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Insect-based protein and oil

By Franck Ducharne

The realities in the development as a new and sustainable alternative source of raw material for the compound feed industry.

With a global mean consumption of seafood per capita rising, the aquaculture industry will have to increase its production by at least 50% by 2050 to meet the foreseen demand of a growing population. Fishmeal, which is considered as one of the best protein source for feed formulation, is unfortunately limited and its production will unlikely improve as such natural resources are already considered as exploited at their maximum.

The feed industry in its entirety has already made important changes during the past decades where fishmeal use in livestock feed was drastically reduced to the benefit of plant-based products. In aquaculture important efforts have been achieved as well and plant-based feedstuff inclusion rates have increased significantly even for feeding carnivorous species. It is unlikely that fishmeal will disappear in aquafeed formulations but its inclusion rate will further decrease and optimization of its use will occur.

The need of fishmeal substitution will benefit primarily plant-based feedstuffs and will stimulate development of other alternatives with a strong focus on sustainability in production and price. Increasing competition will occur within the feed industry when livestock production is expected to double by 2050.

More supply of plant crops can be achieved by expanding cultivated land and increasing yields. This evolution will have, nevertheless, to overcome a certain number of stumbling blocks such as competition with forest and biodiversity conservation programs and urbanization for land access, competition with non-food crops and increasing water access concerns in some regions and soil degradation.

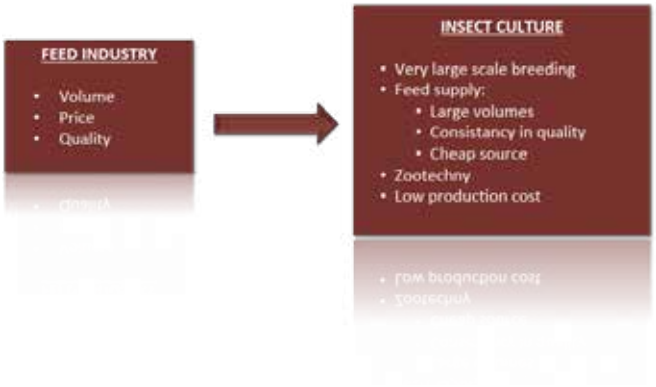
Apart from plant-based materials various new options are under development. Insect-based products recently gained growing interest among public institutions (concretized by different research programs) and private entrepreneurs. Insects, which are naturally a key source of feed for a large part of terrestrial vertebrates and fishes, are also widely consumed by humans all over the world. Therefore, mastering insect mass-culture will become a new alternative for food and feed security.

The asset of insects

Insects are the largest group of animals on the planet; they are present in all biotopes and offer a limitless possibility of feeding regimes, profiles and farming capacity. Insects can handle extremely high density, enabling very high yields and hence requiring less culture areas. Insects can be extremely efficient in converting food with very low feed conversion rate (FCR). Insects present a large choice of detritivorous species, offering great potential for feed security solutions where cost is a critical point.

Insect oil

Figure 1 *Stumbling blocks for insects mass-culture development supplying alternative source of protein and oil for the feed industry*



We have to keep in mind that for whatever solution developed, the key factors which have to be achieved to enable a new product to enter into the commercial feed industry are volume, price and quality.

Volume

It all starts with availability and consistency. The first thing the feed mill will ask is what volume can you supply. Globally, the compound feed industry is huge and hence requires volume. At a local scale, even a small mill will produce at least 10 to 20,000 tonnes of feed per year. Therefore, even considering a low inclusion rate of 5 to 10% would mean between 500 to 2,000 tonnes of product required for one single mill. So to become a reality as a new and recognized ingredient by the industry, large volumes have to be available on a year-round basis.

This will translate to the need for a very strong technical expertise on the insect species to breed and to produce a very large population on a consistent basis. Insects are generally small in size. With the chosen species, an average weight of around 100 mg at harvest and with a 60% moisture content of live animals will mean for each tonne of dry meal, 18 million individuals will be required.

Price

Large scale insect farming can end up as a costly industry. As with any other livestock/aquaculture activity, integrated systems are required including breeding unit, nursery, grow-out and processing plants.

However, at the end of the day, the market price must remain within the range of commodities commonly used by the industry, the upper limit being the best ingredient: the fishmeal. Beyond this, insect-based meal will remain an anecdotic issue and may not become a standard raw material This can be achieved with large-scale operations, strong

zootechnical support and access to a cheap source of feed. This latter point will be the main prerequisite for the success of this new industry.

Quality

Quality is of course among the most critical points when it comes to formulation. Insect nutritional profile varies from species, stage of development and feeding regime. Therefore, the first thing to do is to focus on species with a profile that suits the industry and cultured animals. For livestock and freshwater species, insects are/were originally among their natural alimentary bolus, hence insect meal and oil should match the species requirement. For seawater species, or species which are not necessarily insectivores, a limitation can come with chitin content (problematic for species which do not possess the enzyme chitinase). Other concerns will also come from the limited concentration of PUFA (poly unsaturated fatty acids) and particularly EPA (eicosapentaenoic acid) and DHA (docosapentaenoic acid) as insects are terrestrial animals.

However, these points are not limitations and the industry will adapt and develop solutions as it did and still do when replacing fish meal with plant-based products in aquaculture feeds. Several laboratory studies have been conducted on partial fishmeal substitution with insect meal with good success. With the insect species raised in our operation, trials were conducted by different institutions on species such as rainbow trout, turbot, tilapia and catfish.

