Bacchus

EDIBLE INSECTS

An Industrial Analysis Report of Mealworms

"How westerners can save the world by extending their diet with a healthy and delicious ingredient"

June 2015

Contents

About Us

Scan our LinkedIn

M. Floru
-Belgium-

Active in a student organization promoting entrepreneurial approaches to a more sustainable world, I had the chance to talk to some Belgian innovators believing in insect food. These start-ups triggered my interest in this project.

M. Palit
-Indonesia-

With the passion for food exploration, I find this topic to be challenging. As people fear what they don't understand, I believe this report can help them to get to know insects better, and positively accept it as an innovative source of food.

I. Saenz
-Mexico-

For all what I cab recall, eating insects has been part of my country's culture. I have enjoyed for many years their peculiar flavors. This is why I am highly motivated to promote this delicious and healthy food source.

M. Maniglier
-France-

As a French person, I love eating tasty food. I am also concerned about environmental issues, hence my interest for this topic! I hope this IAR will help the promotion of mealworms as a source of human food.

M. Doerr
-Germany-

Using my engineering knowledge in a completely new field is my motivation. Personal health and sustainability are future challenges for both individuals and humankind. To be part of a team taking up the challenges and making the world a better place.

> Bacchus is the Roman God of wine and plentiness, agriculture and fertility of nature. We chose a Roman god, and not the Greek god Dyonisos, because the Greeks were the artists of ancient times whether the Romans were the engineers!

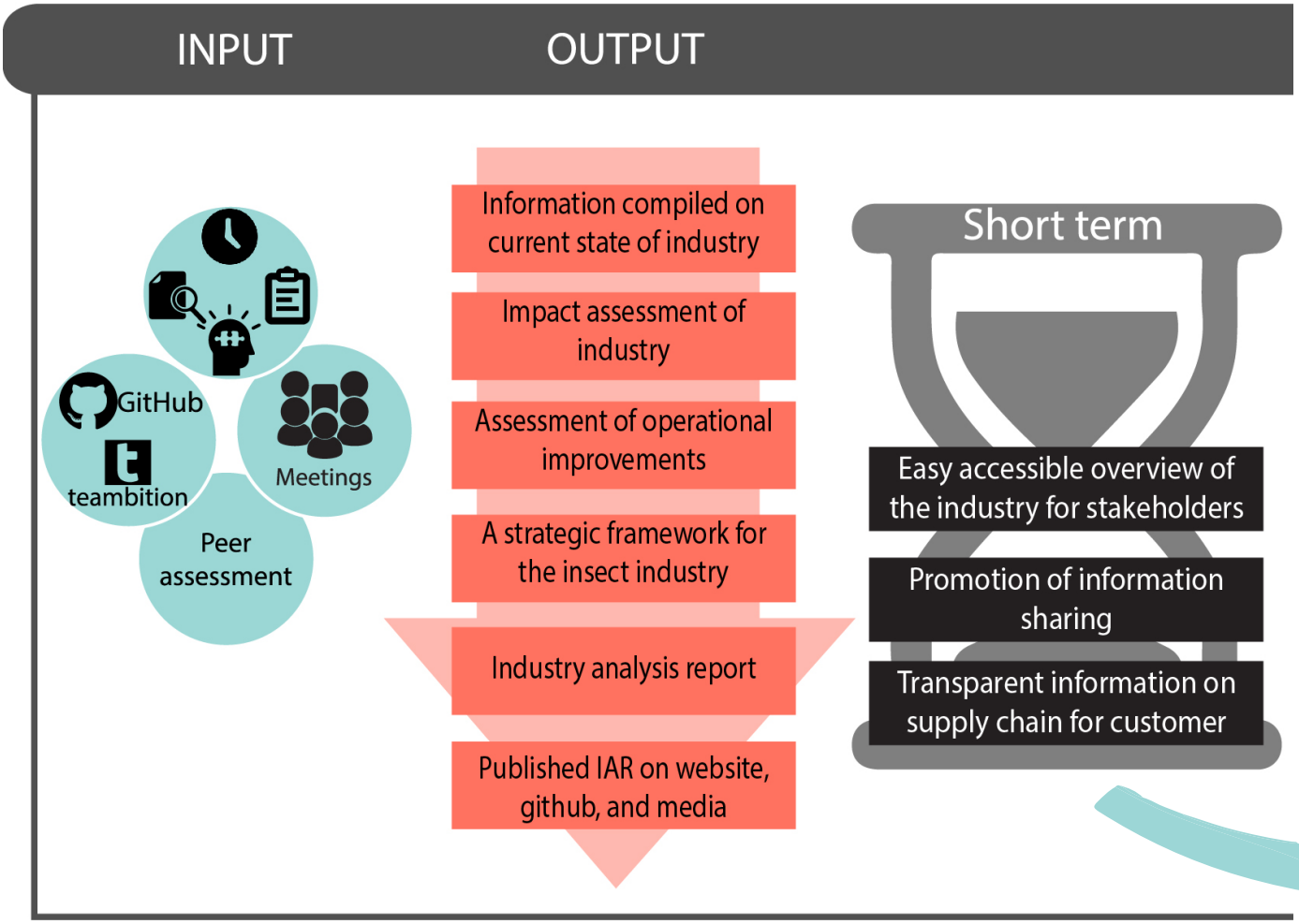
This Industry Analysis Report was written by 5 graduate students at Tsinghua University, Beijing, China. It serves as the capstone of the Global Manufacturing Strategy course, following the XLP teaching methodology (Xtreme Learning Proces) and taught by professor Ben Koo.

