve to de-risk the industry. Some suggestions from workshop participants to address this challenge within the next 5 to 10 years (long-term) were to; develop a national capacity for demo-scale and mid-scale co-manufacturing, produce model production facility blueprints and data sharing to inform process improvement (see further information at https://gfi.org/advancing-solutions-for-alternative-proteins/).
Mycoprotein	**Competition**	The alternative protein space is highly competitive with the plant-based and acellular fermentation (principally mycoprotein) sectors competing for market share. It is difficult to compare the price between plant and fermentation-based protein and therefore it is perhaps worthwhile to compare the cost of fermentation products with actual meat products, rather than within other alternative protein systems. A longer term need to address this challenge is to develop more business to business options for fermentation-based ingredients to keep pace with the plant-based offering.
	Scale up	In the long term there is a need for capital investment for commercial-scale facilities in the fermentation-based alternative protein sector as the product category becomes increasingly mainstream – this will help achieve economies of scale required to compete with plant-based and traditional meat product lines.

Challenges: **Regulatory**

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat and mycoprotein	**Novel food regulation**	• navigating approval process is time consuming	• cost of registration and getting new foods approved for SMEs		
	Demonstrate robust and reproducible process		• cell derivation methods • manufacturing process		
	Lack of clarity on policy and regulatory environment		• regulatory approval process for cultivated meat products • GM legislation for new strains	• standardised relative to other countries • need for clear and transparent path to market	
	Demonstrate food safety		• food-safe reagents used in manufacturing process • safety		
	Freedom to operate in the R&D space		• separate regulation for testing products in R&D context		

Lab-cultured meat and mycoprotein	**Novel food regulation**	It is currently expensive and difficult to navigate food regulations creating a barrier of entry to start-ups and SMEs who want to diversify their product range within or from outside this space. The regulation process would benefit from being streamlined. Participants called for better training to navigate the regulatory processes and suggested that UKRI/KTN could develop a training package to support the navigation of this complex area (specifically to help SME/start-ups). Specifically this would help companies understand the steps that need to be taken in order to achieve the freedom to operate. Workshop participants also discussed the possibility of petitioning for improved legislation surrounding the regulation of novel food products as an industry.
	Demonstrate robust and reproducible process	For the lab-cultured meat sector there is a need to demonstrate robust and reproducible methods for cell derivation and manufacturing processes for the regulator.
	Lack of clarity on policy and regulatory environment	There is a lack of clarity on the policy and regulatory environment for novel foods and genetic modification (GM). In the EU both GM and novel foods take a long time to reach approval. Furthermore there are packaging and labelling stipulations that must be adhered to. There is a need to review the food regulation strategy. Experience of established partners indicated costs of £1 billion were outlaid to reach the UK market, this was due to the extensive testing required to ensure the product is safe for human consumption. Indeed, they have since encountered similarly high regulations when attempting to enter into foreign markets. There is a strong desire to collaborate across partners to achieve fairer and simpler regulations. These issues should be addressed in the medium term by developing a regulatory approval process for cultivated meat products so that there is a clear and transparent path to market. There is also a call from the industry participants to standardise regulation (for GM and novel food) relative to other countries which have approved lab-cultured meat products.
	Demonstrate food safety	Improvements can be made through expediting the regulation process particularly where strain improvement and selection, e.g. of mycoproteins, has led to products that are safer for human consumption.
	Freedom to operate in the R&D space	The USP for the UK's fermentation industry is the fact that they are world leading in fungal fermentation through demonstrating the vertical integration of growing crops for glucose through to the production of the final product.

Challenges: **Consumer**

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat and mycoprotein	**Consumer acceptance**		• low acceptance of meat alternatives • suspicion of authenticity and likeness to existing products	• perceptions of cultivated meat as 'unnatural'	• continued preference for real meat products
	Education		• labelling • will consumers understand precision fermentation?	• perception that alt. prot. is antithesis of e.g. regen ag and organics	
	Animal testing for food safety		• seek alternatives to animal testing		

Lab-cultured meat and mycoprotein	**Consumer acceptance**	Consumer acceptance, particularly of cultivated meat, is a big consumer challenge for this sector. The cultivated meat market are keen to tap into the mid ground market in order to reach those concerned about climate change. There is a need in the medium term for the sector to engage across different platforms including (social media/TV/influencers/endorsers/celebrities) to highlight the benefits of alternative proteins. Often curiosity will drive a consumer to try a new product, but the real challenge is to get people to make a second or third purchase. Taste and recreating an eating experience which is as good as meat is important for repeat purchase, however cost is the primary concern. Factors such as health benefits and low CO_2 outputs can help but they are not the primary factors influencing consumer purchasing.
	Education	Labelling of the product is an opportunity to educate the consumer. Labelling is essential to help the consumer make an informed choice and can act as a way to identify that a particular standard is being met (e.g. organic foods). Although there is a risk that all the different schemes and standards confuse the consumer. Education of the consumer is required to inform the consumer about the minimal levels of processing and health benefits related with e.g. mycoprotein-based products. This break out group agreed that everyone must take ownership over education which aligns with the plant-based group whom felt that all stakeholders (producers, government, knowledge partners (scientists and engineers) and consumers) had a responsibility in educating the consumer. One market leading mycoprotein producer is working with medical professionals to determine and advocate the health benefits of their products, relying on doctors to translate the information that mycoprotein is good for you. Beyond this there are initiatives looking at labelling in order to put claims on the packaging, here there is often a role for non-profit organisations and consumer groups. Marlow foods/Quorn are pioneering messaging on their products with placement of environmental benefits on packaging.
	Animal testing for food safety	Partners within this sector cannot easily use animal testing to confirm the safety of the food products, as there is a reduced appetite for animal testing within the target market. Alternative means of food testing by regulators is therefore required.

Opportunities: **Technical**

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat	**Bioprocess technology**		• computational modelling or novel bioreactor designs	• improving efficiency of suspension growth • semi-continuous bioprocess for whole cut cultivated meat • computational models of perfusion flow through scaffolds	
	Cell culture media formulations		• identify cheap sources of amino acids • identify cheap sources of growth factors • systematic investigation of growth factor needs and effects • map secretome of animal myoblasts, adipocytes etc • out the box cheaper media component solutions		
	Cell line development		• establishment of cell line repositories • standardised isolation protocols		
	Alternative feedstocks		• carbohydrates with increased sustainability and reduced cost	• remove dependency on corn, beet etc as source of carbon • circularity	

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Mycoprotein	New functionality		• protein ingredient to challenge dairy and egg protein market	• other functionality...	
	Precision fermentation		• for animal-identical dairy, egg and meat proteins		

Lab-cultured meat	Bioprocess technology	In the medium term there is an opportunity to apply computational modelling expertise to model the behaviour of mammalian cells at scale which will help inform novel bioreactor designs. Workshop participants also identified technical opportunities the sector could realise in the next 5 to 10 years (long term) as follows; 1) develop semi-continuous bioprocess for whole cut cultivated meat using simultaneous perfusion and stretch; 2) improve efficiency and assessment of adaptation to suspension growth and; 3) develop computational models of perfusion flow through scaffolds.
	Cell culture media formulations	Opportunities for developing new cell culture media formulations will be realised in the medium-term through; Identifying cheap sources of amino acids such as from plant hydrolysates, there may also be an opportunity to use agri waste as a substrate to this end, although this would need caution around mycotoxin accumulation; Identifying alternative cheaper sources of growth factors for proliferation (Medical grade growth factors are not required as the food industry does not need high purity growth factors); by mapping the secretome of animal myoblasts, adipocytes, and other cells used in cultivated meat then cell culture media can be designed to efficiently meet the cells needs (e.g. a systematic investigation of growth factor needs and effects). In order to achieve cheaper cellular process we need to think outside of the box – engineering processes alone will not let us reach cost parity – this needs to be achieved through combining biological opportunities to reduce costs, such as cheaper media components that can replace expensive growth factors currently being used.
	Cell line development	There are currently no commercially available livestock species cell lines, so generally they need to be sourced and isolated directly from animals by using abattoirs or slaughterhouses. There is an opportunity to address this issue through the opening up of access to immortalised cell lines this could be realised in the medium term through the establishment of cell line repositories (including for neglected seafood species) and standardized isolation protocols for the sector.
	Alternative feedstocks	There is a need in the medium term to develop cheaper and more sustainable feedstocks. There are opportunities to explore alternative carbohydrates with increased sustainability and reduced cost. In the longer term there are opportunities to valorise the waste products of processing = minimising waste and increasing profitability and utilising agri waste as a source of carbon (reducing current dependency on corn, beet etc), however this would need caution around mycotoxin accumulation.
Mycoprotein	New functionality	There is a current focus on meat analogues in the acellular fermentation sub sector however there is a huge technical opportunity in the medium term to develop fermentation-based protein ingredients which will challenge the dairy, egg and plant-based protein markets. Other functionality will follow in the longer term particularly as companies utilising precision fermentation become more established and diversify the market.
	Precision fermentation	There is a need to accelerate UK capabilities in precision fermentation to realise opportunities within the medium-term e.g. to develop animal-identical dairy, egg and meat proteins. Further opportunities will follow as this sector develops.

