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From Beans to Bugs – Alternative Proteins to Drive Net Zero Egg Production

Written by:

Alistair McBain NSch

March 2025

A NUFFIELD FARMING SCHOLARSHIPS REPORT

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A NUFFIELD FARMING SCHOLARSHIPS REPORT (UK)

NUFFIELD Farming Scholarships

Date of report: March 2025

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	From Beans to Bugs – Alternative Proteins to Drive Net Zero Egg Production
Scholar	Alistair McBain
Sponsor	The MacRobert Trust
Objectives of Study Tour	1. Assess the nutritional profile of alternative protein sources to determine their suitability for feeding to laying hens. Assess the carbon footprint of each alternative protein, to assess its suitability to drive egg production towards net zero carbon emissions.
Countries Visited	Canada, USA, Brazil, Argentina, United Kingdom, Sweden, Netherlands, Germany
Messages	1. Soya in layer diets currently contributes to around 60% of the carbon footprint of an egg. Using alternative proteins has the potential to significantly reduce the carbon footprint. 2. No single alternative protein source can be considered a direct replacement for soya. A combination of protein sources and in many cases the addition of synthetic amino acids are required to produce a diet with the correct nutritional profile. 3. Constant analysis is required to assess the variability in the nutritional quality of many alternatives, particularly industry by-products. Development in novel protein sources such as insect protein and single cell proteins have the most potential for reducing the carbon footprint.

EXECUTIVE SUMMARY

Globally, the agriculture sector is expected to reduce carbon emissions to help tackle the climate crisis. Soya in laying hen diets accounts for around 60% of the total carbon footprint (CFP) of an egg, so reducing or removing soya from diets will have a significant effect on reducing carbon emissions.

My Nuffield project reviewed alternative protein sources, including grain legumes, industry by-products, insect protein and single cell proteins, to determine the most suitable source of protein for helping to drive egg production towards net zero emissions.

Grain legumes, particularly faba beans, are of particular interest in the UK as a home-grown source of protein. Recent advancements in breeding are bringing varieties that are low in vicine and convincing to market, anti-nutritional compounds which have limited the use of faba bean in laying diets up until now due to effects on performance and mortality. Further investment is needed to breed varieties with increased yields of protein, disease resistance and early maturity to increase the area produced in the UK and Europe.

The use of industry by-products in laying diets is an important part of a circular economy. A key interest is the development of technology to further process DDGS from bioethanol production to increase the protein content. Processed animal proteins can provide a valuable source of protein and are used widely in the US. Regulation change in Europe has allowed it’s use since 2021, and the UK is expected to follow in 2025. One of the main problems with the use of by-products is their variability in nutritional value. Constant monitoring is required to correctly formulate diets to meet the nutritional requirements of laying hens.

The continued development of novel protein sources such as insect protein fed on low grade food waste, and single cell proteins grown on captured Co2 from industrial processes have great potential in providing protein sources with a negative carbon footprint, vital for offsetting unavoidable emissions on the road to net zero. Both sectors are working on scaling their technologies with insect protein expected to be economically viable for livestock feed within 5 to 8 years.

None of the protein sources studied are considered a complete replacement for soya. A combination of alternative protein sources is required to significantly reduce or replace soya completely, resulting in an increase in the cost of the diet. Support is required to cover the cost of using alternative proteins either through investment in finding solutions to reduce the cost of production of the alternatives, i.e plant breeding or scaling insect protein production, or increasing the price paid to egg producers, potentially through differentiated egg brands.

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DISCLAIMER

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Please note that the content of this report is up to date and believed to be correct as at the date shown on the front cover

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Nuffield Farming Scholars are available to speak to NFU Branches, agricultural discussion groups and similar organisations.

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CHAPTER 1: PERSONAL INTRODUCTION

From a young age, I have had a very strong interest in agriculture and particularly in poultry. Throughout my years at primary and secondary school, whenever anyone asked me what I wanted to be when I grew up, the answer was always a farmer.

My experience in agriculture started with helping out on a friend's farm, followed by jobs during school holidays, rouging barley, grading daffodil bulbs and working on the back of a potato harvester.

After graduating with a Bachelor of Science honours degree in agriculture from SRUC's Aberdeen campus I joined a graduate training programme with Farmcare, formerly the Co-op Farms. What followed was two years of experience across the agricultural sector, from working on arable farms in Cambridgeshire and Perthshire, to helping to develop and roll out a supplier audit programme at a potato packing centre, working with the HR department in Manchester as well as time on a top fruit farm in Kent.

Alistair McBain, during his travels to Canada. Photo: author's own

After leaving Farmcare, I moved back to Aberdeenshire to work as an agronomist with Agrovista, where I was part of the national soil health team and had a keen interest in precision farming solutions.

I now work as the farm operations manager for Duncan Farms, a vertically integrated egg producer and packer near Turriff, in Aberdeenshire. The business has a large arable enterprise that produces around 90% of the cereals required to feed our birds. The business also rears day old chicks to point-of-lay pullets for our own farms as well as a growing network of contract producers.

In addition to my role with Duncan Farms, my wife and I were lucky enough to secure a small farm tenancy on a local estate in 2021. We have a flock of 90 continental ewes and grow malting barley.

CHAPTER 2: BACKGROUND TO MY STUDY SUBJECT

Pressure is building for the agricultural sector to reduce greenhouse gas (GHG) emissions, and egg production is no exception to this.

Around 80% of the carbon footprint, CFP, of a typical egg on supermarket shelves in the UK can be attributed to feed. And about 80% of this is typically from the use of South American soya. Soya and soya oil typically make up around 21% of the diet for laying hens.

The first assumption may sometimes be that the high CFP of soya is due to transportation distances. The truth, instead, is that the South American crop's high CFP is associated with deforestation and land use change. Figure 1 shows the difference in carbon footprint between soya associated with land use change and soya excluding land use change, for both Brazil and Argentina. Despite the vast majority of soya being grown on land that has been deforested for many years, the fact that deforestation is still happening and supply chains are not segregated between sustainable and non-sustainable soya, all soya from South America is treated as if it has been grown on land that has been deforested.