Instead of the common passive lecture teaching method, the course forces students to take the lead themselves. The professor provides the tools and laws of the course that becomes a marketplace for exchanging ideas and progress with the rule of open discussion based on extensive readings and the tools or technology for collaboration and coordination of the 21st century. The rest is up to the teams themselves.

Our goal is to provide the world with plentiness of food, delicious food. We are inspired by the plentiness and delicious wine Bacchus symbolizes. As engineers, we want to combine human innovation in agriculture with the use of the fertility of nature to make this happen.

LOGIC

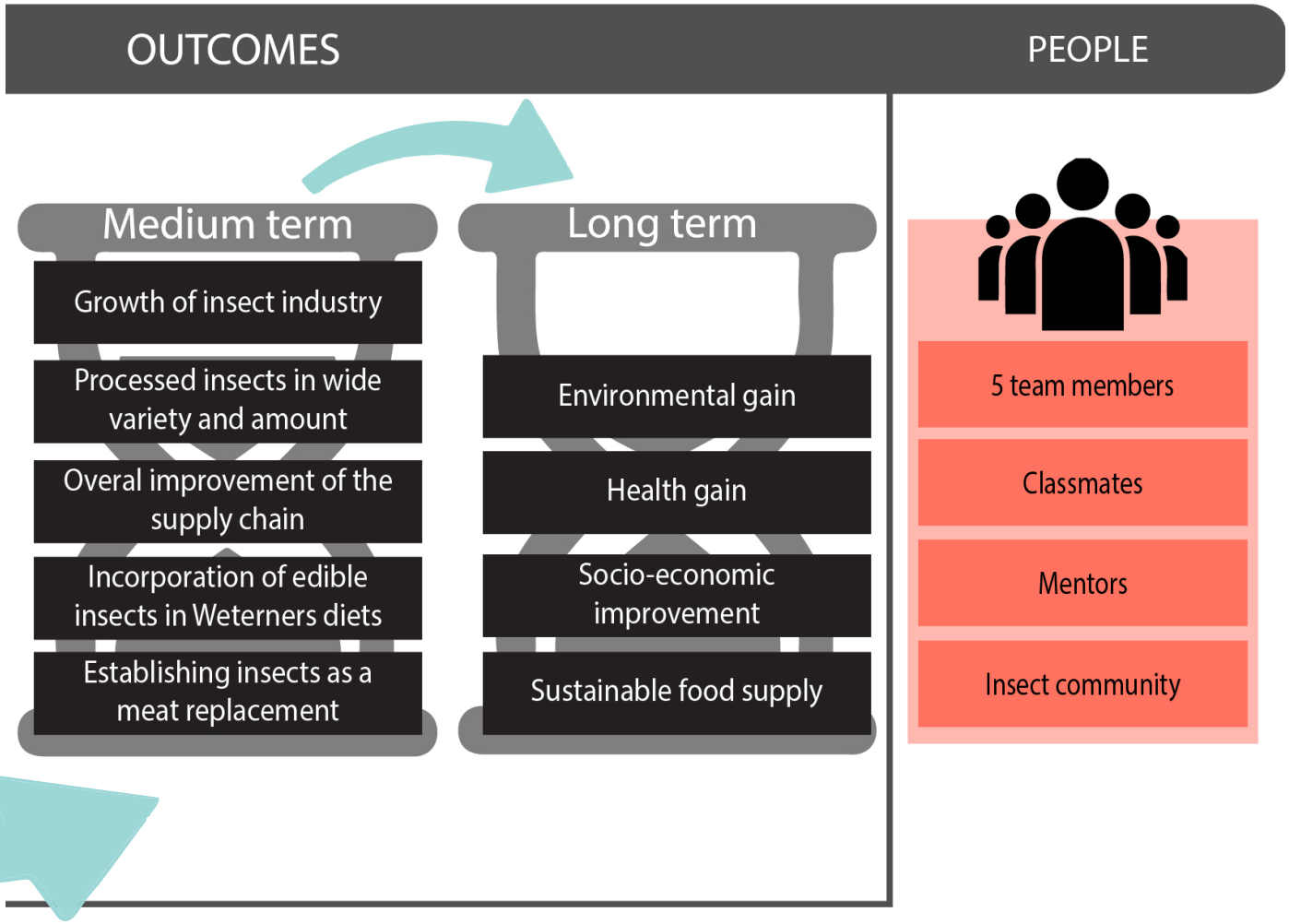
Goal: To provide western society with healthy, sustainable & delicious source of food



Given the trend of population increase, the Earth is expected to be inhabited by more than 9 billion people by 2100. All this population will need food to satisfy their daily nutrient requirements. Considering that 27kg of CO_2 are released into the air to produce 1 kg of beef (12kg for 1kg of pork and 6kg for 1kg of chicken), such traditional protein sources are not sustainable to feed the world. We must find alternative ways to meet the growing protein needs of mankind. We believe edible insects are a part of the answer. More specifically, our proposal is to use mealworms as a substitute for meat. Mealworms have higher content on protein and less content on fat than meat. They require less space for breeding and processing.

MODEL

Problem Statement: Industrialization of insects as food



Their low ecological footprint makes them a sustainable source of food. Of course, there are challenges in legal and social aspects. Although 2 billion people on Earth eat insects, the acceptance among Westerners is not won yet. Also, the absence of a legislative framework makes any industrialization difficult. A lack of knowledge and scale results in high production costs today. Our report wants to reduce the difficulty for people who start producing mealworms by compressing and advancing the knowledge in this field. Mealworms can provide us with a delicious, healthy and environmental friendly new food source. We believe this opportunity has to be seized!

RESEARCH

Up to today, already a lot of research papers have been published about insects as a food source. Also, startup companies are trying out business models for this new food source. So far no industry analysis report has been published about this new industry field. We linked academic research with the business done today and compressed it in an easy to read assessment and guideline for stakeholders in this new industry. With this work, we hope to advance the growth of the insect industry.

One catalisator structuring the project and comparing goals to actual achievements is the logic model. We presented our logic model as one of the first things in this report, as it shows the reader what our goals are and how we achieve them. For us, during the project, the logic model served as a reference to make sure the work we did was helping towards our end goals.