Opportunities: **Commercial**

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat	**Process innovations**			• developing open-access model production facility blueprints • expand capacity for demo-scale and mid-scale co-manufacturing • data lake for aggregating process data and informing process improvements	
	High quality and sustainable protein			• to feed growing global population	
Mycoprotein	**New product development**	• beverage development	• creation of new supply chains • protein ingredients		
	Product innovation	• consumer driven desire for alternative products • using unique characteristics to diversify products			

Lab-cultured meat	**Process innovations**	There is an opportunity to innovate the processes in the cultivated meat sector by adopting an open-access model within the next 5 to 10 years (long-term) and could include; developing a national capacity for demo-scale and mid-scale co-manufacturing, produce model production facility blueprints and data sharing to inform process improvement (see further information at https://gfi.org/advancing-solutions-for-alternative-proteins/).
	High quality and sustainable protein	Cultivated meat will play an important role in providing high quality and sustainable protein to feed the growing global population. This provides global opportunities for this sector beyond the developed markets.
Mycoprotein	**New product development**	The lab-cultured meat and acellular fermentation sub sectors are working towards the development of new supply chains that enable development of new products which including beverage development and hybrids of alternative protein sources. In particular the sector were interested in the potential to integrate plant-based and fermentation-based products, some collaboration is already underway but attendees are also looking for new collaborations. This offers a potential route to market via tapping into an existing market base.
	Product innovation	There is a huge commercial opportunity for this sector to deliver the consumer driven desire for new products which in turn drives innovation. Mycoprotein for example has some unique properties (e.g. fibrosity) which in the short term will deliver a “best in class chicken replacement”.

Opportunities: **Regulatory**

Clear path to market

Easing GM food regulations

Post Brexit opportunities

Easing gene editing regulations

Easing novel food regulations

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat and mycoprotein	Post Brexit opportunities	• freedom from EU regulation			
	Easing novel food regulations	• make registration easy • use lessons learnt in other countries • provide clear guidance			
	Easing gene editing regulations		• accelerate approval process of gene editing techniques		
	Funding landscape		• invest in R&D		

Lab-cultured meat and mycoprotein	Post Brexit opportunities	Post Brexit, we are seeing some movement on novel food introduction. There is an opportunity to collaborate across stakeholders to achieve fairer and simpler regulations.
	Easing novel food regulations	With respect to the novel food regulations there is an opportunity for policy makers and regulators to make registration easy, use lessons learnt in other countries (e.g. Singapore for cultivated meat) and provide clear guidance in order to show a clear path to market for current and would-be companies and investors operating in this space. There is also an opportunity to provide better training to navigate the regulatory process of novel food regulations.
	Easing gene editing regulations	There is a great opportunity to use gene editing to improve strains used in acellular fermentation and the sector welcomes an accelerated approval process to allow these techniques to be utilised, however, its use may lead to greater restrictions associated with selling produce in some export markets, particularly within the EU.
	Funding landscape	The Netherlands can be seen to have extensive funding available for research and development of alternative food sources, this is an excellent example to follow in order to boost the UKs standing within the sector. Also see: https://www.foodvalley.nl/our-focus/protein-shift/.

Opportunities: **Consumer**

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Lab-cultured meat and mycoprotein	**Net-zero**		• policy	• major factor in engaging consumers	
	Consumer engagement	• transparency about the production process			
	Health benefits			• increased awareness of healthy lifestyle	

Lab-cultured meat and mycoprotein	**Net-zero**	Net-zero goals have provided a strong consumer opportunity for fermentation-based alternative proteins however the sector requires policy incentives to produce sustainable products. This would ensure that materials for food production are not sourced from the other side of the world. Particularly as this is a nascent industry and it needs to be able to compete with the heavily established agricultural industry, who are incentivised towards sustainable production. There were calls for open access for life cycle assessment (LCA) of products to allow them to incorporate sustainable practices at the beginning of establishing new companies/products. On policy, there was a discussion about a carbon tax for food products that is costed proportionally to associated CO_2 production costs. Such a tax would factor in externalised costs thus levelling the playing field for food producers, through extending this tax to imports and meat production.
	Consumer engagement	Central to consumer engagement with fermentation-based products is ensuring that consumers and farmers are communicated to in a transparent way through highlighting clearly the benefits to the climate, public health, and food security.
	Health benefits	With the increased awareness of a healthy lifestyle following the COVID-19 pandemic consumers will be seeking healthy alternatives to certain traditional animal-based products.

Novel systems

OBJECTIVE

Develop insect and new aquaculture protein industries as economically viable alternate sources of protein for human food and animal feed. For insects, the real value is in the potential to utilise waste streams on and off farm and convert them into useful products, including protein, towards a circular bioeconomy. Whilst new aquaculture has the potential to exploit the extensive coastline of the UK.

Current Status

Technical

Insects

The insect protein industry is dominated by a few species, particularly the Black Soldier Fly larvae (BSFL; *Hermetia illucens*), the mealworm (*Tenebrio molitor*) and the house cricket (*Acheta domesticus*). There is a need to reduce cost of production by scaling up and automating production processes, improving genetics, as well as using cheaper feedstocks currently unavailable due to regulatory constraints. Also, by-products need to be valorised to increase price competitiveness.

New aquaculture

For new aquaculture, again only around 17 seaweed species are currently used, 10 cultivated, mostly for non-protein uses. Red algae have shown promise in reducing methane production if included in ruminant diet. There is a need for increased R&D to enhance productivity, as well as to reduce the use of plastics (polypropylene) in the production processes.

Commercial

Insect and new aquaculture

The insect and new aquaculture protein industries currently comprise of a few start-ups and small-scale companies that cannot compete with cheaper sources of proteins, such as soya bean. Production volumes are low, and the novelty factor of these proteins hinders both consumer acceptance and the removal of regulatory barriers, which in turn hampers large-scale investment into their production.

Regulatory

Insects

The regulatory situation is fairly complex and challenging for both producers and consumers. Only certain species have been cleared for human food and animal feed in EU. Post-Brexit, the regulatory situation in the UK is in a bit of a limbo, as no approval exists for processed insect protein in pig and poultry feed, and also the regulatory status for use of frass for organic fertiliser is unclear. Another major regulatory hurdle is the current ban on manure and other organic wastes as feedstock, this is preventing the insect protein industry from achieving its full potential in enabling the circular bioeconomy.

New aquaculture

The regulations are currently aligned well with the industry, but regulations need to be adapted rapidly as and when new species are commercialised for protein.

Consumer

There is a lack of consumer awareness and stigma on the use of insect proteins as human food, and as food ingredients. Also, insect proteins cannot currently compete with other proteins on taste perception or cost.

Size of opportunity

Technical

Insects

There is a huge opportunity to use insects to utilise on-farm and organic wastes to produce protein for animal feed and, in the longer term, human food. Automation should cut down on labour and production costs, thereby making insect protein more cost competitive for certain applications (e.g. as replacement for imported soya bean meal).

New aquaculture

Secondary products such as anti-microbials and other chemicals can enable the sector to achieve cost-competitiveness with cheaper sources of proteins.

Commercial

There is an opportunity to reduce dependence on imported soya bean meal in the near term, with the additional benefits of enhanced environmental sustainability, reduced carbon footprint and a reduction in greenhouse gas emissions through better utilisation of manure and other organic wastes.