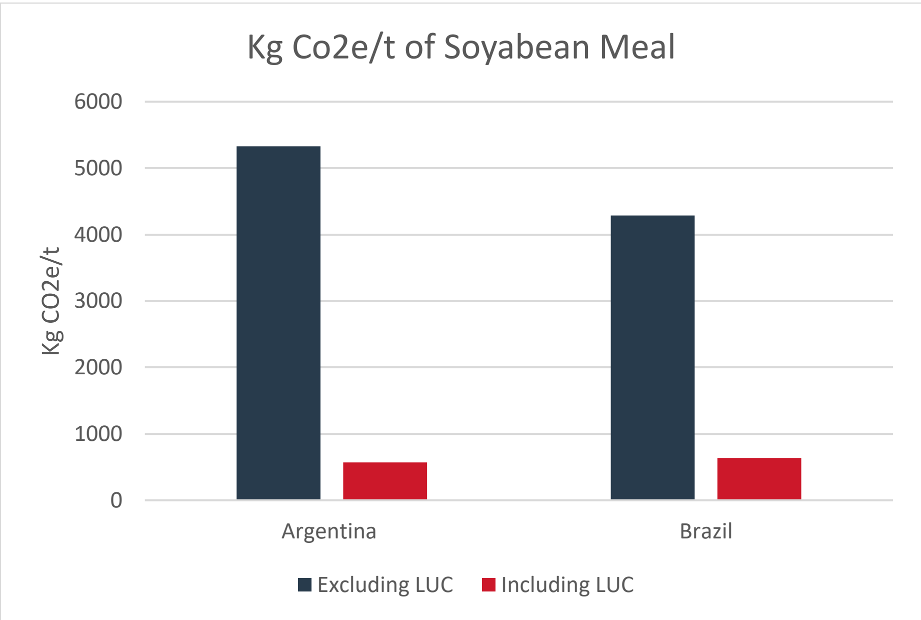

Figure11: Comparison of Kg CO_2E/t of soyabean meal including and excluding land use change. Source: GFLI 2021

Europe is the wolrd's second largest importer of soyabeans and largest importer of soyabean meal. In 2021 the EU imported 33.5 million tonnes of soya products, of which 24.7 million tonnes (74%) was from Brazil, Argentina and Paraguay. The EU only produced 2.7 million tonnes of soyabeans in 2021 (Wagenaar & Jong, 2023).

Given that soya contributes so highly to the CFP of an egg, the use of alternative proteins to reduce or remove soya from diets completely is a silver bullet for the poultry industry.

However, the use of alternative proteins is complex, because: Laying hens have been bred for almost 100 years with selection being carried out with birds fed on soya based diets. Soya is by far the most widely used protein source in layer diets globally. Over many years this selection process has favoured the nutritional profile of soya and created a bird that is almost dependant on it as a feed source. This is known as nutrigenomics.

Soya is the most economical protein source in many intensive livestock diets, hence its popularity. This is due to its high protein content and relative price point compared to other protein sources.

ALTERNATIVE PROTEIN SOURCES

The four alternative proteins sectors studied as part of this project are:

- Grain Legumes
- Industry by-products
- Insect protein
- Single cell proteins

CHAPTER 3: MY STUDY TOUR

Country	Month/Year
Canada	July 2023
USA	August 2023
Brazil	October 2023
Argentina	October 2023
United Kingdom	April 2024
Sweden	April 2024
Netherlands	May 2024
Germany	May 2024

CHAPTER 4: GRAIN LEGUMES

Protein rich crops such as peas and beans have a large role to play in increasing Europe's self-sufficiency in protein. Peas and faba beans are of particular interest for the UK as they can be grown across the country. In Europe, soyabean, peas and faba beans (also known as field bean, fava bean and broad bean) are by far the most commonly grown protein crops, however they only contribute to around 3% of Europe's total crop area compared with 46% for cereal crops . (van Loon, et al., 2023)
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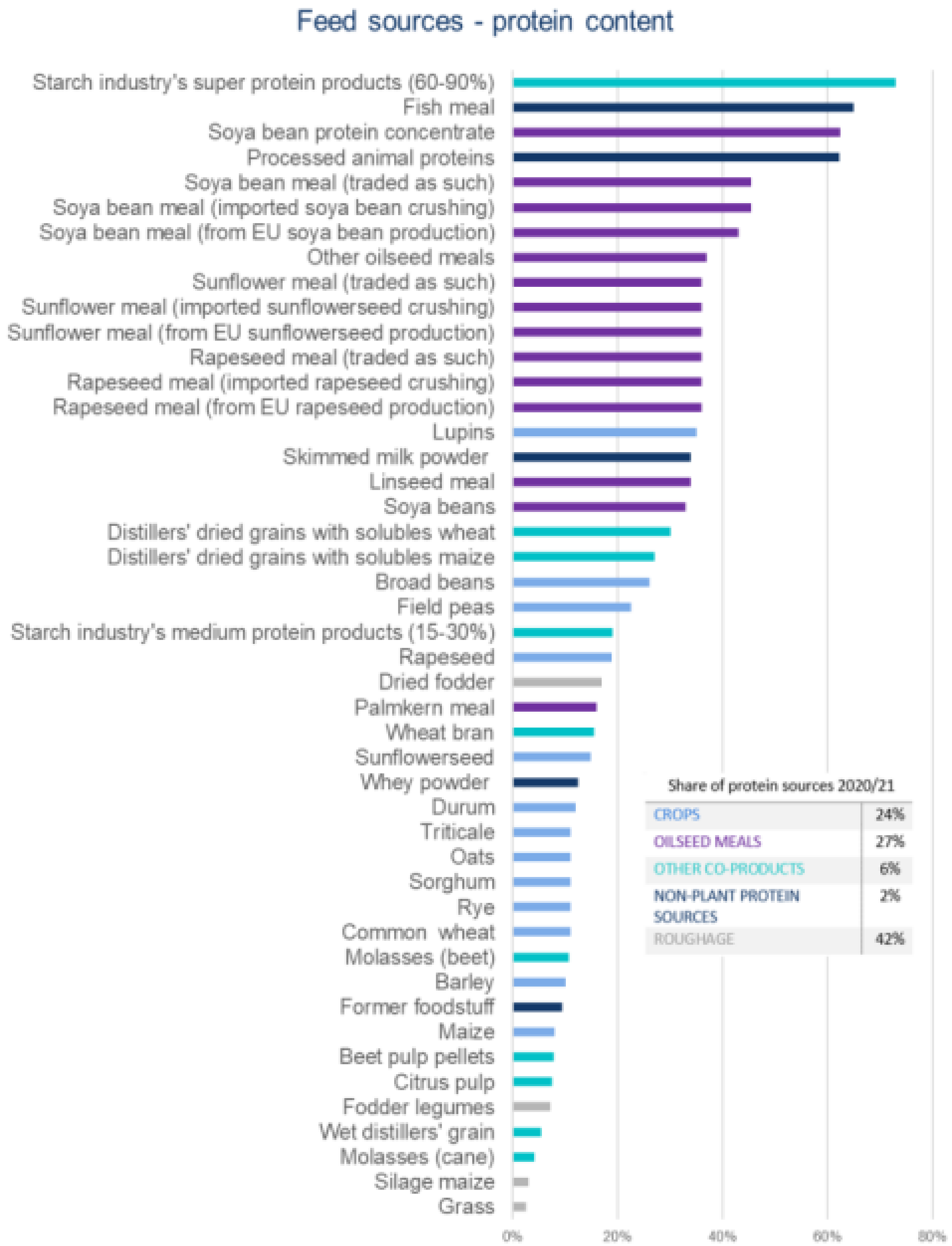
Figure 2 shows the relative protein contents of feed sources.



