Insect production
Nutrition - Applications
New industries

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Proceedings

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Introduction

At the opening of the symposium, Paul Vantomme, Senior Forestry Officer of FAO (Food and Agriculture Organization) reminds of the necessity to find a solution to feed the planet, whose population should reach 9 billion in 2050. In fact, the increase in animal protein demand implies an increase in cereal production needed to feed livestock. Livestock consume, nowadays, 1/3 of the world cereal production and compete with human food. In parallel, there is a boom in aquaculture, especially in Asia, and according to FAO, 60% of fish consumption in 2030 will come from aquaculture (Sylvaine Poret, INRA). Reared fishes are fed with flour of wild fish species although the overfishing impoverishes the ocean, and soybeans, whose plantations lead to deforestation. Insects are, therefore, an ideal solution to replace a part of meat consumption in human diet, as well as in substituting the fish flours and soybean in fish diet and the cereals in pig and poultry diet. Insects are very rich in proteins (60%), they have short life cycles with a rapid growth and they are capable of bio-conversion (Franck Launay). However, is insect rearing a sustainable solution? This is what the different speakers of the symposium Insectinov 2 tried to answer and several propositions have been put forward to try to overcome the current constraints of the sector, concerning the legislation, the rearing technology and the economic and environmental sustainability.

Insectinov2 gathered 200 participants from 20 different countries and belonging to both public and private sector (Figure 1).

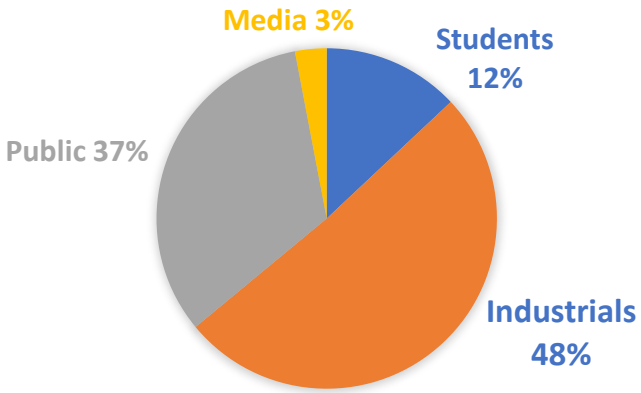

Figure 1: Distribution by type of organization

After the first symposium Insectinov in 2014, a real insect industry has been created in France, and in Europe, with the creation of IPIFF (International Platform of Insects for Food and Feed) in 2015, headed by Antoine Hubert (Ynsect), who is the actual president. This platform regroups 14 countries and 42 companies and facilitates the dialogue between the public authorities of European Union and the actors of the insect industry.

Overview table of the symposium content

Table 1 : Summary of constraints/challenges of the insect industry and the propositions discussed at the Insectinov2 symposium.

	Constraints/Challenges	Propositions
Legislation **Sections** **2.1/** **3.1** **Tables** **1, 2, 3**	The French government does not recognize enough the insect industry	Dialog with the elected entities
		Integrate insects into the French National Food Conference
	Application of the Novel Food Law is different according to the countries of the European Union	IPIFF calls on European institutions to uniform the law application across the countries
	Prohibition on the use of waste and excrement to feed insect larvae	Increase scientific research on health security at European level; Take as examples other countries
	Insect flour is considered in the transformed animal proteins (PAT) and is prohibited in pig and chicken feed	Find a mean to distinguish between insect flour and other PAT by control measures, and allow only insect flour
	French fish farm market still closed to PAT	Inform and convince
Health security **Sections** **1.4/ 2.3/ 3.3**	Lack of knowledge about pathogens transmitted by insects and diagnostic of diseases in insect rearing	Increase scientific research
		Apply the principle of biosecurity in companies
Rearing techniques and technology **Sections** **1.2/ 1.3/** **2.2/** **3.2/ 3.4**	Improve the digestibility of insect flour	More efficient processes to transform the insects into flour
		Extract chitin, but expensive and pollutant
	Variable protein content of insects	Research on substrate types
	Insect cannibalism	Genetic selection