Regulatory

Insects

Amending the regulatory framework will allow the development of the market potential for insect proteins in feed applications, as well as allow valorisation of secondary products such as frass (as fertiliser in organic agriculture). Manure and other organic wastes could be utilised as feedstock, thereby enabling the circular bioeconomy, with environmental and sustainability benefits.

Consumer

Insect and new aquaculture

Insect and novel aquaculture proteins can help address the high carbon footprint of animal protein, while labelling changes can enhance consumer awareness and reduce the stigma of using insects in food.

Barriers and/or trade offs

Technical

Insects

Major technical barriers include lack of breeding expertise for insect species, as well as lack of automation. Investment into automation is inhibited by the size of the market under current regulations. Also, increasing automation will increase the initial capital requirements and serve as a barrier to entry for firms into this market. Instead of large factories, it may be advantageous to have smaller, decentralised production systems based on farms to enable efficient utilisation of on-farm and organic wastes.

New aquaculture

Climate change/global warming offer both opportunities and challenges in terms of species management and production.

Commercial

Insects

Insect protein is currently unable to compete on price with imported soya bean meal. This may change if there is disruption in the global trade or production, increasing fertiliser and agrochemical prices, or trade barriers due to environmental reasons on soya bean meal imported from the Americas. Barriers to scaling up include lack of automation, and lack of government incentives to increase production.

Regulatory

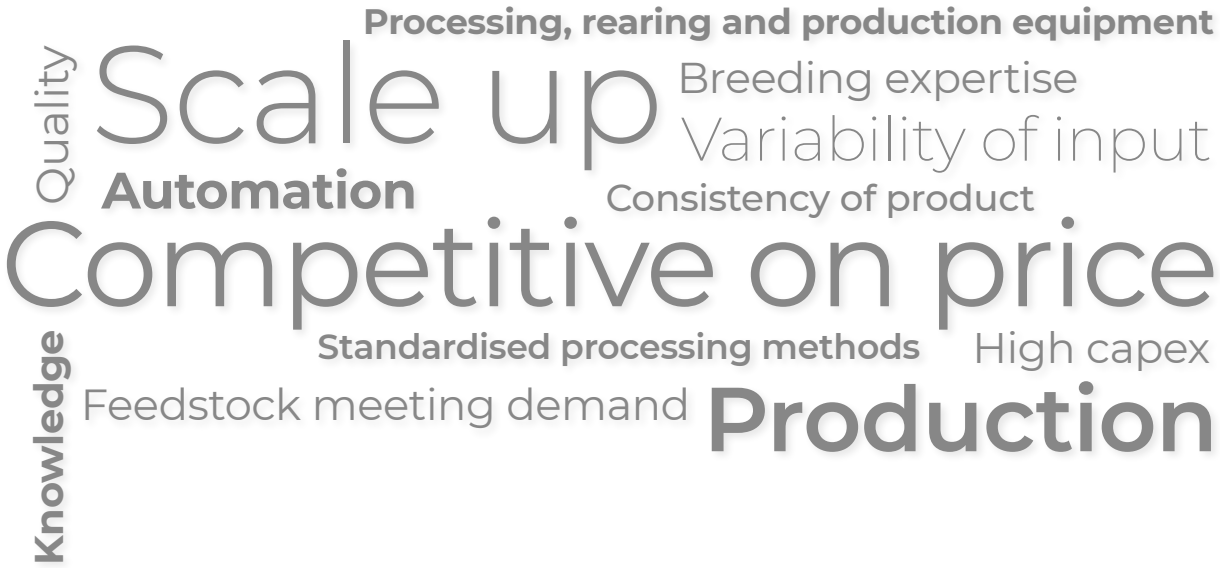
Insects

Currently, the insect proteins are regulated under Animal By-Products (ABP) guidelines, which hinder both use of cheap waste streams (e.g. manure, animal processing derived wastes) and the utilisation of insect proteins in feed and food, due to the risk of pathogen transmission and heavy metal accumulation. Further research and rapid testing methodologies need to be developed to mitigate these risks and reshape regulations to fulfil the potential of this sector.

Consumer

The stigma around eating insects will need to be tackled through consumer education, and the use of insect proteins as processed ingredients rather than through direct consumption of insects themselves.

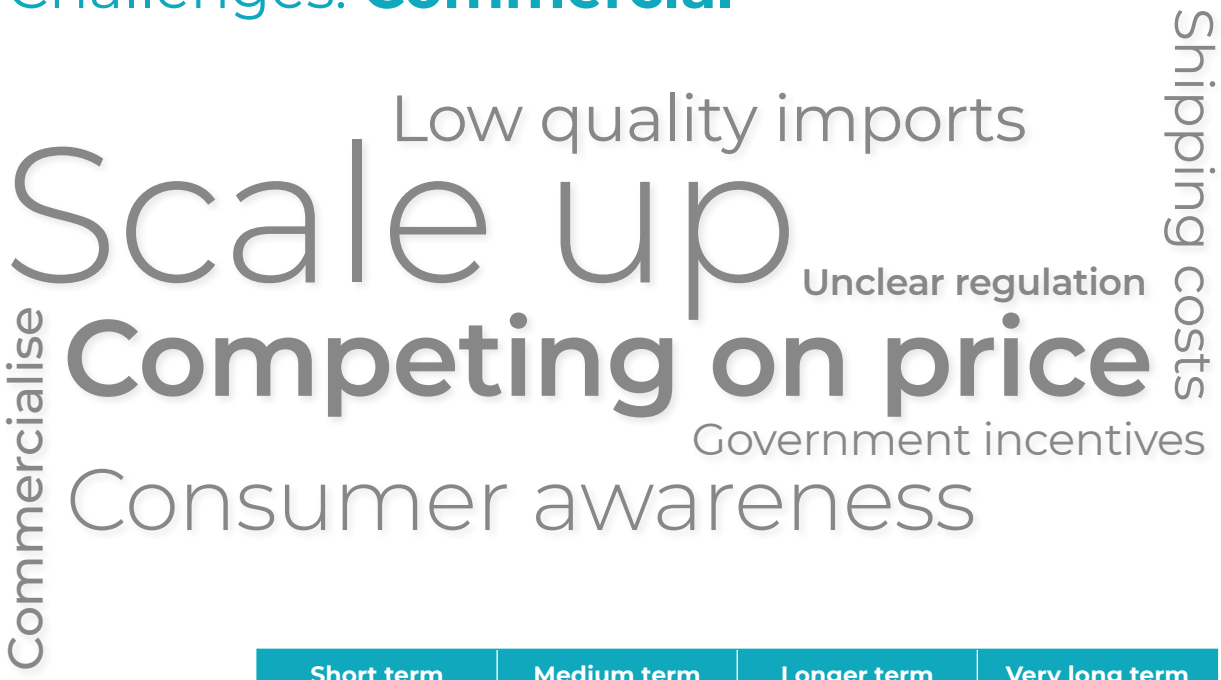
Challenges: **Technical**



		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Insect	Scale up		• lack of expertise in breeding		
		• production			
	Competitive on price		• reduce cost of production • automation • scale up • utilise by-products economically	• access to cheaper feedstocks (e.g. manure)	
	Production		• lack of automation • lack of available, tested machinery		
New aquaculture	Diversify species	• cultivation of some species	• scientific trials		
	Cost of production		• need to be more competitive		
	Sustainability of materials	• alternatives to use of polypropylene in cultivation			