Protein content of feed sources. Source: FEFAC

Faba beans, although significantly lower in protein content than soyabean meal at 26% versus 46% for hi-pro soyabean meal, are the most attractive alternative grain legume. In the UK, Faba beans have a higher protein content (26%) and yield compared to peas, at 22% protein. The average protein yield per hectare based on the Processors and Growers Research Organization PGRO descriptive list is 1,144kg of protein/ha for faba beans and 838kg of protein/ha for peas.

The use of faba beans is currently limited by several factors. One of the main factors is the nutritional profile. Faba beans are high in lysine but low in the main limiting amino acid in egg production methionine. Adding faba bean to diets therefore requires an increased requirement for synthetic methionine along with other sulphur containing amino acids such as tryptophan and arginine. This reduces the cost competitiveness of faba beans compared to soyabean meal, which as of June 2024 is around 10% more expensive per kg of protein. However, relative costs will vary depending on market conditions.

Antinutritional factors, mainly the presence of vicine and convicine, also limit the use of faba beans in poultry diets. These compounds cause favism, a condition that causes hemolytic anaemia, which can be fatal in both humans and animals. High levels can reduce feed intake, growth rates and egg production.

:Nitrogen fixing root nodules on faba bean plant in Canada. Photo; Author's own.

A notable visit on my travels in Canada was to the University of Alberta to discuss research that is being carried out by Doug Korver, professor of poultry nutrition, and Matt Oryschak, a PhD student. Their work is focusing on characterising the levels of vicine and convicine in faba bean. Although faba bean varieties are currently categorised into low and high in both vicine and convicine, little is known about the effect of geographic location on the level of these compounds. In trials the effect of feeding faba beans high in vicine and convicine at a high inclusion rate had a negative effect on performance and mortality.

Another visit I carried out was to the Swedish University of Agricultural Sciences, to see Fred

Stoddart, a visiting professor from the University of Helsinki. Fred has been studying faba beans since 1981 and is considered one of the top three researchers of faba bean in Europe.

Fred was involved in a project along with other researchers that identified the genetic marker responsible for vicine/convicine production in 2014. The breeding process of faba beans is relatively slow compared to other arable crops. This is due to the low seed number produced by each plant slowing down the time it takes to multiply seed stock. As a rule of thumb, from start to finish, it takes 13 years to get a new variety to market. This has been accelerated in recent years by a process called speed breeding, where the first few generations of a variety can be multiplied more rapidly in glass houses. This reduces the time it takes to get a new variety to market to around 10 years. The result is that a wave of new low vicine/convicine varieties are currently coming to market.

Tannins are another anti nutritional factor that cause problems when feeding faba beans. Tannins are polyphenolic compounds that bind to proteins and digestive enzymes, interfering with protein digestibility and mineral absorption. They are concentrated mainly in the hull of the bean, therefore levels of tannin can be reduced by dehulling.

Other attributes that plant breeders are basing their variety selections on include:

- Yield. In the past 60 years faba bean yield has tripled globally

- Higher protein. The protein % of faba beans is highly influenced by genetics and less so by the environment compared to cereal crops. Dr Stoddart noted that 20% of the protein content of a faba bean is set by its environment, and the other 80% by genetics, whereas 80% of the protein content in wheat is attributed to the environment, leaving 20% to genetics.

  The global average protein content of faba is 29%. The average protein content of varieties grown in the UK is lower at 26%. With current plant breeding techniques it is possible to reach a protein content of 35% in theory, and Dr Stoddart suggested this could be higher with the implementation of gene editing.

- Disease resistance. There are many pests and diseases that make growing faba beans more challenging than cereal crops. The number one enemy across the world is chocolate spot, which can cause yield losses of up to 50%. Other diseases that are a problem in certain areas are ascotyta, downy mildew and root rot. In the UK, the main pest is seed weevil.

- Drought tolerance. Drought is one of the major limiting factors which affects the yield of both faba beans and peas. Dr Stoddart noted that the average yield across Finland in the past few years was 2.2t/ha, whereas the most successful producers are achieving yields of up to 6t/ha. The main difference attributed to this yield difference is access to water/irrigation.

