Whitepaper

Animal Feed

Insect protein - Environmental necessity to fledgling industry

Innovations for a **better world.**

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Content.

1. Introduction

You cannot open the pages of a magazine aimed at the animal feed industry without coming across a mass of articles on the use of insects in animal feed. It is an exciting new frontier for agriculture, driven by what many see as a looming global protein gap as incomes rise, diets change and populations grow.

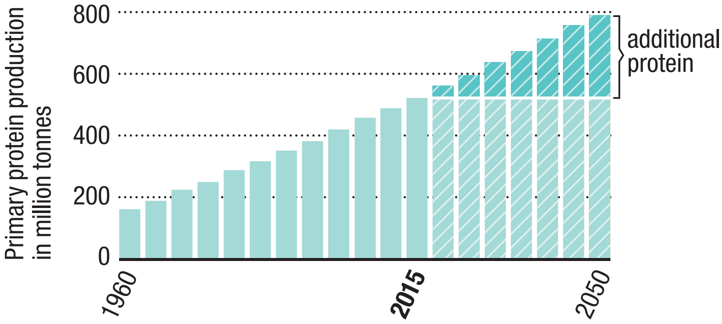
Despite the apparent logic of using a protein-rich resource such as insects as an alternative to crop-based proteins, the new market is in its infancy. While there is a great deal of optimism around the industry, the amount of animal feed being produced from alternative proteins is actually small and currently targeted at niche markets.

This White Paper will look at the reasons why there is a need to find new protein sources and how demographics and population growth are driving change in the feed sector. It will also look at what alternative protein sources might be available and explain why insect protein is looking the most commercially viable. The paper will explore how the insect protein market is evolving, investigate the challenges the producers are facing and the difficulty of achieving the sort of economies of scale needed to make alternative protein sources profitable.

2. Why the need for an alternative protein source?

To understand why the creation of alternative proteins is generating so much interest in the animal feed industry we need to first appreciate the context in which this new industry has emerged over the past decade or so.

There is only a finite amount of protein in the world. Sources of protein for humans either come from animals or in the form of pulses, nuts, seeds, and grains. Wheat, rice, maize, soybeans and rapeseed meet over 80 per cent of our protein needs. In 2015 it was calculated that we produced globally 525 million tons of plant protein each year in the form of corn, rice, wheat or soybeans. This is enough to feed the 7.6 billion people currently living on the planet[1].



Protein production has to cope with a growing world population.

However, nothing is constant when it comes to human behavior. Not only is the global population growing but the aspirations and appetites of large swathes of the planet are also in flux. As countries develop and become wealthier their populations start to demand more from life and what sustained past generations is no longer acceptable as expectations rise.

According to the Brookings Institution[2] the world's middle classes are growing faster than ever before as they increase in absolute numbers by 140 million a year. Numbers are expected to increase even further to 170 million annually over the next five years. Most of these new entrants will be from emerging economies such as Asia, India and China in particular, while in Europe and North America the demographic shift is effectively stagnant. One of the fundamental expressions of increased wealth and status is what we choose to eat.

More of us are also living in cities, with 54 per cent of global population now classed as urban. Those who migrate to cities find they have more money in their pockets and so are able to change their eating habits as they can afford more processed foods and animal-based protein[3].

Population growth is the other driver increasing projected meat consumption. Not only is the UN predicting that global population will increase to 9.7 billion by 2050, but most of this increase is likely to happen in the very regions where meat consumption is already expanding at its fastest.

While meat consumption has been relatively static in the developed world, in developing countries per capita meat consumption has doubled since 1980 and according to the Food and Agriculture Organization of the United Nations (FAO) economic, demographic and population changes are set to increase meat consumption by 50 per cent by the time we reach 2050[4].

The question now is whether we can produce enough plant-based protein to satisfy this added demand for meat. In short, the answer is "no". There is just not enough available land to produce the amount of additional plant protein we are going to need to satisfy anticipated demand. This explains why there is currently such a push to discover alternative proteins as a source of animal feed.

In its 2017 analysis of future food trends the FAO highlights the uneven demographic expansion that is already taking place as one of the top challenges facing food and agriculture in the coming decades. To understand the scale off this challenge we need to do a quick protein calculation.