Business model for mass culture

The Entofood team has been working since 2010 in developing a business model for insect mass culture to match these requirements. In species selection, different species were studied initially to select the most appropriate one for the purpose of feed security. Criteria of choice were based on the following variables:

- Type of development: preferably holometabolous species which will have low chitin content in the larval stages and which can accumulate high concentration of protein and fat to enable metamorphosis into adult
- Fecundity: due to the very large population required to commit to significant volume of production, this is a critical variable to take into account,
- Growth: fast growth and short life-cycle is targeted to optimize output, and FCR.
- Size: the larger the size the lesser population required
- Feeding regime: as mentioned previously, one of the main criteria for developing this new source of protein/fat for the industry is to become sustainable in price first but also environmentally friendly. It is not recommended, therefore, to aim at any species fed with raw materials which could be used directly by humans or livestock. Focus must be placed on detritivorous species and/or species which could be fed on non-edible products and organic side-streams. This principle is based on the fact that massive amounts of food are being wasted along the supply chain and which a recent UN report estimated at 30%, the amount of food wasted globally per year. This represents a limitless source of valuable nutrients which can be re-introduced into the food chain by the action of detritivores. Eventually, when it comes to economics, to be able to become a reality the insect culture industry must have access to cheap feed.

The species presently selected is a Diptera from the *Stratiomyidae* family: *Hermetia illucens*, or commonly known as black soldier fly. Larvae are performing detritivorous and can reach quite a large mean

Defatted insect meal

size at the end of their development (200 mg). Entofood has been raising this species for more than 3 years and has worked to master and improve its zootechny. This long development process is a prerequisite to guarantee upscaling of the operation to commercial level in total confidence, where strong information is acquired and technical and economic forecasts are based on a strong factual data base.

Since 2012 Entofood has built a pilot farm in Malaysia to prepare the groundwork for large-scale development. Over 1,000 production cycles were conducted so far and 2 billion eggs produced. Growth and FCR have significantly improved to enable a complete grow-out cycle in a week, FCR lesser than 1:1 and yield achieved in grow-out exceed 5,000 tonnes/ha per year.

The insect biomass is raised on food wastes which are traceable and collected on a daily basis and fed that same day. Specific feeding regimes and feeding rates have been developed over the years to optimize performance of the larvae which will convert the food in a few hours. This choice of production model enables the production of a very sustainable product with high nutritional profiles. The insect meal is produced from larvae which are harvested upon completion of development, and takes less than a week in grow-out ponds. Larvae accumulate protein and fats which result in a high concentration of protein and fat and low chitin (3% in whole meal).

This species presents the characteristic of being extremely rich in fat with a protein:fat ranging between 75 to 80% (basically 50-50% protein-fat). The very high fat content makes the finished product not easy to process and limits significantly the inclusion rate in aquafeeds. Therefore defatting process was developed to improve the quality of the product. Non- chemical process (solvent) was chosen to do so.

Table 1: proximate analysis whole meal vs defatted meal (% of sample). Source Entofood

Species	Protein	Fat	Ash	Fiber	Moisture
Hermetia illucens	40.4	39.1	6.4	4.2	5.3
Hermetia illucens	57.3	13.9	8.7	6.6	8.0

The meal produced from soldier fly has been tested by different research institutions over the years ascertaining the great potential of this product as a solution to fishmeal substitution. Trials have been carried out on rainbow trout, tilapia and turbot. The EU has launched an ongoing research program on insects as feed. It was reported recently in Chile that feed trials will be launched on salmon fingerlings.

However, to enter in commercial feeds formulation, more applied trials are needed to gather confidence and know-how on this raw material. Entofood is presently preparing a series of trials in partnership with the industry on a wide range of species (shrimp and fish) to gather information on best inclusion rates of the defatted insect meal and insect oil in feed formulation.

Table 2: Amino acid profile, HI defatted. Source Entofood

Aspartic acid	%	5.48
Serine	%	2.50
Glutamin acid	%	7.21
Glycine	%	2.94
Histidine	%	2.1
Arginine	%	3.27
Threonine	%	2.39
Alanine	%	4.02
Proline	%	3.49
Cystine	%	0.29
Tyrosine	%	3.89
Valine	%	3.85
Methionine	%	1.18
Lysine	%	3.53
Isoleucine	%	2.86
Leucine	%	4.11
Phenylalanine	%	2.51
Tryptophane	%	3.12
Taurine	mg/kg	1.72

Table 3: Summary fatty acid profile. HI oil. Source Entofood

Fatty acids	% relative fat
Total omega-3	1.8
Total omega-6	13.0
Total trans fat	0.3
Saturated fatty acids	57.6
Monounsatutated fatty acids (MUFA)	27.2
Polyunsaturated fatty acids (PUFA)	15.2

This work will enable it to elaborate commercial formulations while constructing the first industrial operation. Entofood intends to start its first production module in 2015 with a targeted output of 3,000 tonnes of defatted meal and 1,000 tonnes of oil. From there other modules will be built based on demand. The model developed by Entofood will enable to put on the market, a sustainable supply of a highly sustainable product at competitive price- in other words, within the range of other commodity products.

Further investigations will have to be conducted to ascertain whether there are some yet un-identified benefits that are found in insect meal (functionality characteristics).

Franck Ducarne is CEO of Entofood Sdn Bhd. After 16 years working in shrimp farming industry, Ducarne founded Entofood with his partner Frederic Viala in 2010. Entofood is now based in Malaysia.