- Earliness of maturity. One of the main factors deterring production, especially in northern Britain, is earliness of maturity. Breeders are working on reducing the growing period to allow earlier harvests, when conditions are drier. This earliness of maturity was of particular concern for growers I visited in Alberta, where sowing dates can be as late as May with the first frosts arriving in September. Varieties that are used in Canada are more suited to their extremes in temperature, typically reaching +30°C in the summer to -30°C in the winter with no long spring or autumns to soften the change. These varieties are not commonly grown in the UK and Europe.

Lupins

A lot of research is being carried out to develop lupin as source of protein in Canada and Europe. Lupins have a protein content ranging from 29% to 42%, with 6% to 10% oil. The rest of the plant is mostly cell walls, which makes lupin very high in fibre. This limits its use in poultry diets and confines the crop's use mainly to dairy.

CHAPTER 5: INDUSTRY BY-PRODUCTS

There are many by-products from various industries that will play a role in reducing the use of soyabean meal in poultry diets. The industry by-products that I have studied as part of my Nuffield study are:

- Dried distillers grains
- Processed animal proteins
- Biscuit/Bakery meal

Dried Distillers Grains

Dried distillers grains (DDGS), is the by-product from ethanol and spirit production, and is usually derived from maize, wheat or barley.

The production of DDGS has increased significantly in the last 20 years due to many countries mandating set levels of ethanol in petrol. This is particularly the case in Europe and the US. In 2021 the mandate for ethanol in petrol in the UK rose from 5% to 10%, known as E10.

The nutritional quality of DDGS can vary significantly between, and even within, ethanol plants. Energy levels can vary between 2495 to 3196 Kcals/kg and digestibility can vary from 46% to 78%. This can create issues in ration formulation, so the nutritional value of the DDGS needs to be evaluated on an ongoing basis. Also, mycotoxin present on grains at the start of the distilling process can become more concentrated in the DDGS, and they can negatively impact feed conversion efficiency as well as egg production and shell quality, so levels need to be monitored closely.

Whilst in the US, I visited Optimal Aqua Feed, owned by Green Plains Bioethanol who are the third largest producer of ethanol in the US producing roughly one billion US gallons of ethanol annually from maize/corn. Green Plains has developed a process with a company called Fluid Quip, who they now own, to concentrate the protein levels in DDGS from around 28%, to two separate products containing 50% protein and 60% protein.

Optimal Aqua Feed facility. Photo: Author's own.

The process works by passing the DDGS through a centrifuge system to remove spent yeast cells, which have been broken down by enzymes as part of the fermentation process.

Generally, the 50% corn fermented protein (CFP) product is being used in pig and poultry diets with the higher 60% protein product being used in aqua feed, to meet the higher protein requirement of fish. CFP is being used by the four largest egg producers in the US. According to Sheldon Spratt of Green Plains Bioethanol, CFP can be used to completely replace soya, with additional supplementation of amino acids, however it is generally used at inclusion levels of between 4% and 7%.

Green Plains Bioethanol currently has the centrifuge technology installed in three of their bioethanol plants, producing approximately 1000 tons of CFP every day. If the technology was installed across all 10 of Green Plains plants, annual production could be increased to five million tonnes.

Ensus, one of the largest bioethanol plants in Europe, based in Teesside, plans to install the same equipment, with commissioning planned for 2025.

Processed Animal Proteins

Processed animal proteins (PAP), also known as meat and bone meal, has been banned in the UK since 1988. PAP is derived from rendering animal by-products not intended for human consumption. Rendering involves heat treating the animal proteins at a high temperature to kill pathogens and reduce moisture content. This creates a protein-rich product.

PAP is, however, used widely in the US. Regulation change in the EU in 2021 allows the use of PAP under strict rules. PAP from pigs can be fed to poultry and PAP from poultry can be fed to pigs in the EU. No ruminant PAP can be used because of concerns about BSE. Feed mills using PAP in Europe must be single species mills to avoid the risk of cross contamination between the two PAP species.

It is expected that legislation mirroring the EU legislation will be introduced in the UK in 2025.

In the US I visited Kristjan Bregendahl, a poultry nutritionist working for Devenish, feeding more than 50 million laying birds across the US from small Amish producers to large scale companies with more than 10 million layers.

I discussed the use of PAP within poultry diets with Kristjan. A typical analysis of PAP would be 50% protein, 10% fat, 8% calcium and 4% phosphorus. He explained that like DDGS, the nutritional analysis of PAP can vary significantly, so constant monitoring must be carried out. He mentioned that occasionally, when demand for leather is low, abattoirs include the hides of animals in PAP which can cause issues with poultry as they are unable to digest the hairs.