Out of the 525 million tons of plant-based protein presently available to us annually, 60 per cent is used for animal feed, 25 per cent goes directly into the human food chain and 15 per cent is lost in waste throughout the whole value chain. It is the 60 per cent being used for animal feed that poses the greatest challenge. When you feed an animal it uses most of that protein to sustain itself. As a result, on average, it takes four plant-based proteins to produce one animal-based protein for human consumption. This results in 75 per cent of protein fed to animals being lost. Which is why the more people who eat meat on the planet, the wider the gap becomes between the amount of protein we need and the amount that is available to grow.

Andreas Baumann Head of Technology Bühler Insect Technology Solutions explains: "If you take the value of meat production provided to us by the FAO and calculate back how much protein will be needed by 2050, including all the feed losses, we find we are going to need an additional 265 million tons of protein a year. That means we are going to have to somehow increase protein production by 50 per cent by 2050." The stark truth is we either need to produce more protein or stop eating meat.

2.1 How to solve the protein gap?

We know that our current plant-based agricultural model will not sustain predicted rises in demand for meat as global demographics shift and the world population increases.

The next question is what can we do about it? One solution is to grow more crops. The problem here is the finite amount of land at our disposal. If we want to produce more crops like soy it will mean making ever-greater destructive inroads into our fast disappearing forests, with all the associated environmental consequences. We are already using 85 per cent of available land to grow plant-based proteins. It is difficult to see how we are going to be able to produce 50 per cent more plant protein with what is left. There is just not enough land.

Another option is to stop eating meat. If we were all to become vegans then the current plant- based protein being produced could sustain a global population of 18 billion. Certain communities, typically in the West, are starting to appreciate the public health risks associated with meat-rich diets and others are becoming vegans or vegetarians due to environmental or animal welfare concerns. However, the numbers turning their back on meat does not compensate for the millions who are turning to meat as their status and aspirations rise.

The third option is to find alternative protein sources that do not require growing crops on land. At present this appears to be the most practical solution to the impending protein gap. There are a number of different sources of alternative protein being explored.

3. What are alternative proteins?

While there are a number of different ways of increasing available protein, the use of insects in animal feed is currently the most developed and is looking the most viable commercially. But there are other options that should be considered and will be discussed here.

3.1 Algae

Nutritious and tasty: algae are also consumed as food.

One of the advantages of using algae as a potential protein source is that they do not compete with existing farmland and in the case of marine algae do not require fresh water. Algae are made up of macroalgae, also called seaweed, and microalgae, unicellular and microscopic organisms of which there are around 200,000 species. Because of the harsh environment in which they live, algae have also developed natural protective systems by producing pigments like carotenoids, chlorophylls and phycobiliproteins, which have been put forward as having health benefits for humans and animals[5].

Seaweed has long been a source of nutrition for humans. According to the Food Balance sheets published by the FAO China, the Republic of Korea and Japan are the greatest consumer of seaweed. Some seaweed species can contain as high as 50 per cent proteins (calculated on dry matter), however, though present in some species, most essential amino acids are deficient except for the sulphur containing ones[6]. While seaweed has been used historically as animal feed it can have highly variable composition depending on the species and the seasons, has a large water content and can accumulate high amounts of metals, iodine and other minerals that could potentially lead to a negative impact on animal health. This capacity to accumulate minerals has at the same time put forward seaweeds as a valuable additive for animal feed thanks to their minerals and bioactive compound concentration.

Microalgae are already being exploited for their high protein content and can deliver up to six times more protein per hectare than soya and do not require arable land. Therefore, microalgae have been underlined as one of the single cell protein sources with high potential to decrease pressure of our environmental resources[7]. Research suggests that including microalgae in animal feed could improve growth and meat quality in ruminants, pigs, poultry and rabbits. In particular the microalgae Chlorella, in very low percentages in poultry feed, seems to enhance growth parameters. Chlorella and Spirulina are currently being sold as functional foods for human consumption because of their high vitamin and mineral content.