	Insect reproduction	Lamps that accelerate flies' reproduction (in China)
	Avoid contamination	Filter air and water entering and leaving the rearing facilities
	An expensive labour	Automatization of the rearing
Environmental sustainability **Sections 1.1/ 2.3/ 3.2/ 3.4**	Rearing ventilation is costly in energy	Green energies or biomimicry
	Insect substrate compete with pig and cattle feed	Value food waste
		Use animal manure, but attention to the competition with the methanation process
		Insects to degrade plastic and polystyrene?
	Pollutant transport of co-products or waste intended to the substrate of insect rearing	Industry fragmentation to bring closer the larvae fattening and the raw materials used as substrates
		Increase research on the potential of using the substrate digested by insects as a green fertiliser in agriculture
Economic sustainability **Sections 2.4/ 3.4**	Price of insect flour too expensive: must be reduced to the price of fish flour	Value co-products (chitin, peptides, oil, fertilizer)
		Automatization of the rearing
Social acceptability **Section 2.5**	Cultural barrier, disgust	Integrate the topic "edible insects" in teaching programs
		Make accessible insect consumption by creating basic products and lower prices
	Afraid that insect farms are not healthy	Ask for ISO 22000 certification (as Micronutris for example)

	Modification of the colour and taste of trout flesh fed with insects	Inform consumers

1 Advances in academic research and industrial progresses

1.1) Insect rearing as a solution to environmental and social problems

One third of the world cereal production (soybean and corn) nowadays aims at feeding livestock for human consumption and, in 2050, this proportion will increase to half due to the increasing in animal protein demand. The need for arable lands will be ca. 500 000 ha per year, amplifying environmental damages such as deforestation in the Amazon, Brazil, for soybean production (P. Vantomme, FAO, personal communication). Moreover, mammals are animals of warm blood that use at least 30% of their energy, produced by feeding, to regulate their body temperature. Insects as animals of cold blood do not need to spend their energy in temperature regulation, and are therefore much more efficient in converting food into proteins. Paul Vantomme also highlights the fact that insects consume five times less food than the cow and three times less than the pig to produce the same amount of protein. Insect farms enable, as well, a more efficient bioconversion of plant by-products and the excrements from their activity can also be used as a green fertiliser in agriculture. In addition, insect flour can replace fish flour because it contains as much protein and thus avoid overfishing (Paul Vantomme).

From a social point of view, the rearing of insects, traditionally consumed by one quarter of the worldwide population (FAO), is accessible to the countries in development and can reinforce local economy. Hence, several projects have been set up such as the rearing of crickets in Benin presented by Melanie Ramnuth or the production of larvae of palm weevils in Cameroon, supported by the Research Institute for Development (IRD).

1.2) Which insects do we rear and how?

Since July 1st 2017, the European law allows insect flour in the diet of farmed fishes, and the rearing of insects is now in full development. Two species are mainly reared for animal feed, the larvae of the black soldier fly, *Hermetia illucens* and the mealworms, *Tenebrio molitor*. The latter is also reared for human consumption in addition to crickets and locusts (*Table 2*). The main challenges concerning this new form of rearing concerns the legislation and health risk, the choice of substrates used as insect food, the genetic selection of reared species, the techniques of reproduction and the management of the temperature inside the rearing, and finally insect mass production.

Table 2: Summary of the major insect species reared, their rearing substrates and their destination

Which insect?	Which rearing substrate?	Which destination?
Black soldier fly larvae: *Hermetia illucens*	- Wet vegetable co-products* - Wet organic waste or animal excrements**	Animal diet: -Aquaculture* -Pets and zoos* -chickens and pigs**
Mealworms or flour worms: *Tenebrio molitor*	-Cereals* - Dry vegetable co-products * - Dry organic waste **	Animal diet: -Aquaculture* -Pets and zoos* -chickens and pigs** Human diet***
Locusts, crickets, grasshoppers	-Dry and wet vegetables* -Cereals* - Dry vegetable co-products or slightly wet* - Dry organic waste or slightly wet**	Animal diet: -Pets and zoos* Human diet***
*Authorized in Europe ** Non-authorized in Europe *** Non-authorized in Europe according to the Novel Food Law, but authorized in some countries as Belgium, the Netherlands, United Kingdom, Finland, and Switzerland.		