Insect	**Scale up**	Currently only one producer in the UK is able to produce more than 100kg feed-grade insects per day, yet the industry will need to produce much larger volumes in order to meaningfully displace current meal used in animal feed. This needs to be addressed in the short to long term through the scale up of production processes and facilities which in turn will require the lack of insect breeding expertise to be addressed in the medium-term. R&D can help here by providing better knowledge/solutions of challenges in large scale systems e.g. tolerance of biotic/abiotic stresses in insects; optimum time and method of drying products (to extend shelf life); as well as appropriate equipment.
	Competitive on price	The high capital expenditure required for facilities is a major barrier to entry particularly when considering that the product, insect meal, is essentially a commodity which is competing against other mass produced commodities (soya bean/fishmeal) imported to the UK by large multinationals. In the medium to long term there is a need to reduce cost of production, automate, scale up and also utilise by-products economically. In the longer term the industry requires access to cheaper feedstocks using a de-centralised (e.g. on farm production systems) network could be beneficial both economically (reduced transport costs) and good for dealing with waste = lots of smaller factories instead of single large facility. This model will also work for manure/ farm waste-based feedstocks if this stream were to become legal. R&D invested into developing cheaper, less capital intensive production systems required here.
	Production	The insect farming sector raised a lack of automation and availability of tested machinery as a barrier that needs to be addressed in the medium term to overcome the production challenge they currently face. The machinery manufacturers were not represented at the workshop. Making connections between the machinery manufacturers and the relatively new industry of insect farming could encourage collaborative R&D in this space to address this gap.
New aquaculture	**Diversify species**	Currently the new aquaculture industry are permitted to grow 17 wild species, 10 of which are currently grown at scale. In the short term there is a need to expand and diversify the cultivated species available to the industry. In the medium term scientific trials should be conducted to evaluate the performance of the different cultivated species with regards to yield and resilience to climate change.
	Cost of production	The cost of production can be very high – novel production systems required to maximise seaweed production (to keep cost of production competitive) but balance with environmental impact.
	Sustainability of materials	To address a sustainability challenge of the industry, biodegradable and marine safe alternatives to polypropylene, used as seaweed supports, are required in the short term.

Challenges: **Commercial**



		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
New aquaculture and Insect	Competing on price	• with existing protein sources i.e. soya			
	Scale up	• reducing per unit cost	• limited by technical challenges • commercialise		
	Consumer awareness		• novelty/lack of track record	• low consumer acceptance	
	Dietary shift		• novel food ingredients		

New aquaculture and Insect	Competing on price	The technical and regulatory aspects (described elsewhere) are more relevant to address this challenge however from a commercial perspective for new aquaculture the shipping costs are a big commercial barrier in competing on price. However this does also present an opportunity for domestic production (of seaweed and insect-based protein) to displace the soya and fish meal imports which are more exposed to shipping cost rises.
	Scale up	In the short term the per unit cost will be reduced through the larger scale production and the technical and regulatory aspects to achieve this are described elsewhere. In order to scale up sustainably the sector needs to develop demand through commercialisation (of both primary product and by products).
	Consumer awareness	Consumer education and awareness is required for products produced through these novel system to address suspicion and low consumer confidence about theses food groups. The products, produced from these novel systems, like many other alternative protein sub sectors, have not had the long history of consumption which other staples enjoy. There is scope here for safety studies/biosafety studies to address this.
	Dietary shift	Once the products from these novel systems become established in our diets (including through direct consumption) then biosafety studies would be required, e.g. Human microbiome studies, to assess any impact (positive/ negative/neutral) to inform consumers.

Challenges: **Regulatory**

Regulatory clarity for frass use

Novel food regulation opaque

ABPs

Approval of additional feedstocks

UK regulation of protein for poultry and swine feed

Protein feed regulation unclear

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
New aquaculture and Insect	UK regulation	• insect protein to poultry and pigs currently not permitted in the UK			
		• insect processing regulated as a ABP activity			
	Approval of additional feedstocks	• all organic waste types	• animal by-products (ABPs)		
	Regulatory clarity for frass use	• registering frass as a fertiliser			

New aquaculture and Insect	UK regulation	The use of processed insect protein in poultry and pig feed is currently not permitted in the UK. This is a big regulatory barrier to the industries growth and should be addressed through regulation in the short to medium term. The insect farming sector ask that the UK adopt sensible regulations which are harmonised with EU legislation. The sector recognise that insects fed on certain feedstocks would require ABP regulation (e.g. manure-fed insects destined for non-food/feed use) however, feed and food-grade insects grown on current feedstocks (legal) fundamentally don't require that level of treatment and should be regulated in a framework closer to other animal protein sources with much longer histories of consumption such as dairies/ butcheries. There is a need for science informed regulation, to replace the current regulatory situation which is using regulations made for other sectors which is restricting growth in this sector. ABPs = Animal by products = animal carcasses, parts of animals, or other materials (inc. manure).
	Approval of additional feedstocks	There is a need for the regulators to approve a wider range of substrates for feedstock to address technical and commercial challenges such as access to cheaper feedstocks and realise commercial opportunities such as addressing circularity. In the short term there is a need to approve more organic waste feedstocks e.g. lignocellulose waste. In the medium term there is a need to assess the regulation of the use of animal by-products (ABPs) to help grow the sector. The regulatory framework was described by one workshop participant as "vertebrate-centric". Science should inform regulations here with a need to robustly test for risk of manures as feedstocks for insects destined for feed and food, due to the risk of pathogen transmission and heavy metal accumulation – need for biosafety assessment here.
	Regulatory clarity for frass use	There is a lack of regulator clarity on the main by-product of insect farming, frass (insect excrement). Frass is currently a waste product in the process and there is a cost associated with its disposal. In the short term frass could be registered as a fertiliser which will valorise this waste stream and make the process more economically viable and sustainable. Scope exists to utilise as organic fertiliser but the regulatory framework is holding the sector back from valorising this significant waste stream.

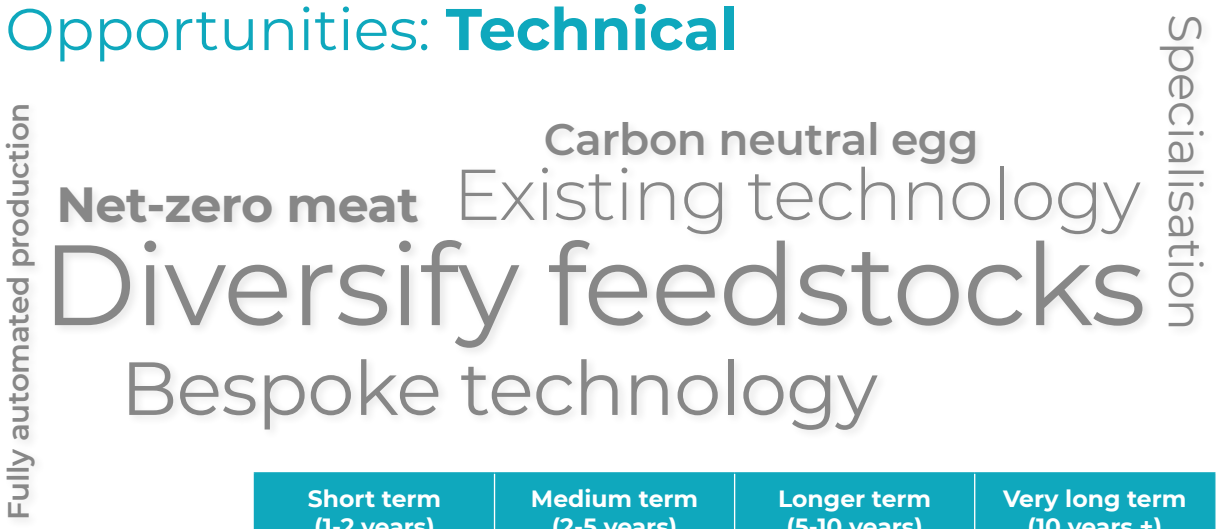
Challenges: **Consumer**

Affordability
Consumer acceptance
Consumer awareness

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
New aquaculture and Insect	**Consumer acceptance/ awareness**	• lack of consumer awareness	• consumer perception that accompany novel ingredients • consumer perception of insects as feed	• stigma	
	Affordability	• uptake will depend on price point (relative to other feed)	• impact on cost of final product (soya fed vs. insect/seaweed fed)		

New aquaculture and Insect	**Consumer acceptance**	There are perception challenges that accompany 'novel' ingredients such as seaweed and insect products (particularly if for direct consumption). To address this challenge consumer education and awareness is required together with transparency of processes and safety data. Probably more acceptance of insect protein as feed than food – this can be built upon. Vegans/ vegetarians may not be happy with insect derived foods.
	Affordability	Cost will always be a factor being considered by farmers and consumers alike when comparing to other, cheaper sources of feed – uptake will depend on price point being right. One workshop participant highlighted that the price per kg of insect meal remains very high with the cost of cricket flour greater than a prime rib of beef by weight – this needs to be addressed through technical and regulatory aspects discussed above.