Within the framework of the logic model, a continuous effort is done to back up the report with reliable data.To do that, a various amount of sources have been collected. Different parts required different sources. The most important resource is the report "Edible insects: future prospects for food and feed security", published in 2013 by the Food and Agriculture Organization of the United Nations. This extensive report is the first thing everybody who wants to start in the insect industry should read.
To get an overview of the state of the insect industry today, traditional international media was consulted. In addition, new media, such as blogs of people active in the insect community, provided useful insights. Moreover, e-mail conversations with companies active in the field gave us an idea of the current issues they are facing.

Data about nutritional content, health issues and environmental impact come from academic research in the recent field of entomophagy. For the market study, we used estimates of market analysts.

Only looking at what is going on in the insect industry and research right now is not enough. It is still a new field, risky and continually changing. Focusing on insects alone would not prepare companies for the real world. Therefore, we also looked to the outside. We did research about frameworks, strategies, market environments and current trends in technology. Management science became the backbone of the report, helping us to asses the challenges and possibilities of this new industry.

Our references are an important part of the project. They are accessible in different ways. First, the most important references have a QR code attached to it in the text. Therefore, it is easy to access them if you want to know more. Furthermore, all the cited references are grouped per chapter at the end of the report, following scientific referencing. In addition, online, we provide a list of links to all the sources we consulted to form an idea of the insect industry, also the non directly cited ones. And on the next page, we provide you with a list of our 8 most important references, to give you the possibilities for further reading at a glance.

METHODOLOGY

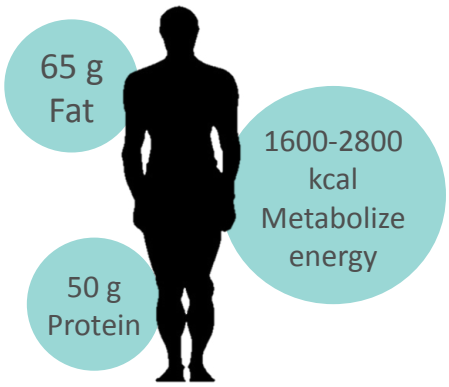
Important References

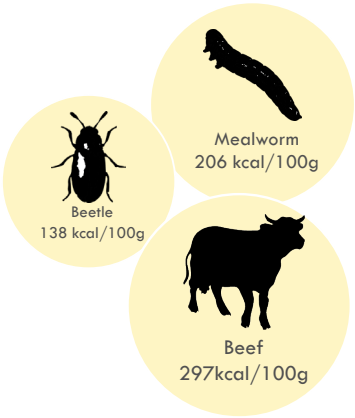
FAO 2013	**Edible Insects: future prospects for food and feed security** The startpoint for everything you want to know about insects for feed and food.
Lessig, 2005	**Code** His 4 forces: law and technology, norm and market give a framework to understand the complex environment in which you start a company. The structure of our report is based on his work.
Megido et al, 2014	**Edible Insects Acceptance by Belgian Consumers: Promising Attitude for Entomophagy Development** A scientific study that talked about the acceptance of edible insects by Belgian consumer, and the promising attitude.
Siemianowska, 2013	**Larvae of mealworm (Tenebrio molitor L.) as European novel food** A scientific study about mealworm as European novel food, the nutrient contents.
Oonincx & Boer, 2012	**Environmental Impact of the Production of Mealworms as a Protein Source for Humans – A Life Cycle Assessment** This article talks about the environmental impact of the production of mealworms as a protein source for humans.
European Parliament 1997	The regulation (EC) n°258/97 on Novel Food
Tiny Farms	A company in California with the goal of industrializing insects. The numerous articles about them and the personal contact we had with them gave us helpful insight. They also have an open source platform for starting insect farms. (www.openbugfarm.com)
Fine, 1998	**Clockspeed: Winning Industry Control in the Age of Temporary Advantage** "Make sure you design your supply chain strategically or you will never seize a market." This book gives a tool and framework for this purpose.