1.3) Insects in human and animal nutrition

Human food: Insect proteins as ingredients

Insects have a high nutritional intake being naturally rich in protein (60%), as well as in iron, magnesium, phosphorous, calcium, vitamin B et C (Micronutris). Once isolated, insect proteins can be used as a novel food ingredient. Samir Mezdour, AgroParisTech, shows that mealworm proteins have foaming properties like milk proteins. Camille Loupiac and PCAV's team from the UMR PAM show that insect proteins are also soluble in water as the proteins from milk or meat. Nevertheless, above 90°C, these proteins lose their solubility and it is therefore necessary to pay attention to the processes used to transform insect larvae into flour or protein extracts.

Animal feed: processes from insect larvae to flour

Nowadays, mealworms and larvae of the black soldier fly are defatted before they are grounded into flour. Samir Mezdour described the process used during the tests carried out within the DESIRABLE project (ANR funding) that started in January 2013. Larvae are washed, cooked (blanched) and then pressed to extract the oil. The solid part is then dried and grounded to produce the flour. Why should the flour be defatted? There is a double advantage: lipid extraction increases the protein concentration of insect flour and thus approaches to that of fish flours, which are currently used as the main food source in aquaculture. In addition, drying defatted flour consumes less energy than non-defatted one.

Christine Burel and Michel Lessire, INRA, have studied the digestibility of insect flour by trout and chicken and tested this effect in animal growth. The results show that fishes digest as well a meal containing insect flour (mealworms or black soldier fly larvae) as a meal of fish flour, with the condition that the proportion of insect flour does not exceed 15% of the total content. The digestibility of the black soldier fly larvae flour was higher or equal to that of soybeans for chickens, while the digestibility of mealworm flour was equal to fish flour for trout. Finally, although the results show a better digestibility of the insect flour after extraction of the chitin, the digestibility remains correct without its extraction.

In another experiment conducted by the R&D department of InnovaFeed, fishes were fed with pellets containing 30% insect flour. The results show that the digestibility of the black soldier fly larvae flour by the bar or the trout is high (87-91%) unlike flours of plant origin, such as soybean. Fish flours prepared at low temperature were better digested by fishes, but they are more expensive. In addition, most fish flours used in aquaculture are made from fishes caught in the Pacific, which generates a strong carbon footprint.

1.4) Research concerning insect health and health security

Knowledge is improving in the field of insect diseases and it is essential that the academy and the governments allocate a budget to this crucial research. According to the veterinarian Claire Beauvais, although insect-specific diseases are rarely transmissible to mammals, they carry pathogens from their environment. Companies must therefore apply the principles of biosecurity, already applied in other rearing industries: no pathogen should enter insect farms, which must be compartmentalized to prevent possible contamination. The rearing facilities must be well ventilated, cleaned and disinfected and diseased animals should be separated from the rest of the rearing. Nevertheless, INRA scientist Christina Nielsen-Leroux showed that larvae of the black soldier fly have a better growth on a substrate in which some bacteria are found, and that are then transformed and eliminated by larvae.

From October 2015, ANSES (National Agency for Food Sanitary Safety, Environment and Labour) and EFSA (European Food Safety Authority) asked to define a framework specific to insect production and rearing conditions. Following these calls, several research projects at European and national level such as inVALUABLE (Denmark), inDIRECT (Belgium) and DESIRABLE (ANR, France) aim at increasing scientific knowledge regarding health risks. One of the risks concerning animal flours, called Transformed Animal Protein (PAT), is that they are at the origin of prions (pathogenic proteins) and are responsible for example for the mad cow disease. In the framework of the DESIRABLE project, Jean-Philippe Deslys, from the CEA, presented the results concerning the study of the health risks involved in the

process of rearing to flour production in insect bio-refineries. This research will allow developing methods of insect flour detection to distinguish them from conventional PAT (animal carcasses) and introduce them in livestock feed.

How to diagnose the health of reared insects? Metagenomics is a very effective tool, says Mylène Ogliastro, of the DGIMI UMR in Montpellier. This tool is used to detect insect viruses and to identify and understand the viral diversity and prevalence in insect populations. The researcher also encourages the scientific community to study the risks of transmission of insect viruses to humans. Jorgen Eilenberg, University of Copenhagen, Denmark, is also working to establish diagnoses for the different species of reared insects[1] and has compiled a list of diseases already observed in insect farms by conducting surveys in about 30 companies. The results are then studied within the framework of the European collaboration network Insectpath, bringing together companies and scientists around the subject.

