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POTENTIAL OF INDUSTRIAL SIDE STREAMS IN INSECT PRODUCTION

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ABSTRACT

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Potential of industrial side streams in insect production

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The purpose of this thesis was to study potential of industrial side streams in insect production as the rate at which insect eating is gaining grounds in Europe, especially in Finland. The changing laws and standards in Europe were analyzed by reading the literatures and comparing with other countries situation. These show that the acceptability of insect eating is growing quickly nowadays, which increases the growing of new insect industry.

The thesis is done by interviewing the manager of one of the current insect company in Finland. Studying both insect production and side stream, also mapping is used when comes to the result analysis in discussion.

The results of the study show that food industry is continually producing lots of side streams for the globe, and now it is possible to use the side streams to feed insect, which could decrease pollution of the global environment. There is also a chance to reuse the materials to achieve certain sustainable development and participate in the chain of circular economy.

On the basis of the results of this research, it can be concluded that there is a lot potential of using industrial side stream for insect production.

Key words: insect industry, side streams, sustainable food production

CONTENTS

1 INTRODUCTION

Insects play an important role in nature. Sometimes, it can be used as indicator for the environment, but in another way, human can also use it in a special way as food source or even feed other animals.

Actually, we live in the world of insects, not the world of human. Nobody can be sure about the total number of insect species and individuals, only some guess of even more than a few trillion million (Shelomi 2013), as we cannot even get the precise data of it from a small single unit. The measurement from different areas in different soil situation was totally different, they are also influenced by the season and time. (Lundy 2015)

This is not only a theoretical thinking, there were already 2111 species that considered as edible from the newest list, and about 1900 species eaten by people now in the world (Lundy 2015). The common use one is just gryllidae, which people usually known as crickets because of the multiple use and high acceptability for them. The situation of population looks like the plan of reducing birth rates has been slower than expected, which shows 1000 million people will be born during this decade. (Sadik 1991) As the increasing population on the earth, the pressure from the crop leads the using of "innovative" food, for example, insect.

At this point, trying to find out the potential of industrial side streams in insect production is a new thing. Insect production can be done by reusing and recycling industrial food waste. Not only simple food waste, but also GHS emission that are created by food production every day. Some insect species almost eat everything and then transfer even the "garbage" input to useful protein in their body. To benefit the whole supply line connected with other industry also, the thinking of improving feed for insects is absolutely necessary.

The reason of studying industrial side streams is to find a possible way to use the pollution as potential input for other industry like insect production, this thought of reusing and recycling method will benefit the both sides and encourage the development of new

insect companies in the future. For this purpose, reviewing of literature and interviewing of manager from insect company in Finland is done to help with the research process.

This thesis is written for Finsect Oy to study the potential of industrial side stream for insect production.

2 INSECTS AS FOOD

Edible insect as a specific objective, is considered to use side streams from other industry as feed. To achieve this goal, there are some topics need to be thought about.

Cricket, the most common type of insect for eating and also the most acceptable one for people. Common in Mexico, Thailand and Cambodia. No matter use as food addictive or directly meal, crickets are always the top one choice. It almost eats everything and produce high percentage of protein from their small size body, which is a common edible insect that easily consider for production nowadays.

Eating insects is a culture in some countries but in EU, it just started to be accepted recently. Here is a list of insect species which were reported to have the biggest potential to be used as food and feed in the EU in 2015 by Evira (2018) (The list on permitted species might be further updated if evidence or notifications become available on other species.):

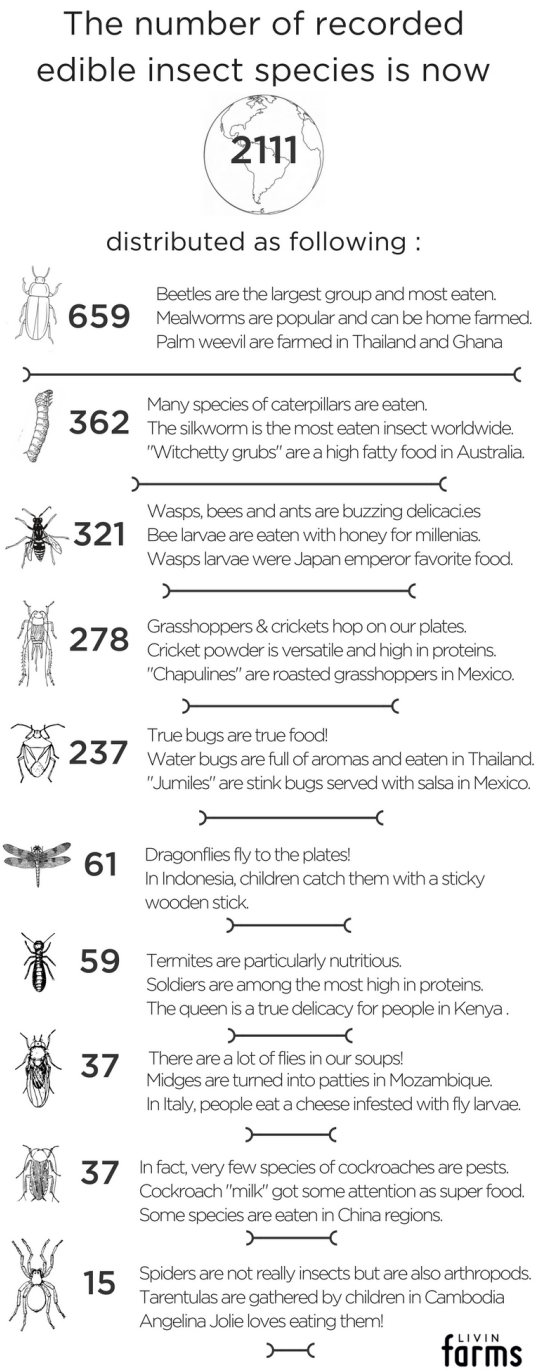
- Common housefly (*Musca domestica*)
- Black soldier fly (*Hermetia illucens*)
- Mealworm (*Tenebrio molitor*)
- Giant mealworm (*Zophobas atratus*)
- Lesser mealworm (*Alphitobus diaperinus*)
- Greater wax moth (*Galleria mellella*)
- Lesser wax moth (*Achroia grisella*)