Opportunities: **Technical**



		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
Insect	Diversify feedstocks	• using all organic waste types as substrate			
	Technology		• fully automated production		
New aquaculture	Microbial control	• compounds with antimicrobial properties			
	Sustainability of materials	• alternatives to polypropylene			

Insect	Diversify feedstocks	There is a great technical opportunity to diversify feedstocks, if regulation permits, allowing the conversion of virtually any organic waste into insect biomass. This could revolutionise the circularity within a range of industries, beyond food & feed, while removing emission-emitting wastes from landfill. No other alternative protein strategy can turn large volumes of heterogeneous waste into valuable protein so quickly and efficiently as insects. Another technical opportunity highlighted at the workshop was using lignocellulose waste (plant dry matter) as a feedstock – further R&D will be required to make this a reality.
	Technology	The automation of insect farms is a technical opportunity that some companies in this space are already realising. In the medium term more companies will be able to automate the process by developments in this area including implementing already tested technology, designing bespoke solutions and equipment, company specialisation to address hardware market and the increasing availability of off the shelf hardware. If this opportunity is to be realised there is a need for greater buy in and involvement of machinery manufacturers which will lead to the involvement of machinery manufacturers in collaborative R&D. Currently their is a limited market so machinery manufacturers are not interested (Catch-22 situation; need public funding push/incentives).
New aquaculture	Microbial control	In the short term the new aquaculture sector see a huge market opportunity to expand by identifying compounds with antimicrobial effect in seaweed.
	Sustainability of materials	There is a technical opportunity to create biodegradable and marine safe alternatives to polypropylene in the short term but R&D will be required to realise this important opportunity to the sector.

Opportunities: **Commercial**

Sustainability

Replacement of imported meal

Automation

Net-zero

Scale

Partnering with agri-food supply chain

Natural alternative

Valorise by-products

Market development

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
New aquaculture and Insect	Replacement of imported meal	• current market conditions favourable for domestic supply			
	Net-zero and Sustainability	• environmental sustainability/ carbon mitigation • the push for net-zero and phasing out of soya	• rewarding sustainable practices of using alt protein vs. staples		
	Market development		• enabling more companies to diversify into the sector • insects as food (for humans)	• feed for ruminants and non-monogastric animals	

New aquaculture and Insect	Replacement of imported meal	In the short term the current market conditions are making domestic supply relatively more favourable over imported meal. With high shipping costs making imported product more costly there is a commercial opportunity for farmers to try alternatives including protein produced from insects and seaweed to replace soya and fishmeal. Other opportunities for this sector were identified in the prework such as replacing meal worms with black soldier fly for wild bird feed. In order to make these current market conditions longer term the industry need to address technical challenges to enable cheaper production which should make insect protein more competitive on price against imported meal. Diversifying the range of fly species for protein production was discussed as a way to compete with imported meal, however, soldier flies are currently the best performing species. Different species often have specific diets, and these diets are not always available through the currently permitted/available feedstocks. R&D required here to develop alternative species to black soldier flies for protein production.
	Net-zero and Sustainability	There is a clear opportunity already being realised in utilising food-waste for insect production and in doing so helping towards net-zero and sustainability targets. In addition to use of waste streams to produce protein, the resulting protein is also displacing less environmentally sustainable soymeal from our food system. There is a big opportunity to expand on this however in order to realise this, more government support will be required through regulatory (and policy) support.
	Market development	There is huge potential for market development for the insect sector. This will be realised through the emergence of new companies in this space which will diversify the sector. In the medium term it is expected that insects will increasingly be used in food (for humans) but in order for this commercial opportunity to be realised then regulatory challenges will need to be addressed (e.g. making the novel food process more 'sensible', make it easier to make food grade insect, need to remove regulatory hurdles) There will also be a need to maintain Quality Assurance. In the longer term there is an opportunity to develop insect-based and seaweed-based feed for ruminants and non-monogastric animals – this will require collaborative, multi-disciplinary research.

Opportunities: **Regulatory**

Use of frass

Market development into food

New feedstocks

Market development in agriculture

Market development beyond feed and food

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
New aquaculture and Insect	**Market development**	• poultry and pigs	• insects as food	• shampoos, fabrics or even energy	
	New feedstocks		• broadening substrates available	• animal manures	
	Use of frass as fertilizer will...	• ...allow rapid scaling of operations	• ...improve consumer acceptance		

New aquaculture and Insect	**Market development**	The commercial opportunities for market development of the novel systems sub sector (as outlined above) are clear but will only be realised if regulatory opportunities are addressed. For poultry and pigs: regulatory changes are required to enable wider adoption, UK regulation needs to be updated, like it has been in the EU. For insects as food: consumer education and awareness is required. For shampoos, fabrics and energy: R&D required to find novel uses. Across all of these areas there is a need to conduct biosafety studies to support regulatory changes.
	New feedstocks	There is a clear opportunity to diversify the feedstocks that the insect sector are permitted to use. Biowastes, such as animal manures, represent a potential feedstock for insects. Regulatory changes and clarity on what sources of feedstocks would be acceptable would be required by the sector to utilise these biowastes. Non-food products (e.g. consumer products, fabrics or energy) could be an alternative market opportunity for these feedstock streams. Regulatory changes and clarity are required by the sector around feedstocks.
	Use of frass as fertiliser	The insect sub sector call for regulatory changes and clarity around the use of frass as a fertiliser which will allow rapid scaling of operations (Frass is currently a waste product from the process which is associated with a cost to dispose of it) and improve consumer acceptance (as it provides another sustainability story to the consumer).

Opportunities: **Consumer**

		Short term (1-2 years)	Medium term (2-5 years)	Longer term (5-10 years)	Very long term (10 years +)
New aquaculture and Insect	Net-zero	• respond to consumer pressure	• labelling of products as insect-fed		• help to address issue of the high carbon footprint of animal protein
	Consumer engagement		• media and advertisement campaigns to increase awareness		

New aquaculture and Insect	Net-zero	The retailers are already responding to consumer pressure for reduced carbon products (Egg suppliers for Morrison's using insects fed from plant-based food waste produced in supply chain) and this will continue to gather pace in the short term. In the medium term there is an opportunity to develop clear labelling to communicate the net-zero credentials and will help inform consumer choice. In the very long term there is a consumer opportunity to help to address issues of the high carbon footprint of animal protein e.g. develop a feed for ruminants that is insect-based (reducing reliance on imported soymeal) and uses red seaweed as feed additive (for methane reduction).
	Consumer engagement	As insect-based food becomes more available consumer engagement will become more important; insects are perceived as more natural than lab grown meat, but still a lot to do to improve the perception. Opportunity to start consumer engagement early with children at school, families to demonstrate the benefits, media, labelling all very important. Raising awareness of insects as feed and foodstuffs. Insect protein consumption will become "more normal" in future.

Recommendations and next steps

An output from the workshop were several recommendations that were shared across the sub-sectors:

- Development of an alternative protein implementation and action plan to coordinate interdisciplinarity, integrating research into the production, processing and onward product development.
- Provide sustainable sources of funding to explore disruptive research and innovation ideas.
- Strengthen capability in the UK to deliver purposeful technology solutions.
- Assessment of the UK landscape to facilitate early engagement and consortia building with suitable industry and academic partners.
- Develop mechanisms to successfully speed up pioneering innovations through the UK market including access to finance for scale-up.
- Develop a core team for coordinating and building the UK ecosystem, providing a centralised resource accessible to all UK stakeholders.

Building on the recommendations coming from this report, a significant next step would be to support the development of a UK Alternative Protein Innovation network. This would aim to advance research and innovation for alternative protein-based food, requiring an interdisciplinary approach to combine research into production, processing and onward product development. Currently, research in this area within the UK has been conducted in a largely organic fashion. There are some initiatives from food industries, but impactful research and innovation in alternative protein-based food via public-private partnerships are scarce in the UK relative to our international competitors.