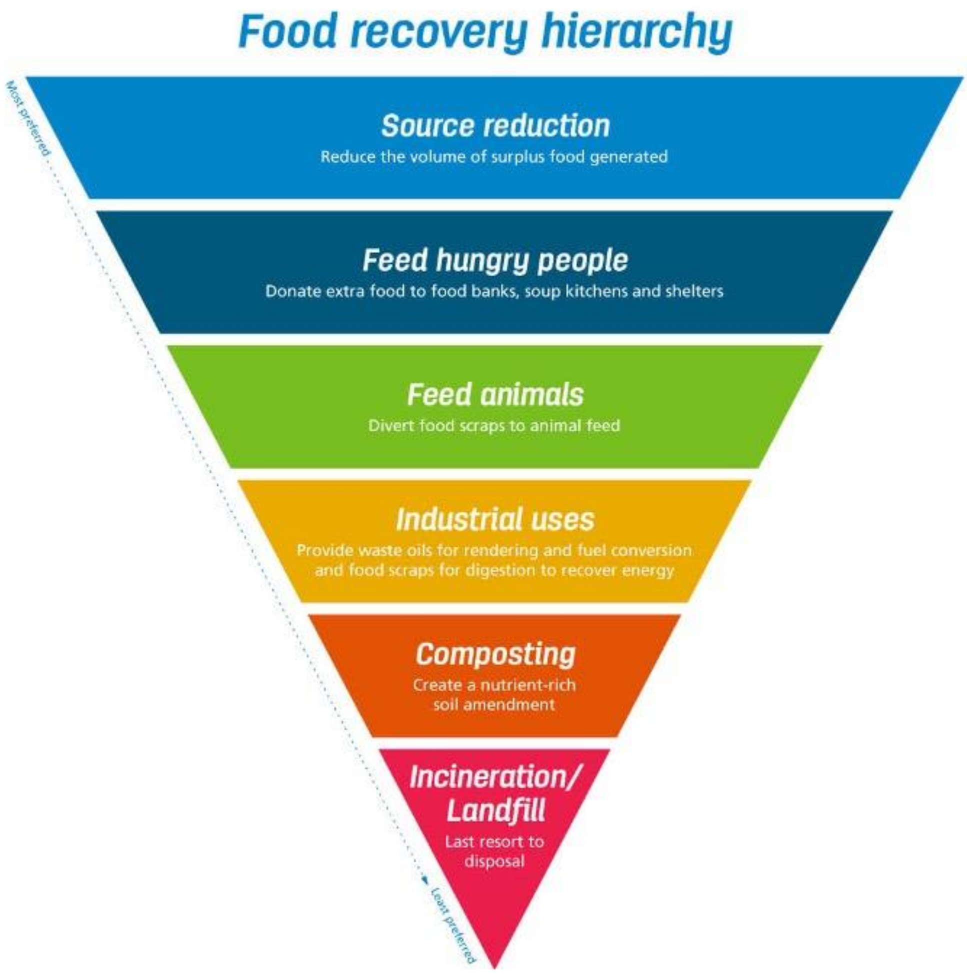
The limiting factor to using PAP is the level of phosphorus. The ratio of calcium to phosphorus required during the growing phase of poultry is 2:1. This increases once birds come into lay due to the high calcium demand required to produce the egg shell. An over supply of phosphorus can cause poor calcium absorption leading to poor shell quality. Typically, PAP can be included in layer diets in rates of up to 5%.

One of the perceived challenges of using PAP in the UK is public perception around food safety, along with transparency and ethical concerns. Although none of these concerns have been a huge barrier to its use in Europe, they will all need to be considered by the UK industry.

Biscuit/Bakery Meal

Biscuit meal refers to feed produced from surplus or out of spec bakery products, such as biscuits, cakes and bread. During my travels In the Netherlands, I visited Nijsen and I was hosted by their business development manager Karel van der Velden. Nijsen works with more than 70 industrial bakeries and a further 160 suppliers. Nijsen collects and processes 100,000 tonnes of food waste every year. Touring their facility, I was staggered by the quantities of what looked like perfectly good food, but which was considered waste. Karel explained that their suppliers follow the food waste hierarchy to manage and direct food waste in the most efficient and sustainable way possible, as shown in figure 3. Feeding former food stuffs back to farmed animals is a valuable step in providing a circular option and utilising waste.

According to Karel , one of the issues with the use of biscuit meal in poultry rations is the variability in nutritional value. Nijsen's scale of operation in working with so many partners means that they are able to supply a product to the poultry sector that has a specific recipe of certain food stuffs. This therefore minimises the variability of the product.



The food recovery hierarchy. Source: Beyond Food Waste (2022)

Case Study – Kipster

One of Nijsen's poultry customers is a company called Kipster. Kipster is a Dutch egg brand known for its sustainable and innovative approach to egg production. I visited Kipster in the Netherlands and also in the US where they have recently built four sheds as part of plans to expand the Kipster brand to other countries around the world. The key aspects of the Kipster brand are:

- Animal welfare. Kipster describes its shed as a next level barn production system, with a large winter garden area, as in the photograph below, and an outdoor access. As well as state of the art housing, Kipster also rears all their male chicks to 14 to 16 weeks of age for meat production. Euthanized male chicks are usually used as feed for reptiles in zoos and for pets.

- Sustainability and Circular Economy. Sustainability is a key aspect of the Kipster brand. The company claimed to have the first climate neutral egg back in 2006, achieved from feed supplied by Nijsen. Kipster aims to feed a diet that is produced solely using by-products which significantly reduces the carbon footprint.

Kipster winter garden area in the shed. Photo: Author's own.

Kipster also uses a large amount of solar on their sheds, allowing the company to be energy neutral. A small amount of imported electricity is still required when the solar is not producing electricity, however surplus electricity is exported to the grid to give an overall neutral requirement.

All exhaust air from the sheds passes through an air cleaner to reduce the levels of dust and ammonia emissions.

Carbon

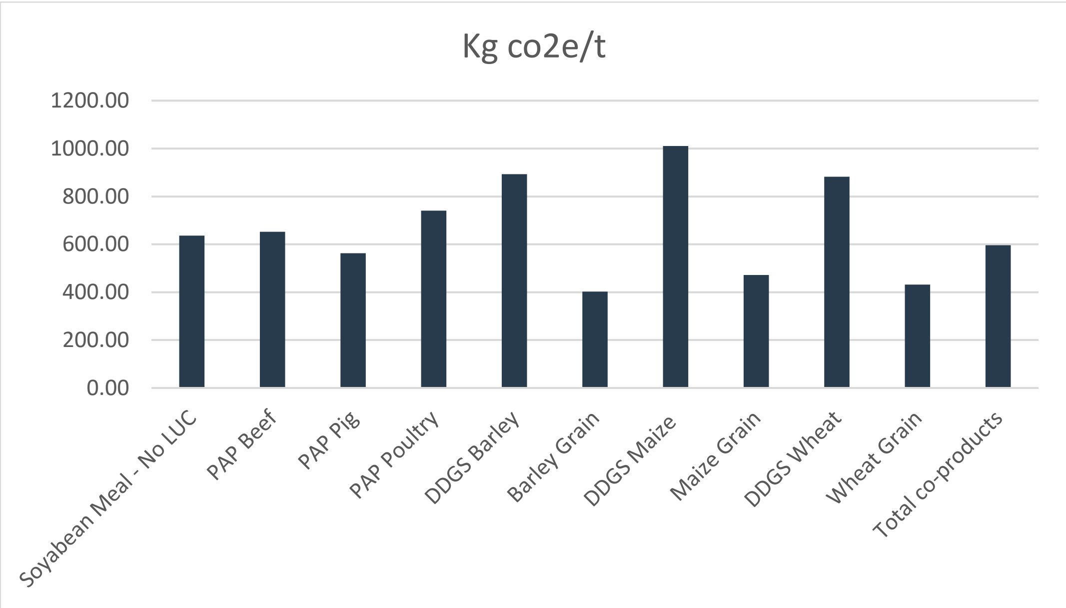
It became clear, when speaking to egg producers and nutritionists, that the use of industry by-products, often classed as waste products, can offer a relatively high carbon footprint. This is because of the method of calculating the carbon footprint.