In Finland during 1.1.2018 - 1.1.2019 the following insect species can be placed on the market as food by Evira (2018) (The list on permitted species might be further updated if evidence or notifications become available on other species.):

- House cricket (*Acheta domesticus*)
- Honey bee (*Apis mellifera*)
- Yellow mealworm (*Tenebrio molitor)*
- Tropical house cricket (*Gryllodes sigillatus)*
- Lesser mealworm (*Alphitobius diaperinus)*

- Migratory locust *(Locusta migratoria)*

From the 2111 species of insect, the most popular families were listed. (PICTURE 1)



PICTURE 1. Number of edible insects' species (Livin farms 2017, permission to use the figure was given by Livin farms on messager)

2.1 Benefits and problems

In this everything-efficiency world, the use of food from transportation point of view is also considered in practicing and developing. Simple calculation for comparing the meat and insect producing materials-plants can give a clear answer that why edible insects are recommending. Also, less greenhouse gases and ammonia are emitted by insects compared with, for example, pig or sheep. And of course, the use of land and water are needed less than them significantly, too. The farming of insects sometimes can help to reduce some environmental contamination if the location was selected in a right way like sidestream, which includes human and animal waste. The development of this kind of new industry also significantly creates more work opportunities for local people. (Lundy 2015)

Also, from risk assessment of The European Food Safety Authority, the way of farming insect may cause problems like hazards for both biological and chemical. From each steps of insect farming, there are some possibilities to get damages. For example, feeding methods, stage of harvest and production base. Reviewing the first evaluation, they only considered about the potential risks and hazard posed by insect farming but not the issue of food and nutrition security. For future recommends, the research should be the microbiological and chemical risk from insects and feed when using particular substrates like food waste and so on. (Lundy 2015)

There are some potential risks like chemical hazards as well as allergenicity and environmental hazards associated with farmed insects used as food and feed considering of the entire chain, from farming to the final product. If we used the feed materials which is allowed at the moment for substrate to feed insects, the possible hazards percentage will be similar in insects as shown in other animals. Data on transfer of chemical contaminants from different substrates to the insects are very limited. Substrates like kitchen waste, human and animal manure are also considered and hazards from insects fed on these substrates need to be specifically assessed. (EFSA 2015)

In short conclusion, that for both biological and chemical hazards, the specific production methods, the substrate used, the stage of harvest, the insect species and developmental stage, as well as the methods for further processing will all have an impact on the occurrence and levels of biological and chemical contaminants in food and feed

products derived from insects. Hazards related to the environment are expected to be comparable to other animal production systems. (EFSA 2015)

The European Food Safety Authority (EFSA) was asked by the European Commission (EC) to assess the microbiological, chemical and environmental risks arising from both the production and consumption of insects as food and feed and to cover the main steps from the production chain up to consumption. EFSA was requested to provide an overall conclusion based on the above assessment, on the potential risks posed by the use of insects in food and feed, relative to such risks posed by the use of other protein sources used in food or feed. In agreement with the EC, this opinion has the format of a risk profile including considerations of hazards associated with insects as food and feed, placed in the context of hazards associated with other sources of protein. It also considers potential risks arising from importation of insects and products of insects from countries outside the EU, but not the importation of live insects. The risk profile addresses biological hazards (bacteria, viruses, parasites, fungi, prions), chemical hazards (heavy metals, toxins, veterinary drugs, hormones and others) as well as allergens and hazards related to the environment. It is concluded that for both biological and chemical hazards, the specific production methods, the substrate used, the stage of harvest, the insect species, as well as the methods used for further processing will all have an impact on the possible presence of biological and chemical contaminants in insect food and feed products. (Kinver 2015)

During the last years, there has been an increased interest in using insects for food and feed. There are several legislative requirements that impact the use of insects as food and feed. Currently, the feed bans provisions of Regulation (EC) No 999/20011 (TSE Regulation) do not allow insect Processed Animal Protein (PAP) to be fed to farmed animals due to lack of a safety profile. With respect to feed/substrate for insects, Annex III to Regulation (EC) No 767/20092 prohibits the feeding of faces and separated digestive tract content even though these materials are used in other parts of the world as substrates in insect production.