The lack of a dedicated interdisciplinary research and innovation network makes it difficult for the interested UK cohort of research leaders and innovators to collaborate and deliver transformative impact. The network would drive discovery and strategic research into alternative protein-based food innovation in the UK by pushing the frontiers of related science and technologies, uniting the UKRI partners across the food value chain and ensuring that R&D addresses market and societal needs.

The network should work as a virtual UK ecosystem to lead transformative innovation through coalescing research efforts to focus on specific market needs and industry challenges. This would complement the development of relevant incubator and accelerator programmes across the UK, which would further drive the market acceleration for alternative protein-based foods.

Implementation of the recommendations would lead to the following outcomes:

- A connected research and innovation landscape, able to take forward the breadth of collaborative R&D opportunities that the UKRI system has to offer
- Accelerated research into alternative protein improvement, with greater focus on market needs and industry challenges
- UK gains recognition as an international centre of excellence that attracts foreign direct investment into our agri-food innovation ecosystem
- Green growth opportunities for the UK bioeconomy

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This report captures the collective feedback of group discussions and breakout sessions and therefore does not necessarily represent the opinions or strategic priorities of individuals, companies or organisations named.

Presentation slides from Alternative Protein: Identifying UK Priority workshop, 22 February 2022

Transforming Food Production: Overview

- £90m funding until March 2024 to enable food to be produced in more efficient, resilient and sustainable ways
- Accelerating the development and adoption of integrated precision approaches to improve agricultural production
- Driving economic growth across the UK

Towards net zero emissions productive food systems by 2040

Transforming Food Production: Delivery

£50m **Future Food Production Systems**
Creating disruptive solutions & high value production systems

£10m **Investor Partnership**
Building a vibrant UK Agri-Tech investment ecosystem

£25m **Science and Technology into Practice**
Strengthening connections between research and practice; enabling adoption through KE & demonstration

£5m

International
Building opportunity in partnership and driving export growth in Asia & N. America

Investment focus on UK AP company growth

Hs Higher Steaks

£1.02m TFP grant to support the SME in developing the UK's first pilot plant for cultivated meat

TFP project: pilot plant for cultivated pork for sustainable food systems

Lead investor: Dismatrix Group. Syndicate with five other investors with a total Series A deal of £2.5m

DISMATRIX

ROSLIN Technologies

£454k TFP grant to take the pluripotent stem cell technology to next stages to serve the burgeoning cellular agriculture industry

TFP project: leading the science of sustainable protein by developing tools for cellular agriculture

MILLTRUST INTERNATIONAL

Lead Investor: Future Planet Capital's British Innovation Fund (previously managed by Milltrust). Syndicate with 12 other investors with a total Series A deal of c.£1m

Funding to support development of the UK AP sector

- Insectrial Revolution – commercial-scale insect production, combining SME expertise with leading research institutions, end-users and the UK's largest retailer
- AGRI-SATT – large-scale algae production on non-agricultural land, mimicking natural algal blooms to cultivate local algal species rich in protein and PUFAs (DHA & EPA)
- REACT-FIRST - commercialising CO_2-to-protein for sustainable livestock feed; recently secured €8m Series A investment round

Coordination activities to support UK AP sector

Innovate UK | GROWING KENT & MEDWAY

Coordination activities to support UK AP sector

UK Alternative Proteins Roadmap March 2021		Short Term 6-12 Months		Medium Term 1-3 Years		Longer Term 3-5+ Years	
1. Commercial	Production Capacity	Lab scale production		Pilot plant production capacity		Access to large scale facilities	
	Market Development	Identify Export/ Import Issues		Researching Markets		Develop Market Pull Opportunities	
2. Operations	Workforce Development	Define training and upskilling requirements for the sector		Upskilling and training programmes		Further assessment & development of upskilling requirements - roll out with relevant education institutions	
	Finance & Investment	Accessing Funding	Securing funds to demonstrate commercial viability		Communication value proposition to investors to deploy at commercial scale	Investment for Scaling (Government & Private Equity)	
3. Governance	Regulation & Legislation	Coordination between Regulators and Industry	Developing Regulatory Frameworks (post-pandemic/Brexit)	Develop QA/QC requirements assurance schemes.	Develop carbon accounting framework and understand and LCA Frameworks	Carbon-trading legislation	
	Sector Strategy	Create a clear definition of the AP sector	Creating a new industry	Establish sector-wide Trade Body (including developing cross-sector metrics and making commitment to transparency and traceability)		Develop National Alternative Protein Strategy	
4. Technical	Research & Development	Existing strains with limited productivity		Development of efficient strains		Intellectual property generation	
	Innovation Community	Engage with innovation community		Create competitive ecosystem - integrate innovation community with value chain		Continued innovation to add further value to the Alternative Protein sector	
5. Communications	Consumer Engagement	COP26 Showcase	Coordinated Messaging		Coordinated Media Engagement		Ongoing consumer dialogue - ensuring future product relevance

Aims and objectives of workshop today

- Bring together leading scientific and commercial experts across the UK Alternative Protein sector
- Discuss issues and identify opportunities and barriers to creating a globally competitive Alternative Protein sector in the UK
- Identify areas of synergy across the research-base & industry and collaboration opportunities to create new partnerships
- Establish a forum for knowledge exchange to discuss issues including technical, commercial, regulatory and consumer for mutual benefit across the Alternative Protein sector

Plant-Based

GROWING KENT & MEDWAY

UK Research and Innovation

Technical: Challenges

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. Long 10 yr+
Functionality				
mimic animal derived proteins		■		
improve and adapt techno functionality		■		
Extraction				
small pilot scale research facilities				■
scalability of novel/sustainable technologies				■
Flavour	■	■		
Genetics and Breeding				
lack of transformation technologies		■		
lack of suitable varieties				■
Processing				
scalable facilities	■	■		

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Plant-Based

Innovate UK

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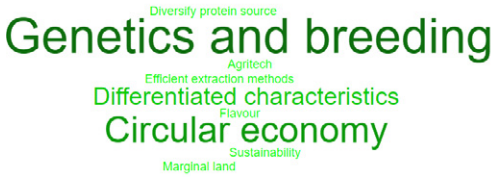
Technical: Opportunities



	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Genetics and breeding				
gene editing				
breed varieties with enhanced functionality				
breed varieties with enhanced functionality				
breed varieties with enhanced health properties				
genome sequencing of crops				
Circular economy				
co-product market development				
engineering design				
utilising waste and underutilised resources				
Differentiated characteristics				
nutrition				
functionality				
protein ingredients with enhanced characteristics				
Diversify protein source				
different sources of proteins				
Efficient extraction methods				
lower environmental impact				
higher extraction yields				

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Plant-Based

Commercial: Challenges

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Economically viable supply chain				
high cost of raw materials				
profitability of farming sector				
government subsidies				
Investment				
ROI to Farmer				
infrastructure investments - farmer				
infrastructure investments - processor				
Flavour taints				
Reduce and/or eliminate beany/earthy flavours				
High costs of masking flavors				
Clean label				
products with added ingredients				
Sustainable supply chain				
access to UK sustainable protein sources				

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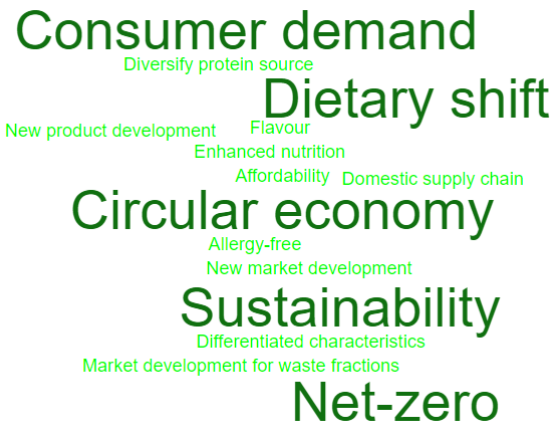
Plant-Based

Commercial: Opportunities



	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Circular economy *use of agri-food waste*		■	■	
Sustainability *sustainable alternatives to animal derived foods*		■	■	■
Consumer demand *increased consumer interest - 15% CAGR globally*		■	■	
Net-zero *opportunity to fix N and reduce artificial N input help achieve climate targets*		■		■
Dietary shift *Shift toward vegan/vegetarian diets*	■			