One of the challenges around microalgae commercialization as an alternative protein source to plant-based proteins lies with the production and processing costs. Phototrophic microalgae (requiring sunlight for photosynthesis) are classically cultivated in open ponds or photo bioreactors (glass or plastic tubes or pouches). Such production systems are typically associated with high production costs of biomass per kilogram, large installations, and limited production capacity, which in turn has led this industry to focus on high added value ingredients with high margins such as pigments (e.g. carotenoids or phycobiliproteins). Some microalgae can also grow in the absence of light, using organic carbon sources instead of the CO2. These heterotrophic organisms can now be cost effectively cultivated commercially in large fermenter tanks for the production of omega-3 fatty acids EPA- and DHA- rich oils with a high potential for aquaculture. First cases of protein rich flour for human consumption have also recently come to the market. This mode of culture also induces lower costs of production and higher capacity, which may allow protein production for animal feed in the future. The first industrial-size installations for microalgae production and processing on a large scale are reaching the market for DHA oil production. It may be that future technological developments in microalgae cultivation along with process optimization that will enable costs to come down sufficiently to allow use of the protein fraction in the feed industry.

3.2 Microbial protein

Next to microalgae as one kind of single cell proteins, microbial proteins gained from bacteria, yeast and fungi have a big potential as future protein source for livestock. This kind of single cell protein requires nearly no land as the microbes grow extremely fast in aerobic fermentation tanks reaching high production capacities. Pikaar et al. (2018) predict that microbial proteins have the potential to replace 10-19 per cent of conventional crop-based animal feed protein by 2050. Next to low land use and high growth rates microbes are able to utilize various nutrients sources which do not compete with human ones like lignocellulosic residues[7]. Furthermore, there are bacteria which can be solely fed on methane or other gases.

Microbial proteins are already listed in the “catalogue of feed materials” of the EU and are therefore allowed to be used in animal feed[8]. With the improvement of cultivation techniques and decrease of prices it can be expected that microbial protein will become a price competitive protein source for animal feed.

3.3 Clean meat

This is one of the more unknown areas of development which offers the opportunity to produce meat through the cultivation of animal cells more sustainably than contemporary meat production. It was Winston Churchill who first predicted the production of clean meat in 1931 “We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium". Eighty-two years later it became a reality when in 2013 Mark Prost, Professor of Physiology at Maastricht University, made scientific and culinary history by developing the first laboratory grown burger and having this eaten by independent journalists.

The process involves taking a small biopsy from a living cow and harvesting it to the point where in theory it should be possible to produce 100 metric tonnes of meat from the single sample. Since 2013, start-ups across the world, such as Mosa Meat, Memphis Meats and SuperMeat, are racing to bring different versions of what is becoming known as "clean meat" to market. All three start-ups claim to commercialize their first products by 2021.

While engineering meat in a laboratory is one thing, what is not clear about this new industry is how the consumer will react and whether the technology will be cost competitive with traditional meat products.

3.4 Processed animal product and food waste

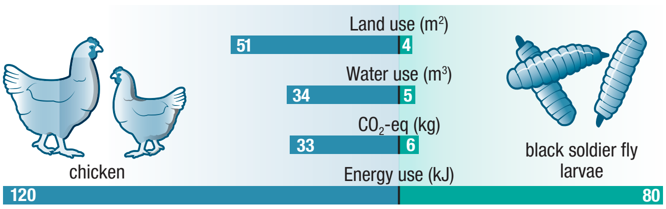
Another potential source of protein is processed animal products such as blood meal or fat meal. The challenge here is that the reputation of this process has been poor since the outbreak of Bovine Spongiform Encephalopathy (BSE) or mad cow disease in the 1990s. Concerns are mostly focused on Europe where controls have been introduced around the feeding of animals with animal protein.

The UN estimates that each year 1.3 billion tons of food produced for human consumption is wasted. In 2012 Europe launched the project NOSHAN to identify functional feeding ingredients derived from food waste. During the four years that the project ran it investigated turning fruit, vegetable, cereal and dairy waste into pork and poultry feed. NOSHAN's business partners are currently looking to turn their research into a product and to commercialize it within the next two to three years[9].

4. Insects as an alternative protein source

One of the most promising alternative protein for animal feed is currently seen as insects. By 2050 it is anticipated that insects could provide 15 per cent of the additional protein that will be needed by then.