The processing and storage of insects and their products should follow the same health and sanitation regulations as for any other traditional food or feed items in order to ensure food safety. Issues to be considered include microbial, chemical and allergic hazards. In addition, general animal (vertebrate) health and welfare rules should also apply

for insects. The EFSA Focal Points of Member States and EFTA countries were asked to share existing and on-going risk assessments on the safety of insects as food and feed performed in their country. Belgium, France, Iceland and Netherlands replied that they have performed risk assessments related to insects as food or feed. With reference to the mandate, the present opinion will have the format of a risk profile and presents the potential hazards associated with using insects as food and feed considering of the entire chain, from farming to the final product. The opinion also includes the hazards arising from import of farmed (not live) insects from outside Europe and also covers hazards arising from procedures which are not in compliance with existing EU legislation. (EFSA 2015)

The use of insects as a source of food and feed is seen as bringing important environmental, economic and food security benefits. Insects are powerful bio-converters, which can transform low quality biomass into nutritionally valuable proteins. Interest in production of insects for food and feed in the EU is growing and seems have a very bright future. Furthermore, import of insects and insect products into the EU as food and feed is an issue that needs to be addressed as the use of insects is more common outside the EU. (EFSA 2015)

2.1.1 Nutritional value

Nutritional value is very important and necessary to consider as the principle one, since if the company wished to get efficient yields, that must also provide sufficient nutrients to the animal. One of the advantages of the insect as food is that it can produce more percentages of protein compared to other normal animal meat like pork.

Cricket and many other insects basically can eat anything that feed but will grow very slowly and poor with no optimal feed low in nutrients. House cricket, as an example, require around 20-30% protein from their feed to have optimal growth. That is likewise the most valuable of the macronutrients, economically speaking. On a national level, better protein self-sufficiency is one of the future goals, thus domestic protein in feed is preferable. (Kyllonen 2018)

The farm even often customizes the feed according to the particular need of company. For example, if people want a higher vitamin A profile, they will feed insect carrots. some farms have distinct lines where they feed the crickets cinnamon and apples, and the flour takes on an apple and cinnamon flavor. (Kyllonen 2018)

2.1.2 Availability and costs

Year around, reliable availability and homogeneous quality are all important, since it is not practical or even wise to change feed composition very often for any single species. They have to make sure that the side screams from other industry is keeping coming and the amount of it reaches the lowest needs.

The costs mainly from two parts: transport and production. Transport costs come into play if the company used side streams that are further away from multiple sources, which will also produce more emission like greenhouse gas during the transportation. And production costs (possible mixing, drying, grinding etc.) can in small batches but increase significantly.

The evaluation of production costs needs to be done before the production really happens, can compare the cost to the possible benefits. (Kyllonen 2018)

2.2 Insect production and the quality of insect feed

2.2.1 Food and feed legislation

The legislation of food and feed also plays a vital role in what kinds of ingredients can be used in feed, especially when considering about insects that are meant for human consumption.

Finland changes the interpretation of the European Union Novel Foods Regulation so that the insect growing and selling of food is also permitted in Finland.

Previously, EU legislation prevented insect sales for food, because insecticide production has not been legally regarded to be a food product, it has not been under the control of food.

At the same time, the role of insects in the production of protein crops and in ensuring the world's food security has triggered debate in other EU countries. It has led some EU Member States to have interpreted the EU novel food regulation so that the production and sale of whole insects have been possible. Now, in Finland, we have decided to recommend the consistent interpretation. Interpretation of food insects means that insecticide production is subjected to the requirements of food law and their control.

In Finland, there are numerous greenhouses which produce surplus. Also, interesting areas are some industry which produces a lot of wasted heat. Some previous animal farms change to insect production. All feed is fed to animals reared as food must be from a supplier registered as a feed provider. More legislation is involved if the side stream is an animal-based product. For this new growing industry, in order to comply with food safety standards, everything the insect eats or do must be logged to keep-recording.

On 2015, Brian Tomasik found in case of Lundy and Parrella (2015), the percentage of mortality for the testing treatments was very high. They raised crickets for themselves and the crickets grew well on "a 5:1 ratio of non-medicated poultry starter feed and rice bran" (the so-called "PF" treatment), also for on "the solid, pasteurized, post-process filtrate from a proprietary, aerobic enzymatic digestion process that converts grocery store food waste into 90% liquid fertilizer and 10% solids (the portion used in the experiment)" (the so-called "FW1" treatment). However, there was over 99% mortality for the other three treatments tried, one of which was "minimally-processed, post-consumer food waste collected from municipalities throughout California’s Bay Area."

Evira, the Finnish Food Safety Authority has prepared guidelines for insect production for both farmers and food control authorities, which guidelines specify how the insects should be farmed and prepared in order to be sold or served as food. Not all kinds of insect are edible and also the way of produce it may affect the quality of it to be used for human being even animal feed.

It is possible that to be allergic to insect food for special group of people. Mostly food allergens are proteins so the sensitization to insect proteins is possible. It is similar to the proteins like crustaceans and molluscs. Thus, people who are allergic to prawns to may have a similar allergic reaction from insect food, which should be taken care of before started. (Evira 2018)

Insect farmers and manufacturers of insect products are responsible for ensuring that the foodstuffs produced and marketed by them are safe for consumers. Insect farmers are controlled in the same way as other food business operators, which means they would be checked regularly to unsure consumer safety. The way of farming crickets might be different from one to another, but here are some basic ideas of process, for example, there should not contain any standing water in the cricket's cages. The fat or protein cannot be separated from insects to be used in foodstuffs, the insects must be used intact.