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Plant-Based

Regulatory: Challenges

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Novel food legislation *EFSA approvals for emerging plant proteins* *uncertainty relating to novel foods* *labelled as "novel foods" but consumed elsewhere*		■	■	
Standard of identity (naming of products) *e.g. milk vs 'mylk' / 'm*ck' or ice cream vs frozen dessert* *food labelling using old concepts*		■	■	
Labelling *Natural classification* *Nutrition*		■		

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Plant-Based

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Regulatory: Opportunities

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Genetics and breeding				
gene editing				
genetic modification				
Reduced allergenicity				
food ingredients with reduced or none allergenicity				

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Plant-Based

Consumer: Challenges

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Perceived as ultra-processed				
Misinformation				
Change consumer mindset				
Consumer acceptance				
Willingness of consumers to try new products				
Reluctance of wider acceptance of plant-based				
shift away from current diet habits				
Consumer behavioir				
Improving engagement and education				
drive demand for healthier and sustainable option				
Sensory acceptability				
Simulate organoleptic properties				
Affordability and availability				
Sourcing/supply chains				
Price of final product				

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Plant-Based

Consumer: Opportunities

Dietary shift
Flavour
Lifestyle shift
Sustainability
Net-zero
Demand
New market development
New product development

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Sustainability *climate benefits associated with plant-based diets* *increased awareness*				
Lifestyle shift *increased awareness of healthy lifestyle* *improved nutrition*				
Dietary shift *shift towards plant-based/flexitarian diets* *wider product range is inclusive of consumer diets*				
New product development *satisfy new dietary trends* *targeting different sectors of the population* *utilise plant functionality to enhance consumer experience*				

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Plant-Based

Fermentation

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UK Research and Innovation

Innovate UK

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Technical: Challenges

Cellular:

Robust cell lines
Alternative cell culture media
Scale up
Scaffolding technologies
Cost parity
Fundamental R&D

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Scale up				
scalable bioreactors				
Alternative cell culture media				
replacement of animal components				
serum free, but not prohibitively expensive				
currently optimised for human or mouse, not livestock				
expensive components (e.g. growth factors)				
Cost parity				
delivering price parity to traditional meat				

Acellular:

Scale-up
Fractionation
Extraction
Functionality
Production optimisation
New strains
Cost parity

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Scale up and investment				
expansion of fermentation capacity				
economical extraction of protein				
Integrated biorefineries for algae, fungi etc.				
overcoming the 'valley of death'				
Production optimisation				
How to control cell structure/metabolism during fermentation				
productivity				
building of robust production processes				

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Fermentation

Technical: Opportunities

Cellular:

Cell line repositories
Bioprocess technology
Scale-up collaboration
Multidisciplinary research
Cell line development
Cell culture media formulations

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Bioprocess technology				
improving efficiency of suspension growth				
semi-continuous bioprocess for whole cut cultivated meat				
computational models of perfusion flow through scaffolds				
computational modelling or novel bioreactor designs				
Cell culture media formulations				
identify cheap sources of amino acids e.g. plant hydrolysates				
identify cheap sources of growth factors				
systematic investigation of growth factor needs and effects				
map secretome of animal myoblasts, adipocytes etc				
out the box cheaper media component solutions				
Cell line development				
establishment of cell line repositories				
standardized isolation protocols				

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Fermentation

Technical: Opportunities

Acellular:

New functionality
New strains
Alternative feedstocks
Gas fermentation
Precision fermentation

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
New Functionality *protein ingredient to challenge dairy and egg protein market* *Other functionality…*				
Alternative feedstocks *carbohydrates with increased sustainability and reduced cost* *remove dependency on corn, beet etc as source of carbon* *Circularity*				
Precision fermentation *for animal-identical dairy, egg and meat proteins*				

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Fermentation

Commercial: Challenges

Cellular:

Scale up
Cost parity
Consumer acceptance
Regulatory approval

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Cost parity with alternatives *efficiency/economies of scale*				
Scale up *lack of capacity for demo-scale and mid-scale co-manufacturing* *lack of model production facility blueprints* *lack of data sharing to inform process improvement*				

Acellular:

Scale up
Product safety
Lack of B2B
Competition
Novel food approval
Cost parity
Market-size

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Competition *from new alternative protein sources* *plant based meat alternatives competing for space* *Lack of B2B options*				
Scale up *Capital investment for commercial-scale facilities* *Needs economies of scale to hit mainstream*				

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Fermentation

Innovate UK

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Commercial: Opportunities

Cellular:

Open-access facility blueprints
IP pooling frameworks
Sustainable
Process innovations
Co-product valorization
High quality
Build market share

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Process innovations				
Developing open-access model production facility blueprints				
Expand capacity for demo-scale and mid-scale co-manufacturing				
Data lake for aggregating process data and informing process improvements				
High quality and **Sustainable** protein				
to feed growing global population				

Acellular:

Product innovation
Protein ingredients
New product development
Beverage development
Resilient supply chain

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
New product development				
Creation of new supply chains				
Protein ingredients				
Beverage development				
Product innovation				
consumer driven desire for alternative products				
using unique characteristics to diversify products				

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Fermentation

Regulatory: Challenges

Cellular & Acellular:

Nutritional profile
Freedom to operate in R&D space
Demonstrate robust & reproducible process
Time
Novel food regulation
Demonstrate food safety
Cost
Lack of clarity
GM legislation

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Novel food regulation				
Navigating approval process is time consuming				
Cost of registration and getting new foods approved for SMEs				
Demonstrate robust & reproducible process				
cell derivation methods				
manufacturing process				
Lack of clarity on policy and regulatory environment				
regulatory approval process for cultivated meat products				
GM legislation for new strains				
standardised relative to other countries				
need for clear and transparent path to market				
Demonstrate food safety				
food-safe reagents used in manufacturing process				
safety of the final formulated product				
Freedom to operate in the R&D space				
separate regulation for testing products in R&D context				

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Fermentation

Regulatory: Opportunities

Cellular & Acellular:

Easing GMO regulations
Work with regulators
Easing novel food regulations
Post Brexit opportunities
Easing gene editing regulations
Clear path to market

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Post Brexit opportunities *Freedom from EU regulation*				
Easing novel food regulations *make registration easy* *use lessons learnt in other countries* *provide clear guidance*				
Easing gene editing regulations *Accelerate approval process of gene editing techniques*				

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Fermentation

Consumer: Challenges

Cellular & Acellular:

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Consumer acceptance *Low acceptance of meat alternatives* *Suspicion of authenticity and likeness to existing products* *Perceptions of cultivated meat as 'unnatural'* *Continued preference for real meat products*				
Education *benefits of mycoprotein over other meat alternatives* *will consumers understand precision fermentation?* *Perception that alt. prot. is antithesis of e.g. regen ag and organics*				

Appearance
Education
Consumer preference
Consumer acceptance
Nutritional equivalence
Transparency
Affordability Flavour

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Fermentation

Consumer: Opportunities

Cellular & Acellular:

Differentiation from highly processed alternatives

Consumer engagement

Labelling

Net-zero

Increased B2B

Dietary shift

Sustainability

Health benefits

Improved organoleptic properties

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Net zero *major factor in engaging consumers*				
Consumer engagement *transparency about the production process*				
Health benefits *increased awareness of healthy lifestyle*				

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Fermentation

Novel Systems

GROWING KENT & MEDWAY

UK Research and Innovation

Technical Challenges

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Scale up				
Lack of expertise in breeding				
Production				
Competitive on price				
High capital expenditure				
Achieving low cost points of production				
needs to be price competitive to replace soy/fishmeal				
Production				
Lack of automation				
Lack of available, tested machinery				

New Aquaculture Specific:
1 - cultivation of some species (1-2yrs)
2 - scientific trials (2-5 yrs)
3 - alternatives to use of polypropylene in cultivation (1-2 yrs)

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Technical
Novel systems

Technical Opportunities

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Diversify feedstocks				
using all organic waste types as substrate				
e.g lignocellulose waste				
Technology				
fully automated production				
implementing already tested technology into the process				
designing bespoke solutions and equipment				
company specialization to address hardware market				
off the shelf hardware				