The reason there is so much optimism around insects is that they are such extraordinary protein converters. Overall insects are able to extract up to 70 per cent of the nutritive value of their feed. Because they are cold blooded, they don't require feed to maintain body temperature. That is why they are able to convert feed into protein at a much higher rate than livestock animals, which partly invest feed to keep a constant body temperature. Insects are also able to efficiently absorb protein because they ingest feed several times. A cricket only requires 1.7Kg of feed to produce 1Kg of live animal weight. In a typical American production system to get the same animal weight you would require 2.5Kg of feed for chicken, 5Kg of feed for pork and 10Kg of feed for beef[10]. Last but not least, insect rearing does not require much land, while there is the added advantage that they can be fed on organic waste.



Impact on the environment per kilogramm of protein

Insects can be produced with little environmental impact.

4.1 Insect feed in aquaculture

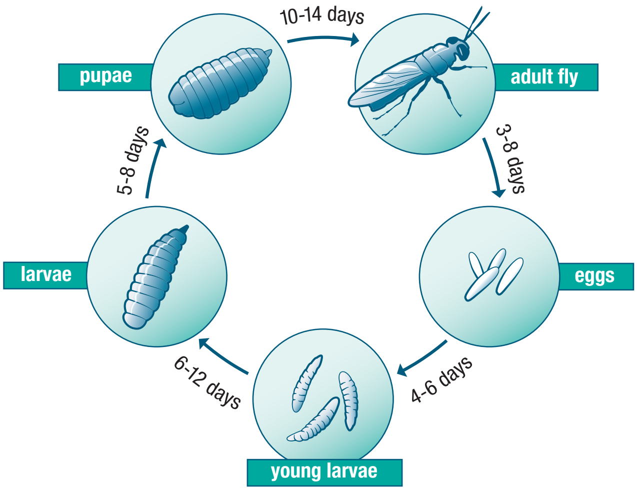
Insects are a natural food source for many fish, which is why fly fishing is such a popular pastime and maggots are used as fish bait. Aquaculture is also the only agricultural sector in Europe where you are legally allowed to use insect protein in feed at the moment. Pet food is the other sector where insect proteins are currently being used. It is, for example, applied in hypoallergenic dog food.

Out of the 20 million tons of wild seafood caught each year it is estimated that a quarter goes into fishmeal. Research published last year suggest that 90 per cent of this produce being diverted from the food chain could in fact be fit for human consumption[11]. Fishmeal is seen as one of the drivers contributing to the depletion of our fishing stocks, so replacing fishmeal content with insect protein is being considered a more sustainable solution. Tests have shown that salmon can be successfully fed on a diet of up to 50 per cent insect meal without any adverse impact on the fish. Research indicates that the use of insect protein can even help to maintain a better gut morphology, leading to improved feed conversion and lower mortality rates during production.

Insect protein is also more likely to become a competitive alternative thanks to the cost of conventional fishmeal. Aquaculture is the fastest-growing agricultural segment in the world. This has led to rising demand for fishmeal, which has forced prices up. This price rise has made the relatively high cost of producing insect-based protein meal less of an inhibitor when breaking into the aquaculture market.

4.2 Live insects as chicken feed

Feeding live insects to chickens is also possible from a legal perspective in Europe. The live larvae are added to the traditional diet of egg laying hens. It is said that using a live feed encourages the chickens to return to their natural behavior. Customer feedback on the taste of the eggs is very good. However, it needs to be evaluated, how this concept can be realized on a larger scale since transportation and storage is complicated.



Life cycle of balck soldier flies.

5. Turning insects into feed

Insect processing for feed on an industrial scale is currently being seen in terms of the circular economy. Insects are farmed on organic waste and in turn become a protein source for animal feed. The backdrop for the development of the industry is the growing demand for animal protein set against the growing problem of food waste.

5.1 Rearing

The first stage of the process is the rearing of the insects. Species that can be considered for industrial-scale production require certain characteristics. They need to have a high reproduction rate, a short development cycle, high survival rates of immatures, the ability to live in high densities, low vulnerability to disease and a high potential of biomass increase, for example weight gain per day. Two insect types that meet these criteria and so are considered most suitable for animal feed are the black soldier fly (Hermetia illucens) and mealworms (Tenebrio molitor, Alphitobius diaperinus).