2.2.2 Production conditions

As insect farming in Finland is largely done by hand at the moment, the development of using automating production would be an essential way to lower costs and cheaper insect products at the same time.

There is a warm condition need for insects surviving, usually the farming of it will take a lot of energy. A possible solution came out by Pertti Marnila that the farm can be set up next to factories which produce waste heat, electricity and side streams that insects can possibly make use of. If so, insect factories will be part of agricultural symbioses, but until now no one has yet specialised in this kind of egg production but only doing overlapping work. (Helska 2018)

There might be other kind of production conditions needed for insect farms, it also depends on the choice of individual insect farm.

2.2.3 Farming system

There are some notifications that must be submitted by insect farmers. First of all, all operators who raise insects for use as food, for example, primary producers, need to register as a primary production site with the food control authorities of their own municipality already before the start of operation. Producers already engaged in primary production of another production type, such as pig farming and so on, need to amend their registration of a primary production site to cover also raising of insects for use as food. The primary producer also needs to register with Evira as a primary production operator in feed sector. Other authorities, like environmental protection should also be contacted to find out about any other required permits and/or notifications.

Also, operators who process or produce insect foods need to register their food establishment operation with the food control authorities of their own municipality before the start of operation Registered food establishments already in operation wishing to start the processing or production of insect foods are not required to submit a new food establishment notification or notification of an essential change in operation. The food establishments wishing to process or produce insect foods do not need to apply for status of approved food establishment, as insect sector operators are not establishments. However, operators who process or produce insect foods need to register their food establishment operation with the food control authorities of their own municipality before the start of operation. Insects are considered to be just raw materials, just like eggs or milk. Therefore, all that is needed is to take the use of the new raw material into account in the operator's in-house control plan. (Evira 2018)

It contains the same characteristics as other animal production systems: The insects need access to water and feed (substrate) to supply energy and nutrients for growth and excrete intestinal content (frass). The production is impacted by the physical conditions (small scale/large scale, low or high level of technological management solutions etc.) and the level of biosecurity in place to prevent introduction of e.g. microorganisms from the surrounding environment (wild life, neighbouring animal farms, waste management units etc.). In principle, there are no differences in the farming system regarding rearing of insects for feed or for food although they have to comply with different legislative frameworks. The existing differences among systems described by the hearing experts were related to different combinations of insect species and substrates applied and to the level

of automation/industrialization of the farming (and processing) system. In European insect farms, insects are kept in a closed environment, in boxes/cages, where the atmosphere, substrate, water etc. can be controlled. Species produced for harvest as larvae are grown on a substrate in which the animal waste/frass is also excreted. The physical conditions and time for developing the eggs to be harvested as larvae depend on the species. Eggs are introduced onto the substrate either manually or mechanically or by natural oviposition directly from adult flies. The larvae are maintained on the substrate for 1 to 2 weeks depending on species and also temperature. For instance, it takes 8 to 10 weeks at a temperature of 28 to 30 °C and 60 % relative humidity for mealworms (Tenebrio molitor) and lesser mealworms (Alphitobius diaperinus) to reach the size for harvest (NVWA, 2012; cited in FASFC, 2014). For the black soldier fly (BSF; H. illucens), the time will be approximately 12 days. Harvesting of the larvae of the farmed species is in general characterized by a need for an active process to separate the larvae from the substrate. In less industrialized farming systems, this can be done manually by sieving whereas for industrialized systems, automatic systems of different types for the harvesting process have been developed. In less industrialized farming systems, the food substrates are often removed from the insects' hours/day(s) before harvest in order to let the insect empty their intestinal tract. This procedure is not always included in the more industrialized farming systems where the insects normally undergo extensive processing after harvest. Crickets and locusts/grasshoppers are produced to the adult stage before harvest. The production is a two-step production system, one for egg laying and hatching and one for growth to harvesting size. Cricket species are mainly for human consumption and live for pet food. The commercial production systems are characterized by a production phase for egg laying, hatching and growth of nymphs, which are transferred to grow out containers where the adult crickets are raised to harvest size. The overall production time is 3 to 4 months. During the growth period the adult crickets actively move for feeding and drinking. Substrates and waste can largely be kept separated. Substrates are sometimes totally removed before harvesting for gut emptying. Insects (e.g. crickets) in the adult stage move around, which is reflected by different areas in the cages for feeding and for excretion of waste. This natural behaviour gives a physical separation of the insects and the waste enabling harvest of the insects leaving the waste/frass in the production by picking up the insects. In larger farming systems, harvesting can also be done by a more or less automatic sieving procedure. After harvest, the insects may or may not be killed before further processing. As an example, freezing has been mentioned by the hearing experts for killing of crickets and mealworms. Risk profile of insects as food and feed. In addition

to the production of insects either as whole insects and products thereof or as raw material for the production of protein, fat/oil and chitin, these farming systems will also generate a by-product in terms of insect excreta and remains of substrates. (Evira 2018)

3 SIDE STREAM

3.1 Valorization of side streams

There are many side streams which are produced by agriculture and newly developed bioefineries. It is very important to optimize the quality of these side streams and try to find another way to reuse it to cut costs or even generate income,

Identifying food industry side streams as raw materials and their efficient use provides New raw material sources and a wider range of product options.