The most common method of allocating the carbon footprint of a by-product is using economic allocation. The total carbon emissions of a production process are divided between the economic value of both primary products and by-products. One of the disadvantages of this method is that the carbon footprint of each product fluctuates according to market prices.

Other methods of allocating the carbon footprint include:

- Mass allocation, which allocates the carbon across the total weight of all products produced from a process.
- Energy allocation, which splits the carbon over the calorific energy content of each product.

Figure 4 shows that the economic allocation method in many cases turns the use of by-products that would otherwise be classed as waste, into products that have a higher carbon footprint than soyabean meal produced in areas in Brazil that are not associated with land use change.



Comparison of the carbon footprint of industry by-products versus soyabean meal and grain crops. Source: GFLI (2021)

CHAPTER 6: INSECT PROTEIN

Insect protein is a novel protein source with particular interest for upcycling food waste into a nutrient rich product. As part of my travels, I visited several insect protein producers across the UK, Germany and Holland.

Huge investment has been poured into the insect protein sector from start-up companies to large multi nationals such as Cargil, Tyson Foods and ADM. Several insects are being farmed across the world, including meal worms, crickets and black soldier fly. Black soldier fly are considered the most suitable for animal feed.

Most production systems grow the insects in trays. Dedicated breeding colonies are kept in breeding nets, where they mate and lay eggs, which are then collected and placed in an incubator. In most cases the hatched larvae are kept at the breeding facility to grow for seven days into neo nates, which are then transferred to dedicated growing facilities.

At the growing facility, a prescribed amount of neonates are placed into a single tray with an equally prescribed amount of feed stock. At the end of the production cycle, all that is left in the trays is the larvae and their faeces, known as frass. The larvae should be fed to livestock before they start developing into the pupa stage, and before the protein in the insect is converted into chitin.

In the UK, the same legislation that does not allow the use of PAP is preventing the feeding of processed insects to livestock. Insects can be fed to pig and poultry but they must be alive at the time. A handful of poultry producers are currently feeding live insects to laying hens, by distributing live larvae throughout their laying sheds. This requires increased labour and it cannot be relied upon as a feed source as its not possible to guarantee each bird will receive the same amount of larvae, or any larvae at all. This does however act as an enrichment for the birds and trials have shown that this brings performance benefits. The current UK legislation does not allow any meat, or feedstuffs that may have had contact with meat, to be fed to the larvae. This rules out any consumer waste being fed, as the segregation of meat cannot be guaranteed. The expected legislation change that will allow the use of PAP, is also expected to allow the use of insect protein meal. It is also believed that DEFRA is carrying out food safety trials that may allow consumer waste to be fed to insects.

One of the key interests in insect protein production is the use low grade food waste, which cannot be used to feed livestock directly. As shown in the food waste hierarchy in figure 3, if the waste could not be fed directly back to livestock, the next stage down the hierarchy is for use in industry and anaerobic digestion. Insect protein would fit in between these two stages. This would upgrade the low grade waste into a protein rich feedstock that can then be used to feed livestock or in some cases, directly for human consumption.

Current UK legislation does not allow the full potential of the use of low grade food waste to be realised. The insect facilities I visited were feeding a combination of brewers grains, cheese whey, bakery waste, grapes and apple waste from cider production. Many of these feed stocks have a use higher up in the waste hierarchy, and can be fed direct to livestock.

Another reason for the use of these feed stocks in insect protein production is their consistency and their availability. "They are what they eat" was mentioned by several people I visited. The nutritional value of larvae fed on low grade waste would be extremely variable, limiting its use in poultry rations. A typical crude protein analysis of insect protein meal is 52%, when fed on these higher grade feed stocks.

The current cost of production of wet larvae is estimated to be €600/t at 70% moisture content. When dried down to a meal, the cost is around €1,100/t. Most of this cost is depreciation, due to a high capital requirement to build the facility. Other major costs are electricity to run ventilation systems and machinery, as well as labour. Depending on the location and what feed stock is used, some producers may also have to buy their feed stock.

Due to the high cost of production, most of the interest in establishing insect protein production facilities in the UK is coming from large waste handling companies, such as Suez and Veolia, as well as large multi-national companies and retailers who all have commitments to reduce food waste. The high price point means that in Europe the vast majority of insect protein meal is being used in pet food, with some also being used in aquaculture. Julis Hamelmann from Better Insect Solutions predicts - in 2024 - that it will take between five and eight years for the industry to scale to a level where it is feasible to feed insect protein meal to pigs and poultry.