New Aquaculture Specific:
1 - identify compounds with antimicrobial effect in seaweed (1-2 yrs)
2 - creating biodegradable and marine safe alternatives to polypropylene (1-2 yrs)

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Technical
Novel systems

Innovate UK

GROWING KENT & MEDWAY

Commercial Challenges

Scale-up

Low quality imports

Competing on price

Shipping costs

Unclear regulation

Government incentives

Commercialise

Consumer awareness

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Competing on price				
with existing protein sources i.e. soya	■	■	■	
achieving low cost points of production			■	
Scale up				
reducing per unit cost (through high scale)	■			
limited by technical challenges		■		
commercialise		■		
Consumer awareness				
novelty/lack of track record		■		
low consumer acceptance			■	

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Commercial
Novel systems

Commercial Opportunities

Natural alternative

Valorize byproducts

Sustainability

Automation

Replacement of imported meal

Scale

Net-zero

Market development

Partnering with agri-food supply chain

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Replacement of imported meal				
high shipping costs making imported product more costly	■			
protein produced from insects replacing soya and fishmeal	■			
replacing meal worms with black soldier fly for wild bird feed	■			
Net-zero and **Sustainability**				
environmental sustainability / carbon mitigation	■			
rewarding sustainable practices of using alt protein vs. staples		■		
the push for net zero and phasing out of soya	■			
Market development				
feed for ruminants and non-monogastric animals			■	
enabling more companies to diversify into the sector		■	■	

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Commercial
Novel systems

Regulatory Challenges

Approval of additional feedstocks

Novel food regulation opaque

UK regulation of protein for poultry & swine feed

protein feed regulation unclear

ABPs

Regulatory clarity for frass use

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
UK regulation				
insect protein to poultry & pigs currently not permitted in the UK	■	■		
insect processing regulated as a ABP activity	■			
Approval of additional feedstocks				
"vertebrate-centric" regulatory framework		■		
approving a wider range of substrates	■			
animal by-products (ABPs)		■		
Regulatory clarity for frass use				
lack of regulator clarity on by-product	■			
registering frass as a fertilizer	■			
currently a waste product - with cost associated to dispose	■			

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Regulatory
Novel systems

Regulatory Opportunities

New feedstocks

Market development into food

Market development in agriculture

Market development beyond feed & food

Use of frass

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Market development				
poultry & pigs	■	■		
insects as food		■	■	
shampoos, fabrics or even energy			■	
New Feedstocks				
broadening substrates available		■		
challenging polluting substrates like animal manures			■	
regulating the end use depending on what the insect was grown on				
Use of frass				
regulatory clarity will allow rapid scaling of operations	■			
use of frass as a fertilizer will improve consumer acceptance		■		

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Regulatory
Novel systems

Consumer Challenges

Affordability
Consumer acceptance
Consumer awareness

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Consumer acceptance				
consumer perception that accompany novel ingredients				
consumer perception of insects as feed				
stigma				
Affordability				
uptake will depend on price point (relative to other feed)				
impact on cost of final product (soya fed vs. insect fed)				
Consumer awareness				
lack of consumer awareness				

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Consumer
Novel systems

Consumer Opportunities

Media
Nutrition
Labelling
Consumer engagement
Net-zero
Quality
Sustainable
Retailer-led
Affordability

	Short 1-2 yr	Medium 2-5 yr	Long 5-10 yr	V. long 10 yr+
Net-zero				
alternative for farmers/retailers in response to consumer pressure				
*opportunity for **retailers** to become pioneers/**lead** the field*				
***labelling** of products as insect-fed*				
potential to be lowest footprint animal protein on the market				
Consumer engagement				
Increasing consumer awareness through media and advertisements				

GROWING KENT & MEDWAY

Consumer
Novel systems

ANNEX 2 – WORKSHOP PRESENTATION SLIDES

Research capabilities and resources through Growing Kent & Medway

Supporting the UK alternative protein sector

Networking & research facilities - Growing Kent & Medway

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UK Research and Innovation

University of Kent

School of Biosciences; Canterbury-Kent

Fungal Biology
(10 Research Groups)

KFG Kent Fungal Group

Verticillium nonalfalfae
Human pathogens
Candida
Saccharomyces cerevisiae
Filamentous fungi
Schizosaccharomyces pombe
Budding yeast
Cryptococcus
Schaffersmyces stipitis
Mucoromycetes
Plant pathogens
non-convential

Industrial Biotechnology
(7 Research Groups)

Antibody
Fermentation
Vaccine
Bio-Pharmaceutical
CHO Cell Culture
Synthetic Biology
Natural Products

https://www.kent.ac.uk/biosciences

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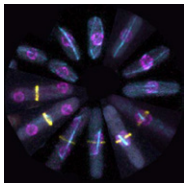
University of Kent

School of Biosciences; Canterbury-Kent



Novel Fungal Strains Selection
Genomics
Proteomics
Metabolomics
Fermentation
Protein Expression and Purification

https://www.kent.ac.uk/biosciences

GROWING KENT & MEDWAY A.Buscaino@kent.ac.uk in/alessiabuscaino Alessia Buscaino

Yeast biocatalyst for safe, animal free high-value protein production

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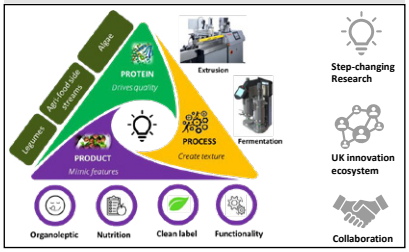
Medway Food Innovation Centre | University of Greenwich

Protein4NetZero



Facilities

New facilities are coming up
- Food processing laboratory
- Flavour & sensory analysis

Food accelerator programme

KEY EQUIPMENT
- Air classified fractionator
- SCF extraction
- High pressure homogenizer
- Advanced drying facilities (SD, DD, FBD, VFD)
- Twin screw extruder
- 3D printer
- Bioreactors & raceway ponds
- CEM Fat analyser
- Centri-GCxGC-ToF MS

Research focus

EXTRACTION	PROCESSING	ORGANOLEPTIC	CLEAN LABEL
Eco-innovative extraction of plant and algal proteins	Improved protein functions via sustainable processing	Science unlock to create optimal organoleptic attributes	Innovate clean label formulation for plant-based food

Current projects (2021 -)

ALGAE

- Algae for taste
- Seaweed protein extraction

UPCYCLED

Upcycled plant proteins for meat and cheese alternatives

LEGUME

Improving quality of fava bean protein concentrate

STFC Food Network+ | European Commission | defra

GROWING KENT & MEDWAY | Locate in Kent

Contact: p.acharya@greenwich.ac.uk

NIAB

Facilities

- 2 major research centres
- UK-wide field trials
- Glasshouses
- Growth rooms
- Cold stores
- Speed breeding
- GM containment
- Insectary
- Spore-proof pathology suite
- Analytical Services
- Molecular biology
- Fermentation facilities
- Barn 4 bio-incubator
- Eastern Agritech Innovation Hub
- GreenTech Hub
- Crop Science Centre

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UKRI Innovate UK | GROWING KENT & MEDWAY

NIAB

Capabilities

- Trait discovery / prebreeding / breeding
- Pathology & entomology
- Crop modelling & physiology
- Genomics & bioinformatics
- Quantitative genetics & statistics
- Biochemistry
- GM & gene editing
- Micropropagation
- Remote phenotyping
- Image analysis & machine learning
- Agronomy & Farming Systems
- Contract trials
- Training
- Knowledge exchange & outreach
- Statutory work: variety testing, seed certification, seed testing

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Crops

Legumes

- Faba bean
- Pea
- Grasspea
- Chickpea
- Lentils
- Soybean
- Phaseolus

Others

- Wheat
- Oilseed rape
- Barley
- Potato

Mycoprotein

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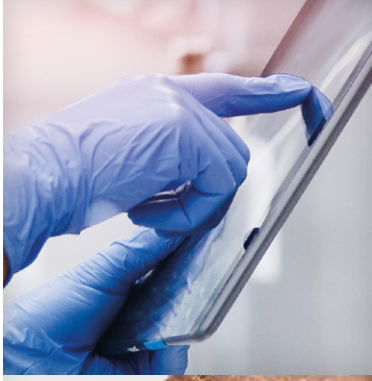




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