Freshlying waste is valuable feed and it can be fed to production or game animals, and also reuse in the insect Farming. There are hundreds of vegetable and potato peeling farms in Finland. Disposal of untreated wastes generated through vegetable and potato can have a significant effect on the environment. During the peeling process, 30-40% of the potatoes and vegetables will just become completely Waste. In addition to this, some of the vegetables and potatoes are also subjected to sorting, which make the number even bigger. Peeling waste can be composted or anaerobically digested or fed to production or game animals. Composting of peels is difficult because the Waste is very wet, which means it contain high rate of water, so the better way is to consider it as the raw material for other product like feeding crickets.

3.2 Bio converting organic side streams

Organic side streams can be used as feed for insects, which also contributes to the sustainable management of bio wastes and produces high-protein product. In a global view, one-third of all food produced totally, 1.3 billion tons, is wasted per year. For example, in some developing countries, the collection and treatment of waste is continually increasing as the main problem need to be solved. There are two ways to deal with it, either reducing the organic waste disposal, or using their valorization of waste from the back side, which could be considered as reuse them as certain input for another purpose.

Saprophages like earthworms can convert of organic refuse into compost. Except that, many other insects, e.g., larvae of the black soldier fly (BSF) (*Hermetia illucens*), the common house fly (*Musca domestica*), and certain mealworm species, can also be used for this purpose. BSF as an especially interesting candidate for converting organic refuse, can convert dairy, poultry, and swine manure to body mass, reducing dry matter mass by up to 58% and associated nutrients such as P and N by 61–70% and 30–50%, respectively. The larvae also reduce Escherichia coli counts in dairy manure and Salmonella enterica serovar enteritidis in chicken manure. Problematic house fly populations are also decreased in chicken manure. BSF larvae can also reduce and recycle fish offal from processing plants. BSF larvae grown on 1 kg of cattle, swine, and poultry manure have a high fat content that allows the production of 36, 58, and 91 g of biodiesel, respectively. House fly larvae have been grown on municipal organic waste and the yellow mealworm on dried and cooked waste materials from fruits, vegetables, and cereals in various combinations. Wastewater sludges have also been used to mass-rear the codling moth, *Cydia pomonella*, for the production of granulovirus for biocontrol. (Arnold 2012,566-567.)

However, until now, most of the experiments have been done only in the laboratory. For industrial scales, the development and standardization of mass-rearing techniques could become a new economic sector. There is still a large amount of challenges in different parts, like for biotic and abiotic at the same time, that need to be addressed, e.g., rearing, automation, and safety issues related to pathogens, heavy metals, and organic pollutants. (Arnold 2012,566-567.)

3.3 Importation and exportation

The import of insect foods is possible from EU states where insects are included within the scope of food control. Importation is then considered comparable to control of places of first arrivals and guidelines related to such operation. But for side stream that be considered used for insects, internal importation is very hardly be confirmed, as the side stream is meaning come from waste.

The exportation of insects for use as food is possible. The requirements in force in the destination country for food imported to the country shall also always be verified prior to

exportation. However, for side stream, the export is basically impossible as the expired time. Indeed, local use or close distance is the path to success.

3.4 Potential in the future

There are many ways to think about the connection of side stream and insect production. First of all, the cooperation between primary production industry and single insect farm.

There are two major food factories in Finland that be focused on for this case now: Atria and Saarioinen. Atria is the market leader for fresh meat with 8 main manufacture areas in Finland, it even uses solar power park to create low-emission production process. They both ensure about the quality and safety of their product and follow the right Finnish regulation or law. There might be some products that not reach their high level to not selected, but still good enough to be used as feed for insect production. The outgoers is produced in same strict way as other final product, so it should be good enough to be reused in other industry production. According to the location, the owner of insect farm in different area can have the deal with the local side stream producer for more personal details like amount and schedule. There might have possible visit for the owners and official form for using. (Atria 2018)

The second one might be the connection between local markets, for example, shops under s and k companies, with insect farms. Everyday there would be many products that might be expired soon and nobody want to buy. Also, the outlook of food might affect the interest of customer like with ugly black dots but good and edible bananas. They can be collected regularly by insect farms to be use for insect production. All the ready to sale products already passed the test of quality, they can be directly used for feed as the food quality is stricter than feed legislation.

There might be a possibility to connect with local restaurants also. But the food has to be collected separately before them going to the mix waste. For example, daily salad from kitchen and unused parts of vegetables. If so, there will be significate benefits for each side and at the meantime, the waste could be managed better and reused.

4 FINLAND AND FINNISH COMPANIES/ INSTITUTIONS

4.1 Latest situation in Finland

For example, in Tammela, pig farm three years ago now renovates for Z shape room. It was difficult to decide to give up the traditional pork production and change a whole new kind of farming.

Insects have now officially acquired the status of food in Finland. Our authorities have changed without delay the interpretation of the EU Novel Foods Regulation for whole insects.

Finland now permits the use of whole-grained insects as a foodstuff. Whole insects can be smashed, grinded or dried, but they cannot remove parts (wings, feet or heads) and do not isolate or extract ingredients (fat or protein shakes). Insect producers can now register as food business operators, which will be issued as part of food law and supervision. Insect products thus produced can be sold as food. In the past, insects have been sold, but the label is a kitchen decoration, not a foodstuff, because they were not produced and controlled under food law, and their safety was not guaranteed.