Carbon

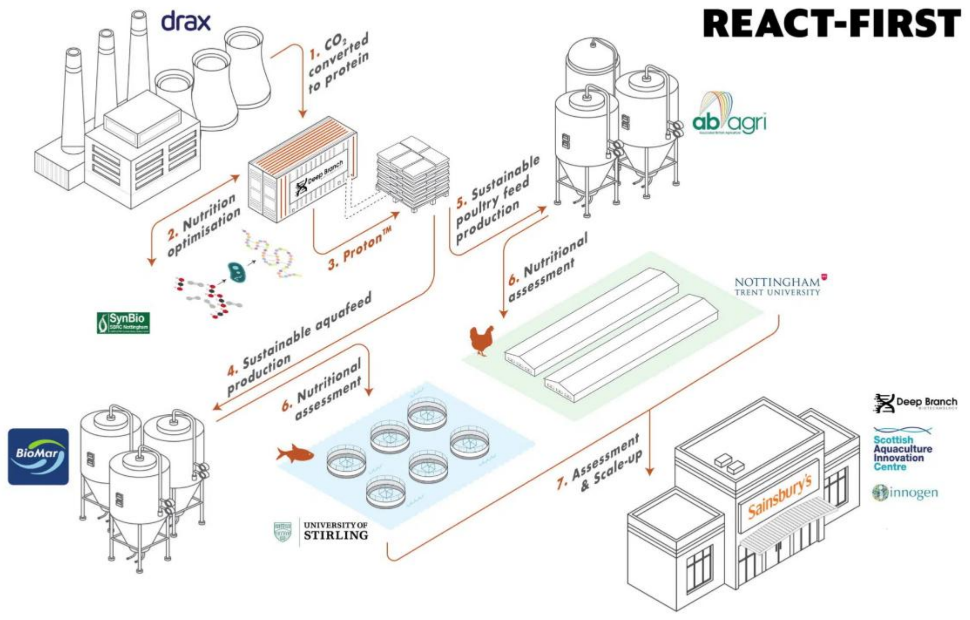
No official method exists for calculating the carbon footprint of insect protein. Many people I spoke to in the insect protein sector agreed that this is something that needs to be addressed, but it comes with challenges as insects can be fed on many different feed stocks with different carbon footprints.

CHAPTER 7: SINGLE CELL PROTEINS

Single cell proteins are derived from the biomass of microorganisms (bacteria, algae and yeast), which are cultivated in controlled environments. They are grown on various substrates, from crop residues, industrial by-products, specially designed growing media and even CO_2. As well as being used in animal feed, single cell proteins are also being developed to produce meat analogues.

One of the major opportunities in the production of single cell proteins is the use of Co_2 as the growing media. This was seen in a visit to the University of Kentucky's Centre of Applied Energy Research. They have a project underway to develop a method of growing algae by capturing CO_2 from coal fired power stations in the US, to help them meet carbon reduction targets. The algae fed from the CO_2 from the power stations would be harvested and biorefined into several different products, including biodiesel, bioplastics and protein.

One issue that the researchers have faced was that the algae required a specific temperature range to grow. This temperature was only achieved during summer,



React First Project Illustration. Source: Nottingham Trent University (2020)

which meant that scaling the algae production up was not feasible for power stations who require a year-round solution to capture Co_2.

An alternative option for capturing CO_2 is currently being researched and trialled at Nottingham Trent University in partnership with Drax power station, biotech company Deep Branch and other industry partners, shown in Figure 5. Deep Branch has developed a process that uses microbes to convert CO_2 into protein. Nottingham Trent will trial the effect of the protein on the performance of broiler chickens. It is hoped that the trial will start during 2024.

Carbon

The CFP of single cell proteins varies between products depending on their production process and should be assessed on an individual basis. One of the most exciting factors of the use of single cell proteins is their ability to utilise waste CO_2 from industrial processes, potentially providing a negative CFP. Due to the high moisture content of the production process, drying is required to produce a stable product, but this adds cost and carbon to the process.

CHAPTER 8: SUSTAINABLE SOYA

As part of my travels, I went to Argentina and Brazil to see what is being done as part of sustainable soya schemes to improve the sustainability of soya production. I focused on one of the most widely used and recognized schemes, the Round Table of Responsible Soya (RTRS). RTRS is an organisation whose objective is to develop the production, trade and use of responsible soya. Although the main objective of the RTRS standard is to ensure soya is produced on deforestation and conversion free land, farmers must meet more than 100 other actions designed to further improve the environmental and social impact of soya production. These points are split into five sectors;

- Legal compliance and good business practices
- Responsible labour conditions
- Responsible community relations
- Environmental responsibility
- Good agricultural practices

When travelling in Brazil and Argentina I visited several RTRS certified producers. The use of sustainable farming practices including the use of cover crops, precision agriculture, carbon footprint tools and sprayer cleaning facilities was very encouraging and changed my perception of agriculture in South America.

One of the major benefits of an accreditation scheme such as RTRS is that growers see a clear financial benefit from being certified, which is not always the case with accreditation schemes in the UK. Sustainable soya credits are traded on an online platform and typically sell for around $4 per tonne.

Biobed system on RTRS certified farm in Argentina. Photo: Author's own.

Due to the vast scale of soya supply chains, from transportation to processing, most sustainable soya credits are traded on a mass balance system. Mass balance is a method used to measure the amount of sustainable soya entering and leaving the supply chain, ensuring that the volume sold matches the volume produced, even though the physical soya used by the end customer may have been mixed with non-sustainable soya. A mass balance system is an efficient method of developing sustainable soya production, without incurring the cost of segregating large supply chains.

The EU implemented the EU 2023/1115 directive on deforestation free products (EUDR) in June 2023, which comes into force on the January 1, 2026. This requires commodities such as soya, cattle, wood, cocoa, palm oil, coffee and rubber to be sourced from land that has not been deforested or converted after December 31, 2020. Unlike the mass balance approach used currently for credits, the physical soya being imported into Europe must be through a segregated supply chain. At the time of writing this report, it is still unclear as to how this is going to be implemented and what the cost is going to be.

Although the UK is no longer in the EU, most of the soya imported into the UK passes through EU ports. Many UK retailers such as Tesco, Sainsbury's, Morrisons, Lidl, Aldi and M&S are all signatories to the UK Soya manifesto which mirrors the requirements of EUDR.

One of the disadvantages of implementing EUDR is that it may reduce the demand for sustainable soya schemes such as RTRS. The sole requirement of

EUDR is that the soya must not have come from land deforested after December 31, 2020, whereas schemes such as RTRS include a range of standards to improve the sustainability of soya production environmentally and socially.

CHAPTER 9: DISCUSSION

A common theme of all the visits and interviews I carried out was that there are several reasons why soya bean meal is so widely used across the world as a source of protein in layer diets. It is cheap, has an excellent amino acid profile with high digestibility and it has a relatively low amount of anti-nutritional factors compared to other protein sources.