5.2 Larvae

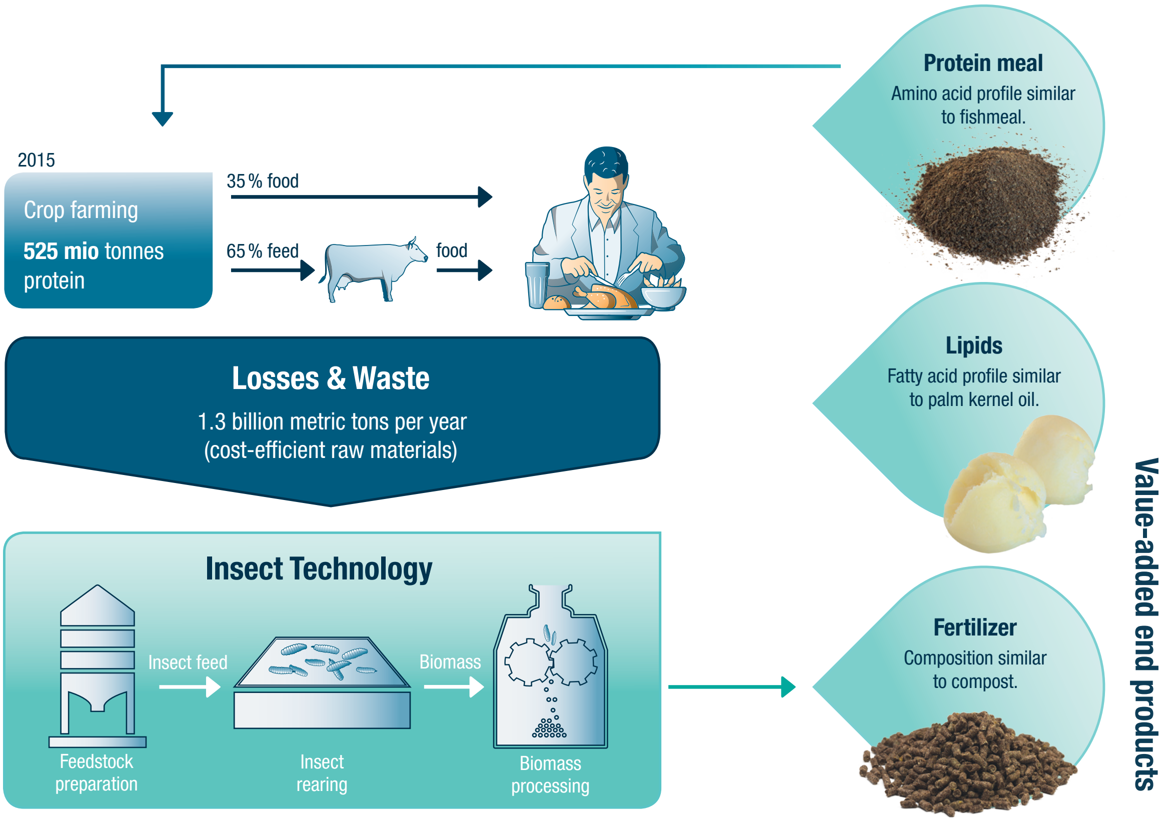
Within the life cycle of an insect, the larva is the most suitable stage for being used as animal feed. They have a dry matter of 30 per cent of their total wet larval mass, of which 40-55 per cent is crude protein. Fly larvae can be raised on a wide range of organic waste products. Since they have a high lipid content, partial fat separation is necessary.

Larvae are grown in containers, in which they ingest a chosen mix of organic residue material and shed skin while growing. At the end of the growing phase, larvae are separated from rearing residue, which is composed of skins, insect excrements and residual food, known as Frass. Frass can be dried and turned into pellets ready to be used as fertilizer or soil conditioner.

Once the larvae are separated from the rearing residue, a washing step removes any remaining non-larvae material. Then they are heat treated to inactivate enzymes and pathogenic microorganisms. Components like lipids or chitin can be separated in order to achieve insect fractions with a high protein content. Drying of the protein-rich fractions, results in a shelf-stable end product.