The insect breeder, the manufacturer and seller of insect products, are responsible for ensuring that the food they produce and sell are safe for consumers. In production, care must be made, for example, on good hygiene and, for example, the correct and sufficient information on the label. It is nice to note that insect proteins can cause an allergic reaction.

Fazer, the famous Finnish backing company, has been developing insect bread since 2016 summer for its assortment of its in-store bakery products with Finland lifting of the ban on selling insects as food in November 2017, finally introduced the new insect bread that is made by flour mixed with crickets. (FBR Staff Writer 2017)

PICTURE 2. The cricket-based bread from Fazer (Fzaer 2017, permission to use the figure was given by Fazer,courtesy of Cision on messager)

6th of April, the restaurant of TAMK-Campusravita served cricket food in the campus for staff and students during lunch time.

4.2 Companies and institutions

There are some companies and institutions started to innovate insect production. They also show the interests for the potential of other industrial side streams to be used as insect feed.

4.2.1 Finsect Oy

Finsect Oy is a two years old company for promoting insect production. At this point, no visitors are allowed because of regulations of food production and that they are scaling up with technology. They are very interested in potential side streams for insect production from other industry.

Finsect Oy is developing very fast and considering about updating new development for insect industry, for example, this thesis is written for Finsect Oy to help open the view of using other industrial side streams for potential insect feed.

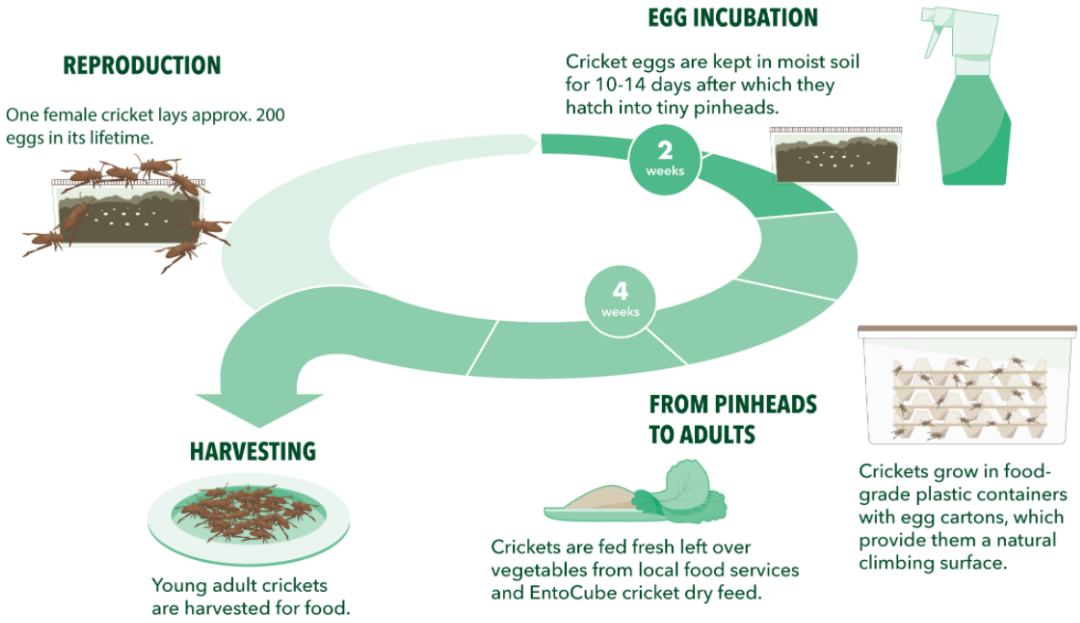
4.2.2 EntoCube Oy

Distinct from the previous one, EntoCube Oy, which is located in Espoo and started from 2014, not only provides insects farming solutions but also sell their products online themselves.

They have not yet used specific side stream in feed use for insects. Because when considering food chain side streams as feed for insects (or any potential farm animal), there are some of the biggest things need to think about as mentioned before. However, they have done and are doing their own basic research in that area. One of their ultimate goals is to make side streams work in their production system on a larger scale.

Insect is a high quality and sustainable protein source and EntoCube Oy offers the world a solution for it. They do this in two ways: offer the technology to farm insects for insect producers and vision of a world where insect protein is a regular part of our diets. EntoCube Oy will play a major role in the change of increasing insect eating people with the developed world.

For technology, EntoCube Oy currently has the ability to produce structured atmosphere shipping containers of various sizes that can be manually operated to farm food-grade insects. The system is robust but very flexible in terms of layout and the internal climate so that it can be modified to fit different insect species. In their vision an EntoCube farm is built like LEGO blocks, stacked or in a row.