KEY FACTS

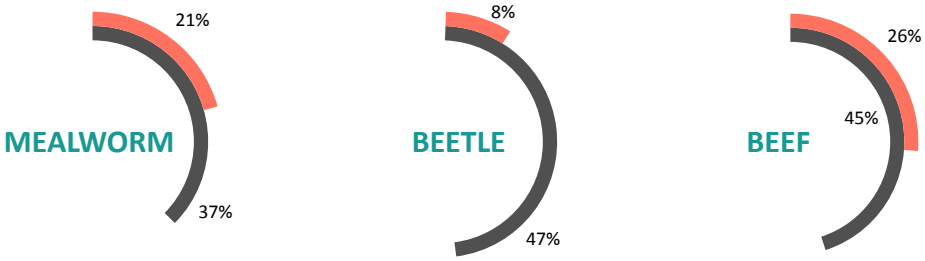
Nutritional value

Human Nutrition Daily Need





Average ratio of nutrition content with daily recommended value



Source:
FAO (2013)
www.wolframalpha.com

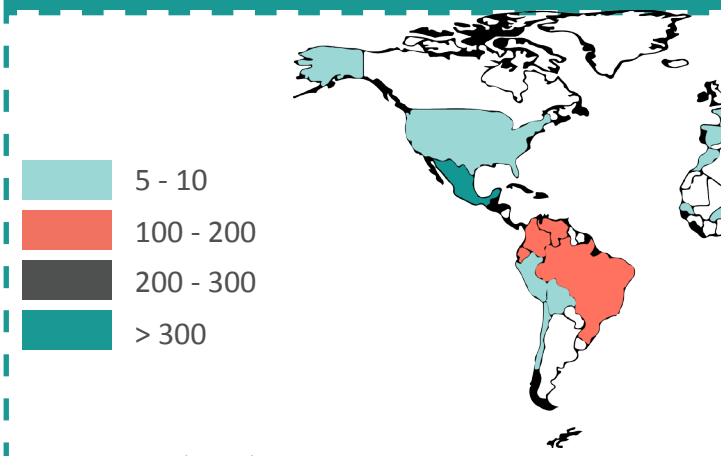
Entomophagy is FAMOUS!

80 PERCENT OF NATIONS EAT INSECTS

TOTALLING 2 BILLION PEOPLE WORLWIDE

Source: www.ediblebugfarm.com

Number of edible insect spec



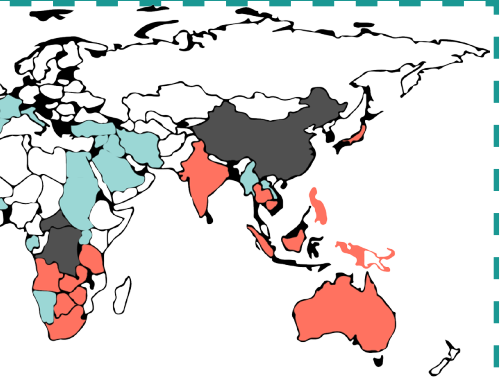
Source: FAO (2013)

ON INSECTS

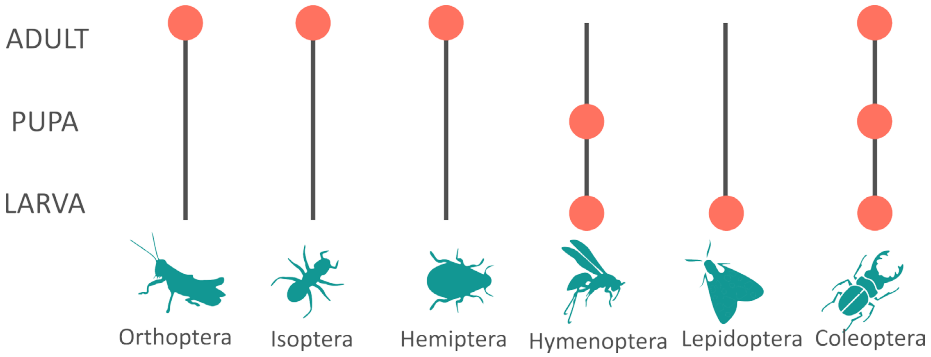
Ecological aspects

Source: FAO (2013)

ies around the world



At what stage are they eaten?