Some applied research programs have also been implemented by the private sector, as for example the CertiFLY project of MUTATEC. In collaboration between various partners, this project aims to develop a protocol for assessing health risks related to the production and consumption of insects, such as *Hermetia illucens*.

Finally, concerning allergenic risks in human nutrition, Justine Courtois, from the University of Liège, presents the results from her research and collaborators, on which they show that individuals allergic to shrimps and mites have also an allergic reaction to crickets. Preliminary results show that these arthropods share the same allergenic protein, which remains however to be identified.

1 https://www.researchgate.net/profile/Jorgen_Eilenberg/publication/273499752_Diseases_in_insects_produced_for_food_and_feed/links/553d40510cf2c415bb0f5a4f/Diseases-in-insects-produced-for-food-and-feed.pdf

2 – Main constraints and industry initiatives to lift them

2.1) Legislative constraints: What to understand?

Animal nutrition

Animal flours, PATs, are banned in animal feed since the mad cow crisis. Nevertheless, PATs from non-ruminant animals are already authorized for feeding of farmed fishes, which allowed the authorization of the use of insect flours in aquaculture. However, it is still forbidden to give insect flours to pigs and poultry. The legislation is so strict that Michel Lessire, INRA, has been prohibited to test insect-fed chicken in consumers during an experiment he presented at the symposium. According to Brigitte Heidemann, DGAL, the solution would be to find a method to distinguish between insect flours and other animal flours

Human nutrition

The European regulation Novel Food prohibits the commercialization of food that was not consumed in the European Union before 1997, without obtaining a special authorization issued only through a dossier of risk management. This law was revised in 2015 labelling clearly "whole insects and their products" as novel food, which removes the legal uncertainty. The law will become effective in January 2018 and concerns all countries of the European Union. Nevertheless, some countries of the European Union have legally authorized the marketing of some insect species before the revision of the "Novel Food" law. This is the case of Belgium, the Netherlands, the United Kingdom and Finland. Companies already commercializing insects in these countries have then a period of two years to present the dossier of risk management while continuing their activity. As France did not established a law authorizing insect commercialization in its territory, French companies should then adapt to the new law by January 2018 and thus suspend their activity during the authorization procedure.

Table 3: Summary of the current legislation.

Domain	Subject	Which regulation?
Insect rearing	Which substrates can we use to rear insects?	Regulation CE 999/2001 article 7 annex IV Regulation CE n° 183/2005
	What to do with insect excrements?	Regulation (CE) 1069/2009 Fertilisers regulation CRPM-L225
Animal nutrition	7 insect species are authorized to produce transformed animal proteins (PAT) for aquaculture and pets	Regulation (EU) n° 2017/893 Regulation 142/201, Annex X Regulation (EU) n°2017/1017
Human nutrition	Insects and their products are prohibited to commercialization without a marketing authorization	Novel Food Law: Regulation (EU) n°2015/2283, effective from January 1st 2018
	Can we import insects from other countries? Yes, if the quantity is inferior to 2kg	Regulation 206/2009

2.2) Technical and technological constraints: from the rearing to the transformed product

The control of rearing techniques remains a constraint because some insect species are difficult to reproduce and many variables influence their mating and egg laying. Cannibalism is also observed if insects do not get enough nutrients in their substrate (Jorgen Eilenberg, University of Copenhagen). Finally, although an insect farm has millions of individuals, they breed with each other and consanguinity can lead to an important loss of genetic diversity. It is therefore necessary to refresh the reared population with unrelated and external individuals.

Furthermore, solutions must be found to fully automate the rearing of insects. Sorting, cleaning and slaughtering are labour intensive, which is why the price per kilogram of insect flour is so high today. Marc Bardinal, ADEME, also emphasizes the need to control the storage and treatment of substrates since to produce 100 tons of insects, it is necessary to

use 200 tons of substrate. To avoid any contamination, an air and water filtration system should be installed in the rearing facilities (Valery Bonnet, Neu Air Moving Technologies).

Finally, the quality of insect flour obtained nowadays after processing is very variable depending on the processes used (drying temperature, grinding equipment). According to Michel Lessire, INRA, the protein composition of mealworm flour can vary between 55 and 74% and the flour digestibility by fishes and chickens is also very variable depending on the process used during transformation.

2.3) Environmental constraints: is it sustainable?