PICTURE 3. Crickets production process (EntoCube Oy 2018, permission to use the figure was given by EntoCube Oy on messager)

Insects use for food is a constant source of inspiration for all. EntoCube Oy is thrilled to vision futuristic scenarios where astronauts use insects as their main protein source when setteling Mars or the Moon. They are actively working for example with NASA and seeking out new partnerships across industries to step into the future. (EntoCube Oy 2018)

4.2.3 Nordic Insect Economy Ltd

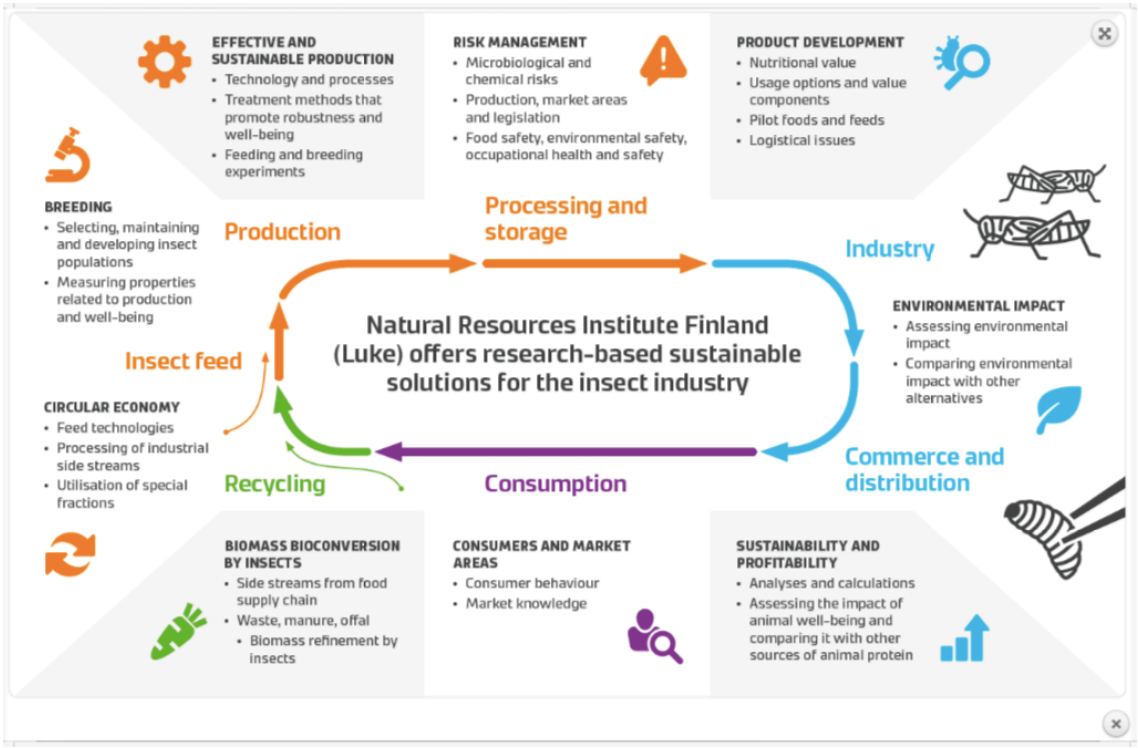
Nordic insect economy ltd is the first entomology company in Finland and focus on raising insects ethically, with attention to environmental and social consequences. It offers complete, ready-to-use insect farming solutions for starting off small-to-medium sized edible insect farms, as well as more specialized stand-alone products aimed towards more established actors in the broader insect industry. NIE has combined safety, quality, efficiency and ethical farming practices to offer the best products in the current market that is oriented towards small-to-medium sized insect farms. The company is also active in the field of insect dining.

NIE Ltd was created in October 2014 and took not long for this insect business to draw interest, and quickly grew into a multi-skill team. Prototypes are currently being constructed and tested in Kouvola, Finland. At the moment, NIE is fast growing and plan to start sales in the near future.

Three keywords for it: mission, vision and value. It is committed to offering the technological, economical and ethical platform on which the new edible insect farming industry will flourish. Profitable, ethical and sustainable insect food business is an asset for all partners and customers. It is also committed to safety and economic fairness between customers and the company partners. (NIE 2018)

4.2.4 Luke (Natural Resources Institute Finland)

Luke (Natural Resources Institute Finland) is doing their own research on using side streams as insect feed sources at the moment. (Kyllönen 2018) It considers insect economy growing in Finland and believe high possibility to become one of the top countries in the near future. (Hilkka 2018)



PICTURE 4. Research-based solutions give a boost to insect economy (Luke 2018, permission to use the figure was given by Luke on messager)

There are four research projects ongoing (Reetta 2018):

EntoLab: Focuses on promoting insect farming in Southern Ostrobothnia, Finland (2016–2018).
HyväRehu: Examines the suitability of various industrial plant-based side streams as insect feed (2017–2020).
Maggots–Meal for Fish: Accelerates the construction of an insect economy ecosystem by seeking synergy between Luke's other insect projects (2017–2018).
ScenoProt: Seeks new protein sources for the benefit of food security and the environment (2015–).

5 DISCUSSION

Obviously, "the food chain side streams" could be used from the local, and the local using is much better than from other places as the transportation costs need to be considered for the insect production, also local input is easier to get better quality and when something goes wrong, the feedback system and communication can be done in a quicker way. It is a sustainable local agribusiness if managed well. It could be considered as a waste management project for indigenous agriculture and also a reuse system for recycling the materials to make efficiency. Therefore, a simple stakeholder mapping could be done by using salience model from Mitchell (1997). Insect farms, side stream producers and transportation companies will be the three main keys (Figure 1).