5.3 Insect processing

At present most companies are focusing on protein meal and lipid production. Since extraction needs economy of scale, the insect processing has to be done on a relatively large scale in order to be cost competitive.



A circulatory system: from insects to feed and food.

There are a number of different methods for processing insects into microbiologically safe food or feed products. They usually involve several processing steps depending on the properties of the desired end product. The high fat content in some insects such as Hermetia illucens (the black soldier fly) often requires lipid removal. Here we describe three processing methods:

The first is aqueous insect processing. Insects are first boiled in excess water after which the insect-water mixture is mechanically pressed into a cake which is then dried into an insect meal. The remaining liquid is then processed through centrifugation or decanted to remove the lipids. The soluble proteins are then recovered through concentration and drying.

The second method involves a patent initially owned by Bühler's partner company Protix that is currently being transferred to Bühler. In this method the insects are first squashed into a pulp through squashing or enzymatic hydrolysis. The pulp is then heated to 70 – 100 °C followed by physical separation either by centrifugation and/or decanting. The final stage involves either spray or air-drying.

The third method is the dry insect processing pathway. It is recommended to start with a precautionary decontamination process either by microwaving or steam blanching. The insects are then air-dried, the lipids removed mechanically and then the resulting press cake is ground into a defatted insect meal[12].

The aim of these processes is to deliver a raw material that is both safe and of high quality. The end product must be of consistent quality, capable of being safely stored, marketable with different fractions tailored for specific needs.

Insects are known as food in about 80 % of the world's nations.

6. Regulation and insect feed

The processing and storage of insects clearly need to be controlled by similar types of health and sanitation standards that govern more traditional feed items. The biological nature of insects pose additional food safety concerns, in particular around microbial safety and toxicity.

Europe is considered to have the tightest legislative controls on the use of insect protein. Lipids (fats) are not subject to the same regulatory controls as insect protein. Under existing laws aquaculture is the only agricultural sector able to use insect protein at the moment, thanks to the European Commission permitting the use of insect protein as fish feed in July 2017. The unlocking of EU Regulation 2017/893 follows a vote by EU Member States in December 2016[13]. Earlier this year the industry received another boost when EU Health and Food Safety Commissioner Vytenis Andriukaitis told the world's first insect feed and food conference that the Commission was looking to authorize the use of insect feed for poultry and possibly pigs by 2020.

The current authorization is limited to seven species with controls in place on what they can be fed. The species are: Black Soldier Fly, Common Housefly, Yellow Mealworm, Lesser Mealworm, House Cricket, Branded Cricket and Field Cricket. Under the regulation these insects need to have been fed on "feed grade" substrates such as vegetal origin materials or with a limited number of animal origin materials including: fishmeal, blood products from non-ruminants, egg and egg products, milk and milk-based products, honey and rendered fats.

China has an established regulatory framework that is seen as more favorable towards insect processors than Europe, as well as having a large enough internal market to make it easier to achieve the economies of scale needed to make insect protein production viable.

Never the less, a clear and comprehensive legal framework at both national and international levels is going to be needed if the sector is to attract serious investment leading to the full development of an international trade in insect based animal feed products on an industrial scale.

7. The insect feed market

Startups have so far dominated what is a young industry. However, as the industry starts to mature there are signs that companies are specializing. Businesses involved in all aspects of production are now focusing on specific sectors such as insect breeding, processing, technological solutions or sales. Larger companies are also recognizing insects to be an emerging commercial opportunity.

Companies who handle large quantities of organic waste and feed producers are exploring the new commercial opportunities opening up thanks to technological advances. The ability to recover 70 per cent of protein from organic by-products has caught the interest of food processors, waste companies and government agencies responsible for processing waste. In the past, waste to energy and composting have been the two most common destinations for organic waste streams. Insects are now providing new opportunities to recycle organic waste into the food value chain.

Feed producers are also showing an interest in the insect sector. Historically vulnerable to price fluctuations, especially if they have to import their raw materials, feed producers are also watching demand for plant protein increase as meat consumption rises. In their search for alternative protein sources insects are being seen as an increasingly viable alternative.