If the only products allowed as a substrate for insects are the same as those for cattle, is insect farming really a solution to the environmental problems raised by conventional farms today?

According to Jean-Philippe Deslys, CEA, larvae of the black soldier fly would be good recyclers of organic animal waste, at the PAT origin, as well as waste from agri-food industries, canteens, restaurants or supermarkets and even animal manure. All these organic substrates, once digested by insect larvae, would be distributed on agricultural lands, allowing a circular economy.

These alternative substrates are allowed in other countries such as in China. For instance, Longyu Zheng, from Huazhong University, rears *Hermetia illucens* larvae on chicken droppings and pre-treated waste. However, European legislation does not allow any of these substrates for health safety reasons. There are indeed risks of transmissions of mycotoxins via organic waste or antibiotics via animal excrements, and that is why the European project ProteInsect is studying these risks during the last two years.

The second environmental constraint concerns the energy consumption of an insect mass rearing. According to Valéry Bonnet, Neu Air Moving Technologies, ventilation and air conditioning in an insect mass rearing are essential, since they cannot regulate their internal temperature, but it consume up to 60,000 € in electricity per day. The sustainability supported by waste recycling is quickly counterbalanced by energy costs, unless companies use green energy or rethink their aeration systems by making biomimicry of existing natural structures such as termite mounds.

2.4) Economic constraints: a price too high

The price of insect flour is higher than that of fish flour. According to Philippe Schmidely, AgroParisTech, the replacement of fish flour by insect flour, in aquaculture, will only be possible if the price of insect flour is reduced about 1,500 € / tone. Solutions to reduce the cost of production of insect flour pass by the automatization of insect farms, on the one hand, in which the company Ynsect has already made some progresses, and the use of waste as insect substrates, on the other hand. Longyu Zheng, from Huazhong University, presented the results of a larvae rearing of *Hermetia illucens* that is 100% automated, larvae are fed on waste or animal excrements and are then sold as poultry and fish feed. According to this model, a farm is economically viable producing up to 50 tons of insects per day.

2.5) Social constraints: Actors acceptability in upstream and downstream industry

The acceptability of consumers, but also of breeders or elected agents is one of the big challenges of the insect industry.

According to Antoine Hubert, Ynsect, 60 to 70% of fish farmers in France still meet their own specifications for fish feed, which prohibits the use of PAT. A work on informing the associations of fish farmers is therefore urgently needed.

The results of the survey conducted by Sylvaine Poret, INRA, as part of the ANR DESIRABLE project, show that consumers are generally ready to eat trout fed with insect flour but they want safe products, without the taste of insects and labelled with the information on environmental benefits of insects.
However, Michel Lessire, INRA, highlights that trout fillets fed with pellets containing 15% insect flour (*Hermetia illucens*) are less popular for consumers than those fed with conventional pellets. In addition, the colour of the fish flesh is also modified, which can influence the consumer choice at purchase. Finally, insects are animals, and one can wonder whether scalding insects or confining millions of them in boxes is ethical (Philippe Le Gall).

Finally, both in animal and human nutrition, insects are seen with disgust, and according to Paul Vantomme, this "Yuck" factor is the first barrier to overcome and integrate insects into our food systems. To reassure the consumer, the company Micronutris took the initiative to ask for ISO 22000 certification. This international norm certifies that the company manages the risks at all steps, from rearing to insect transformation.

3- Propositions and recommendations of the industry actors for the future

3.1) Propositions for the legislative framework

Antoine Hubert, president of the IPIFF (International Platform of Insects for Food and Feed) invite actors of the industry to read the position papers concerning animal feed[2] and human food[3], including propositions for legislative issues (*Table 4*).
Currently, IPIFF is developing a guide of good hygiene practices for the insect industry and calls for EFSA to handle health safety matters and allocate a research budget to the field.

Table 4: Summary of IPIFF recommendations to European institutions.

Recommendations of the IPIFF to European institutions	
For animal feed	**For human food**
Authorize insect flours in feed of non-ruminant livestock (pigs and poultry)	Detail operations and facilitate the procedure to apply following novel food certification.
Consider and evaluate the risks of the usage of supermarket/restaurant waste as substrate for insect rearing	Clarify the law so that all EU countries are on an equal footing about the 1 year period granted to companies already commercializing insects in countries where this activity is "legally" recognized
IPIFF is committed to share with the European authorities the information concerning the sanitary safety of insect farms and their products and invites companies to prepare jointly dossiers by sharing the necessary information.	