Source: guardiandigitalagency, 2015

Why Insects?

"For most of the Western readers of this report, insects are not seen as desirable. Insects as a food source are even more exotic. However, they can be a tasty, healthy and environmental friendly novel food. Discover with us how insects can provide our current world society with a new source of valuable nutrients."

Insects as a new source of food

In 2013, the UN Food and Agriculture Organization (FAO, 2013) published a report urging us to start eating insects in order to fight world hunger. European hipsters in cities such as Paris, Amsterdam, Brussels and London start embracing insects as a delicous snack. American startup companies are looking into new ways to produce insects for food. Is this a temporary hype or will this trend lead to a Western society in which eating insects is as normal as going to McDonalds? This is a question this industry analysis report will try to answer. Moreover, we compose a framework to evaluate the insect for food business and will include strategies to tap into this new field. We want to become a reference for everybody, from startups to investors, researchers to big companies, who is looking into insects for food from a business viewpoint. But first of all, why, among all possible food sources, do we choose for these crawling animals most people hate?

So, why insects? Regardless of its looks that most of people don't fancy, insects as food does not only contain high nutrition (protein, vitamins and minerals) that can be found in fish and meat as well, but it's also healthier as it contains less fat (as for the ratio). Harvesting insects is easier than cows, pigs and sheep; they need less land, water and less food, and emit fewer greenhouse gases. In order to be able to feed our growing world poplation, a food source that has all these advantages of limited resource used and high nutrition, should be given considerable attention. Last but not least, farming insect can become a new form of business that can be done in the developing tropical countries (which usually suffer for poverty) where those insects mostly live.

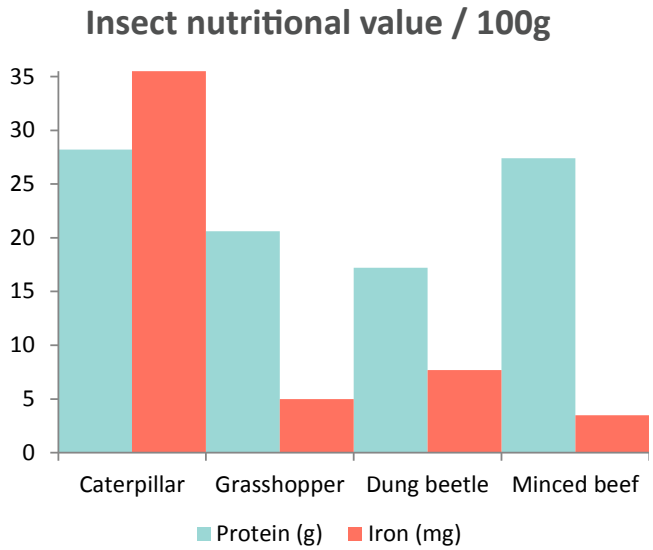
Here are the brief explanations of the advantages of eating insects (Huls, et al., 2013)

- **Environmental opportunities:** the environmental benefits lie in the high feed conversion efficiency of insects. For example, crickets require only 2kg of feed for every 1 kg of body weight gain. Insects can be reared on organic side-streams (including human and animal waste) and can help reduce environmental contamination. They emit fewer greenhouse gases and less ammonia, require significantly less land and water, and compared with mammals and birds, insects also pose less risk of transmitting zoonotic infections to humans, livestock and wildlife (although this topic needs further research).

- **Nutrition for human consumption:** insects are a highly nutritious and healthy food source with a high protein, vitamin, fiber and mineral content. For example, the composition of unsaturated omega-3 and six fatty acids in mealworms is comparable with that in fish, and the protein, vitamin and mineral content of mealworms is similar to that in fish and meat.

- **Insect as animal feed:** insect-based feed products could have a similar market to fishmeal and soy, which are presently the major components used in feed formula for aquaculture and livestock. Animal feed is using a vast amouont of our current resources: 40% of all agriculture use and 20% of all fish caught goes into animal feed. Insect can have a big impact by reducing this burden.