Insect feed products are currently expensive due to a lack of economies of scale along with relatively high production costs. Unable to compete directly with more traditional animal feed producers, companies are carving out niche markets for themselves. These include live insects as feed for egg producing poultry or protein meal for hypoallergenic dog food. Lipids from insects are also being used in the pig industry to reduce diarrhea in young pigs. Another potential market for insect producers is as a biological fertilizer to meet rising demand for alternatives to chemical usage.

The high price of fishmeal has resulted in aquaculture being one of the earlier adopters of insect protein. "At the moment companies are relying on their niche markets and it is only when production levels increase that they will be able to better compete and the market will open up. The area this is likely to happen first is in aquaculture and once we see growth here then the industry will start to expand faster than it can at the moment," explains Baumann.

Companies currently rely on licenses and patents to protect their market position. The question is how these businesses will evolve into the high-volume low-cost producers that they need to become if they are to compete with more traditional feed producers.

This will depend on whether insect protein producers will be able to convince the wider market, by operating on lower margins, that insect protein is commercially viable. It is already proven that the basic nutritional composition of insect feed product is comparable to more traditional alternatives. However, insect producers will have to demonstrate that insect protein can provide improved performance, whether through higher survival rates or better animal health. The insect industry also has an interesting story to tell when it comes to the environment and sustainability. The question is whether it can leverage this enough with consumers to give itself a competitive advantage over more traditional feed raw materials.

8. Current challenges

One of the biggest challenges facing insect feed producers is the scale of the existing animal feed industry and the typical quantities of feed ingredients required by clients. A feed stock manufacturer will regularly process millions of tons of feed in a highly industrial process. With that comes the sort of economies of scale that a fledgling industry cannot hope to compete with. An insect feed producer who can produce a ton of high quality insect meal will have little impact on the market.

Production constraints are also a problem for the producer. “At present there are only a few insect protein producers who can produce reasonable amounts of product and the costs are still relatively high,” explains Baumann. “But in order to serve larger feed producers, at least 1000 tons of insect protein need to be available per year, otherwise there is no chance to penetrate the feed market.”

Economies of scale are not just about volumes. The insect producers also need to scale up in order to prove their reliability so that consumers can be confident about product quality, consistency and safety.

Since insects are grown on industrial byproducts and sometimes even waste, it needs clear standards in order to mitigate feed safety risk. As the industry grows, systems such as Hazard Analysis Critical Control Point (HACCP) will need to be developed as well as higher standards put in place around existing certifications such as GMP+ and SecureFeed.

The insect feed industry is developing fast. It is attracting increased investment as demand for meat protein rises and awareness grows about the environmental benefits of insect protein. However, this speed of growth is creating its own challenges. New industries normally have the advantage of being able to evolve steadily as academics, technology providers, consultants and researchers develop the required in-depth knowledge. In the case of insect feed it is the insect producers who are at the vanguard of research, which is both challenging and time consuming. A lack of published research on the benefits of insect protein is making potential buyers reluctant to take the plunge while producers struggle to position their products effectively in the market.

Regulatory bodies are also struggling to keep pace with the industry. There is currently a lack of consistency as different regions respond differently to potential risks. Australia, for example, is very concerned about bio-security and so has very strict rules on importing live insects with companies needing approval to bring in insect-derived feed products. Therefore, it will need more regulatory cohesion to make it easier for companies to expand geographically and to facilitate international trade of insect-based products.

9. Conclusion

Alternative protein is an exciting new industry, born of concerns around an anticipated global protein shortfall as the world population rises and the aspirations of developing countries mature. Out of the various sources of new protein available, insects look the most viable due to their high protein content and low environmental impact. Aquaculture is at the vanguard of change due to the already high price of fishmeal and strong environmental pressure to improve the sustainability of already threatened fish stocks.

However, the insect industry has yet to develop specific applications for their products by elaborating key benefits in the animal feed market. The penetration of the very well established feed industry with tight margins is only possible by establishing strong economies of scale. Young companies are breaking into the market with niche products but it is yet to be seen how the sector is able to mature to the point where it poses a real threat to traditional feed ingredients.

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* Infographics by Daniel Röttele: p.3, p.6, p.7, p.8

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