3.2) Propositions and orientations to companies in animal feed and human food industry

Many lines of research and development remain to be explored for companies producing and commercializing insects. Thus, Patricia Le Cadre, Céréopa, invites companies to value insect by-products such as oils in the food and cosmetic industry, biomolecules in the chemical and pharmaceutical industry, and organic materials as fertilizers and thermal insulation (Gregory Louis, Entomo Farm). Research should also be conducted on the rearing substrate. For instance, caterpillars of the wax moth can digest the plastic[2], and the mealworms, the polystyrene[3] (Philippe Le Gall). Finally, rearing techniques remain to be innovated and improved. In China, for example, special lamps are used to accelerate the reproduction of *Hermetia illucens* flies (Longyu Zheng).

Funding opportunities exist also in the insect sector. The French Environment and Energy Management Agency (ADEME) launches numerous calls for projects concerning eco-

[2] https://www.sciencedirect.com/science/article/pii/S0960982217302312
[3] https://www.scientific.net/AMR.113-116.1972

efficient industry and agriculture and circular economy, and BPI France also offers support for innovation to which several companies in the sector have already benefited from.

Finally, the biggest market of aquaculture in the future will be Asia, and especially China. The new start-ups for fish feed based on insect products have all interest in including in their business plan an opening to this region of the world (Patricia Le Cadre).

3.3) The urgent need for scientific research

Frédéric Marion-Poll, AgroParisTech professor, reminds that the insects we rear today are not those that are generally studied, such as Drosophila or bees. The scientific community must therefore mobilize to increase knowledge on farmed insects for animal feed and human food. He also adds that teaching at the bachelor's and master's level should include courses with the topic of edible insects.

Additionally, the management of the genetic stock of reared insects is important since one of the consequences of rearing is the reduction of genetic diversity. This loss of genetic variability can be associated with a deactivation of vital functions in insects such as the loss of natural defences in the case of bees, for example. Nevertheless, Frédéric Marion-Poll suggests that it can be interesting to select genetic traits that can improve taste or nutritional value, and in the longer term, lead to a better domestication: more docile insects, with reduced flying capacity, easy to reproduce, without cannibalism, non-toxic, and with small risk of escaping to avoid invasive species. Moreover, the genetic selection of insects can occur rapidly since they have short life cycles and there are millions of individuals in a farm, unlike cows. This raises many questions, however, related to the evolution of species, for example dogs have several breeds that behave very differently, so Frédéric Marion-Poll demands in which direction the various actors of the sector expect to go with the selection of reared insects.

Knowledge on insect pathogens, including viruses, bacteria and fungi, as well as knowledge of insect resistance to these pathogens is a major health issue. Therefore, Christina Nielsen-Leroux and Mylène Ogliastro, INRA, invite colleagues to increase research in this area and for each insect they advise to identify well the substrate, in which it feeds, and its pathogens and symbionts like their gut bacteria for instance. Another challenge is to better understand the toxins produced by reared insects, such as the quinones produced by mealworm adults, which can have undesirable effects (Paul Vantomme).

Nevertheless, in case of contamination, one must be careful with the use of antibiotics in reared insects, because their gut bacteria contain probiotics that can be used in animal and human nutrition and that will be destroyed under antibiotic administration. Insects contain antimicrobial peptides (AMPs) and it will be therefore interesting to promote insects for pharmacological purposes (Paul Vantomme). Longyu Zheng, from Huazhong University, adds that insects, such as black soldier flies, have innate antimicrobial immunity and its incorporation in fish or chicken’s diet can improve their immune system, reducing the antibiotic application in the rearing of these animals.

Samir Mezdour, AgroParisTech, also encourages to increase knowledge on the properties of insect proteins to use them as ingredients in human food, as well as to mix them with other proteins to innovate agri-food industry.