"With a world population of 10 billion people expected in 2100, we need food to satisfy the daily nutrient requirements"



Source: Montana State University

- **Extracting nutritional components:** insects are often consumed as whole but can also be processed into granular or paste forms. Extracting proteins, fat, chitin, minerals and vitamins is also possible. At present such extraction processes are too costly and will need to be further developed to render them profitable and applicable for industrial use in the food and feed sectors.

- **Livelihood and economic improvement:** insect gathering and rearing as minilivestock at the household level or industrial scale can offer important livelihood opportunities for people in both developing and developed countries. It also can offer employment and cash income, for example in developing countries in Southern and Central Africa and Southeast Asia. The process of insect gathering, rearing and processing is easily within reach of small-scale enterprises.

SNAPSHOT

Can we feed the world?

The United Nations Food and Agriculture Organization estimates that about 805 million people of the 7.3 billion people in the world were suffering from chronic undernourishment in 2012-2014. That means 1 in 9 people were suffering for that (World Hunger, 2015).

Regardless of the decreasing number of hungry people that can be seen in the table presented above, world hunger is still a major issue. For example, Europeans see poverty, hunger and the lack of drinking water as the biggest problem in the world (World Hunger, 2015). Humanity is constantly making progress towards reducing the number of hungry people in the world. Most of this progress happens by increasing the production rate in the agriculture sector.

However, is it true that the main reason for hunger is that we don't grow enough food to feed everyone? It turns out that the growth of the global agricultural productive potential has so far been more than sufficient to exceed population growth (Food and Agriculture Organization, 2012). It is because poor people, especially in developing countries, cannot afford the food they need, that world hunger is such a big issue. Meat, one of the most important sources for necessary proteins, is in most poor households a scarcely eaten product. The vast amount of resources needed to produce meat makes it too expensive. Therefore, we need a new source of food that is reliable to support; or even better – a substitute of today's food sources

Undernourishment around the world, 1990 to 2012
Number of undernourished and prevalance (%) of undernourishment

	1990 - 2(Numb)	1990 - 2(%)	2012 - 4(Numb)	2012 - 4(%)
World	1.014,5	18,7	805,3	11.3
Developed regions	20,4	<5	14,6	<5
Developing regions	994,1	23,4	790,7	14,5
Africa	182,1	27,7	22,6	20,5
Sub-Saharan Africa	176	33,3	214,1	23,8
Asia	742,6	23,7	525,6	12,7
Eastern Asia	295,2	23,2	161,2	10,8
South-Eastern Asia	138	30,7	63,5	10,3
Southern Asia	291,7	24,0	276,4	15,8
Latin America & Caribean	68,5	15,3	37	6,1

Source: FAO The State of Food Insecurity in the World 2013 p.8

Key Drivers

"Despite all the advantages of insects, it is still not sure they will be able to establish themselves as a serious alternative for traditional meat. Lots of issues will have to be addressed, especially to market them in Western countries. Here, we give a short overview of the key drivers that will decide whether insect food will become a real industry or will die as a temporary fashion."

Acceptance among Westerners

"A key challenge towards selling insects for human consumption will be people in the West accepting insects as a food source. Indeed, Westerners culturally associate all insects with nuisances and see their consumption as primitive and disgusting. A better understanding of why most Westerners do not like the idea of eating insects nowadays (FAO, 2013) can help finding creative solutions to improve global insects acceptance."

Legislative security

"In many countries, there is no regulation for insects as food and feed. This is particularly true for Western countries. In the United States, insects as food do not correspond to any category of the FDA (Food and Drug Administration), meaning that there is no legislation on this issue. In Europe, edible insects are ambiguously considered as Novel Food, with no specific regulation for this sector. This fuzzy legal context is one of the big barriers to insect mass-production as investors fear to put money in a lawless -therefore hazardous- business."