Where I saw the majority of alternative protein sources being used, was where there was local availability of an industry by-product, such as biscuit meal and PAP, or the alternative protein was adding nutritional quality to the diet, for example sunflower meal to increase the soluble fibre content, improving gut health.

In many cases the inclusion of the alternative protein reduced the cost of the diet. However it is widely recognised that to significantly reduce the soya bean meal inclusion level, or remove it completely, raises the overall cost of the diet. This raises the question of who should pay for the increases in production costs that are introduced to support improved environmental sustainability. If customers are willing to pay more, there needs to be differentiation of meat or eggs from poultry fed soya based diets and those on non soya, but more expensive diets .

This was illustrated by a visit to 2022 Dutch Nuffield scholar Johan Leenders . The visit to his poultry unit highlighted the role of sustainability when developing a

Winter garden of Oranjehoem shed. Photo: Author's own.

brand and relationships with customers.

Johan is a broiler producer and arable farmer from the Flevoland region of the Netherlands. He has developed a brand to market his chicken meat called Oranjehoem, which translates to orange hen. Johan feeds his birds on a non-soya diet, but uses a range of alternative proteins to give the correct diet specification. This includes peas, sunflower, rapeseed, potato protein, bakery products and PAP. This alternative protein diet has reduced carbon emission by 40%.

As well as feeding a non-soya diet, Johan differentiates his brand from standard produced chicken meat by using the following:

- Better life quality mark. Beter Leven is the quality assurance scheme developed by the Dutch Society for the Protection of Animals, which scores producers on a 1,2 or 3 star basis, with '3' being the best. Johan was the first broiler producer to gain a 3-star accreditation.
- No antibiotics.
- Energy neutral farm. Solar panels produce the electricity required for the farm.
- Distinctive colour and taste of the poultry meat. Through the changes in diet and the use of a specially designed slow growing breed of bird, Johan produces chicken meat that is distinctive in colour and taste.
- Diet using locally recycled food. Johan collects food waste from his customers, who include Hello Fresh, an online meal kit delivery service, which he then processes into a pellet and feeds to birds in their winter garden to provide an enrichment.

CHAPTER 10: CONCLUSION

1. Currently the use of South American soya bean meal and oil makes up around 60% of the carbon footprint of an egg. The use of alternative proteins will play a major role in driving the egg production sector towards net zero.
2. Currently none of the alternative proteins studied were considered complete replacements for soyabean meal. A combination of alternatives is required to replace soya. This makes the feed production process more complex.
3. Egg producers need to evaluate available alternative protein sources. This will vary by country. Accurate testing is often required to establish the nutritional quality of the protein source. Care must be taken to formulate a balanced diet. Synthetic amino acids will play a large role in balancing the amino acid profile in reduced and no soya diets.
4. Novel protein sources, such as insect protein and single cell proteins, have the most potential in terms of net zero egg production. Their potential use in a circular economy, whether upcycling of food waste, or the capture of CO_2 from power stations, gives the potential of a negative carbon footprint. However, these are not commercially viable in most production situations.
5. Recent advancements in breeding are bringing faba beans to market with lower level of vicine and convincing, considered a major anti nutritional factor to poultry.
6. It is hoped that regulatory changes in the UK in 2025 will allow the use of processed animal proteins to be used in poultry and pig rations. The same set of regulations are expected to allow the use of insect protein meal.

CHAPTER 11: RECOMMENDATIONS

1. Retailers should look to incentivise the use of alternative proteins, to allow their use to be financially viable for producers. This will assist retailers in their drive to reduce their scope 3 emissions.
2. Carbon accounting methods must be standardised in their method of calculating the carbon footprint of food production to allow comparisons to be made.
3. The method of allocating the carbon footprint of industry by-products should be weighted more towards the primary product to encourage the use of by-products as part of a carbon reduction plan.
4. Investment in the breeding of faba beans and other protein crops is relatively low in the UK due to the relatively small area of protein crops grown. More government and industry investment is required to further develop these crops, making them better suited for our changing climate and for the nutritional requirements of livestock. An increased supply of UK grown protein crops will reduce our reliance on imports from other countries, strengthen food security and limit the impact of global market fluctuations on producers and ultimately consumers.

CHAPTER 12: AFTER MY STUDY TOUR

Carrying out a Nuffield farming scholarship has taken me to places I would never have been. It has opened my eyes to farming around the world and changed my views particularly around agriculture in South America.

The journey has developed me both on a professional and personal level, building my skills in public speaking and thinking about subject matters on a wider level. Being part of the Nuffield community has given me confidence and inspiration to look outside the box and it has allowed me to network with people outside my usual industry circles.

During the period of my Nuffield Scholarship, Duncan Farms has implemented reduced and no soya diets on selected flocks with the support of our retail customers. The knowledge gained from my Scholarship has aided the development of these diets and helped to shape the direction of travel going forward. This has allowed us to significantly reduce the carbon footprint of these flocks.

CHAPTER 13: ACKNOWLEDGEMENTS

First and foremost, I would like to thank my wife Rebecca, for being so supportive of me during my travels and tolerating me being away from home for weeks at a time. The support of family and friends is what makes a Nuffield Scholarship possible.

I would also like to sincerely thank my sponsors, the MacRobert Trust, for their extremely generous support.

I would also like to thank my employer, Duncan Farms, who encouraged me to apply for the scholarship and gave me the time and space to carry out my scholarship. I would also like to thank my colleagues for picking up my workload whilst I was travelling and for taking on board the findings and suggestions I came back with, particularly in a year full of business change and growth.

Lastly, I would like to thank all of those who took the time out of their busy schedules to meet and host me during my travels. I have mentioned many of them in my report, but there are many more who provided me with great knowledge and insight not just into their businesses, but their culture and way of life.

The support of the 2023 Nuffield year group has been tremendous, with each person bringing different viewpoints and thoughts from across the agriculture industry from arable to flower farming, and journalism to rewilding.

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