3.4) Propositions and perspectives for environmental and economic sustainability

Local economy

Insects can degrade waste. It would be a shame to counterbalance this advantage by a strong environmental impact due to the transport of waste over long distances (Paul Vantomme). Thus, entrepreneurs can consider promoting short circuits, by installing the rearing facilities, for instance, close to farms and use crop derived co-products as substrates. Getting closer to the substrate source will reduce the logistic, economic and environmental impacts. Anne Deguerry, Entofood, for example, proposes a segmentation of the sector between a unit of reproduction of insects, where the eggs are produced, a unit of mass production or larvae fattening, that must be close to the farms, and transformation or industrial process. Grégory Louis, Entomo Farm, proposes also another model, in which insect eggs are given to farmers for larvae rearing and are then bought by the company.

Co-products valorization: chitin et chitosan

Insects biomass is broken down into lipids, proteins and chitin and all three have an enormous potential for marketable end-products says Leen Bastiens of VITO (Flemish Institute for Technological Research) within the European project InDIRECT. Chitin and chitosan have antibacterial and antioxidant properties, and have several applications such as in wastewater treatment, biopharmaceuticals, agriculture (seed coating, bio pesticides, and bio stimulants), as well as in bio fibres. Leen Bastiens confirms that the use of chitin can thus be a good way of insect valorization and the demand in chitin is increasing. Nevertheless, Franck Launay, IPSB, alert to the fact that entrepreneurs should pay attention to bacterial contamination in insect rearing in case they consider using chitosan for cosmetic industry. Antoine Hubert, Ynsect, however, affirms that currently companies do not extract chitin to produce their insect flour because it is economically expensive and pollutant (use of caustic soda). It is, therefore, necessary to find cheaper and more environmentally friendly solutions to eliminate chitin from insects. A less polluting way of extracting chitin in insects is to use enzymes, such as those extracted from the shell of crustaceans. However, since these enzymes are not very effective on insect cuticles, more efficient enzymes need to be found.

Environmental sustainability

France produces more plant proteins than it actual needs but lacks some specific proteins, found in rapeseed, sunflower or soybeans, says Patricia Le Cadre, Céréopa. For this reason, France imports plant proteins, for example, from Brazilian soybeans or Ukrainian sunflowers, which corresponds to 41% of the raw materials given to livestock. Questions are then raised about the dependence of farms on soybeans. Although soybeans have an important intake in amino acids and it is available in large quantities at low prices, the environmental problems underlying the use of GMOs or the deforestation for soybean plantations make the use of soy a non-sustainable resource. In addition, insect farms consume much less water than soybean plantations or animal farms[4], which seems particularly important in the future where freshwater will be a scarce and limiting resource[5]. However, global soy protein production in 2016 was 100 million tonnes, while insect protein

4 https://www.researchgate.net/publication/283624505_Mealworms_for_Food_A_Water_Footprint_Perspective

5 http://www.fao.org/docrep/018/i3253e/i3253e00.htm

forecasted for 2025 is only 1.4 million tonnes, so very small compared to soy protein. Patricia Le Cadre argued that wishing to replace soybeans by insects is a utopia.

Conclusion

The actors in the insect production industry are becoming more and more numerous and the subject is even starting to interest equipment manufacturers, such as Flottweg, Haarslev and HF group, all present at the Insectinov2 symposium. This symposium also initiated partnerships between the actors present, as Entomo Farm and Ovalie innovation[6].

Marc Bardinal, ADEME, summarizes well the determinants of the success of this industry: minimize the health risks, reduce the environmental impacts and lift the cultural constraints. On this last point, few days later after the symposium, an agreement was signed between the company InnovaFeed and Auchan to launch a range of fish fed by insects[7]. In this way, insects come closer to the plate of consumers. Several research projects are also undergoing at European and national level such as inDIRECT (Belgium), inVALUABLE (Denmark) and DESIRABLE (ANR, France). These projects aim in increasing scientific knowledge to create a sustainable and efficient industry to produce insect-based animal proteins.

Finally, over the 2000 insect species consumed by humans worldwide, corresponding to 0,2 % of all insect diversity existing in the planet, only ca. 10 species are currently reared in the west, such as the house cricket, the short-winged cricket, the silkworm, the migratory locust, the mealworm and the black soldier fly etc. The potential is therefore enormous and Philippe le Gall encourages entrepreneurs and researchers to consider rearing more species.

[6] https://presselib.com/lentomologie-service-de-lagriculture-partenariat-a-ete-signe-entre-ovalie-innovation-filiale-rd-de-maisadour-vivadour-start-up/
[7] https://www.auchan-retail.com/uploads/files/modules/articles/1508331801_59e751193843f.pdf