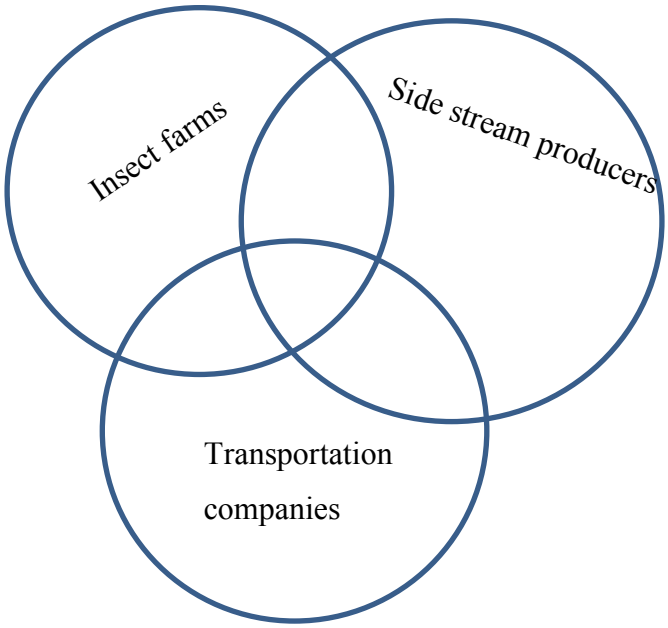


Figure 1. Stakeholder mapping of the potential of industrial side stream for insect production

Besides corporations, there are other things that needs to be considered would possibly benefit insect companies in the future. For example, they should concentrate on the changes of feed and food legislation from the point of view of developing the use of side streams further. There are other issues like distance corporation combined with import and export also quality management should still be studied.

The automated farming technology for example, is using in some company nowadays like EntoCube Oy, they use a special box to produce the insect. The practical technology like that does not need to separate different locations like urban areas and rural. For managing the side stream as insect feed, the security of product safety solely the responsibility of every commercial operator and also official control over them. Once that food resistance has now been officially handed over to insects, they will be subjected to the same food safety regulations. The control is quite similar to that of other product groups. The situation is clearer now than before but still there are many challenges and the hype is gradually decreasing.

For the potential developing, trying to combine different industries business together and reuse, recycling the side stream for insect feeding based on the standard limitation is possible now. The location selection should be considered and the industry type, for example, food industry.

It is possible that the living insects imported will come with inferior species of human beings; parasites harmful to nature or their parasitic eggs, or edible insects, which then spread to Finland's wildlife. For this, we need insect guide to reduce the risk. For industrial scale framing, where chooses to use bio waste as major feed for insect production is impossible because of multiple consideration and limitation. But if thinking about low scale farming, then it is a considerable choice. The risk of zoonotic infections (transmitting diseases from humans to animals and back) could rise with the careless use of waste products, the unhygienic handling of insects, and direct contact between farmed insects and insects outside the farm due to weak biosecurity.

There is potential of industrial side streams in insect production and calculating the potential of side streams could be really big thing for the improvement and development of insect production and benefit both insect industry and other industries which offer the usable side stream for it.

There were some difficult to study this topic during the process when meet the real technology using in insect production at the moment, because of the confidentiality in companies in Finland, which was a pity.

Developing related system to complete the process or help with the farmers and food company is also another possible step. For example, the check list in an online system could make the process more perfectly for all stakeholders, which would be especially useful for the client-Finsect Oy to collecting data and follow all the steps online. Cloud system will be much better than paper work to understand the up-to-date situation and make changes/development in time. It will be environmental-friendly and easy to handle by managers from each side. For example, there could include picture update channel for insect farm to check the look and freshness of side stream from food industry before they make any decision.

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APPENDICES

Appendix 1. Short interview with Tiiu Kyllonen from EntoCube Oy.

How do you think about using industrial side steam in insect production? Can we use" the food chain side streams " from the local? How does it connect to sustainable local agribusiness? And automated farming technology and solutions (urban and rural)? How do you manage the side stream from the insect producing? How do you think about potential developing?

When considering food chain side streams as feed for insects (or any potential farm animal), some of the biggest things to consider are:

1. nutritional value

Nutritional value is important, since if you wish to get efficient yields, one must also provide sufficient nutrients to the animal. Crickets and many other insects eat practically anything but grow very slowly and poorly with non-optimal feed low in nutrients. House crickets for example require around 20-30% protein from their feed to have optimal growth. That is also the most valuable of the macronutrients, economically speaking. On a national level better protein self-sufficiency is one of the goals, thus domestic protein in feed is preferable.

2. year around availability or good way to preserve feed

Year around, reliable availability and homogeneous quality is important, since it’s not practical or even wise to change feed composition very often.

3. transport costs

Transport costs come into play if one uses side streams that are further away of from multiple sources.

4. production costs (possible mixing, drying, grinding etc.)

Production costs can in small batches increase significantly. It’s important to evaluate the cost to the possible benefit.

5. food and feed legislation

Finally, food and feed legislation play a vital role in what kinds of ingredients one can use in feed, especially when talking about insects that are meant for human consumption. All feed fed to animals reared as food must be from a supplier registered as a feed provider. More legislation is involved if the side stream is an animal-based product.

Because of these reasons, we don't as of yet have a specific side stream in feed use. We have done and are doing our own basic research in that area and one of our goals is to make side streams work in our production system on a larger scale. I'm sure you might be aware, Luke (Natural Resources Institute Finland) is doing their own research on using side streams as insect feed sources at the moment, but research is still ongoing.