Production cost barrier

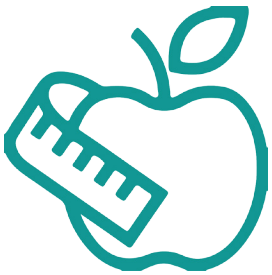
"Systematic food production has been known for over one thousand years in the agricultural business. The agricultural optimization and food processing technology has made huge leaps forwards since the industrial revolution. Many systematic and technological transformations were implemented (Boye, 2012). Recently the last leaps were the use of fertilizers, modern varieties, irrigation and labour productivity (Mette, 2008). For insects seen as a substitute to agricultural products and more specific meat, research only started in recent years and an insect industry is not yet established. The reason for this fact is mainly the absence of cultural acceptance in industrialized countries. Farming and harvesting of edible insects today is mostly done by private farmers for their own use. It is done on a small scale and without cost-effective industrialized processes. Companies like Tiny Farms, All Things Bugs and the Aspire Food Group hope to jump on that bandwagon to break through the production cost barrier. Right now the farming of insects cannot compete with established agricultural products in price as well as on a qualitative level."

Health issues

"As they are cold-blooded and much different from humans and mammals, insects are less likely to share common infections with us. However, they are rich in moisture and nutrients like any meat and can therefore provide a favorable microbial environment (FAO, 2013)."

Nutritional Value

"If and only if insect can compete with traditional livestock regarding their nutritional values will they be able to pretend to replace them. Therefore, edible's insect protein, fat, minerals and vitamin content shall be studied and compared to the ones of animals such as beef. Studies conducted on mealworms tend to prove that their content is similar to when no better than beef (Finke, 2002; Siemianowska, 2013)."



Environmental impact

"It is known that livestock rearing causes many environmental problems. According to studies, livestock production accounts for 70 percent of all agricultural land use and its rearing is responsible for 18 percent of GHG emissions (CO_2 equivalent) –more than the transport sector (FAO, 2006). It also consumes 70% of freshwater worldwide (Pimentel, et al., 2004). With world's growing population, it is time to find a more environmental-friendly source of protein."

Mealworm Powder

"Insects as a group consist of thousands of different species. Some are better suited to address the key drivers than others. The way of processing and marketing them will also influence the success of insects. Discover here why mealworm flour is probably a good bet to establish a serious insect industry."

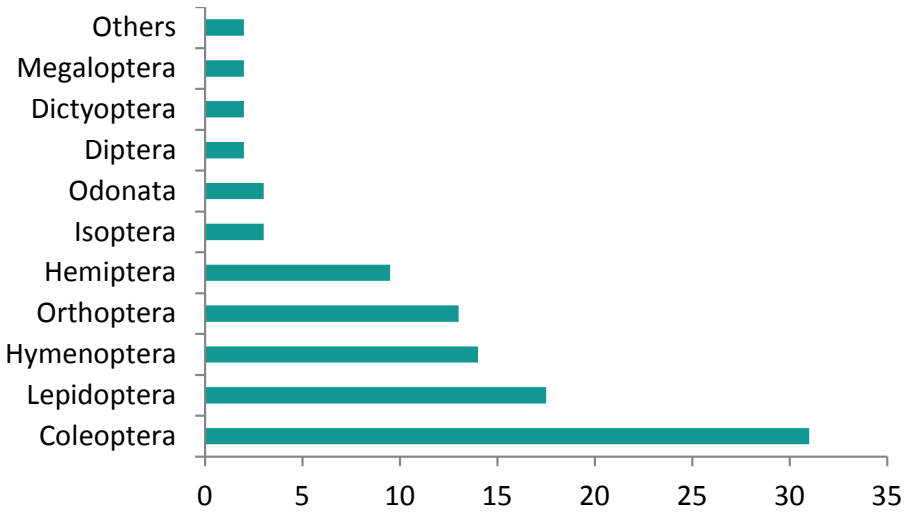
Mealworm powder as a solution

If you are still reading this report, the infographics and part about 'why insects?' probably triggered you to believe that insect food can become a desirable new food source in the world. To make that become true, research, industrialization and a global marketplace, including selling insects for food in Western countries, has to be institutionalized. A solution to drive the growth of the insect food industry needs to overcome barriers such as acceptance in the West, the lack of legislation, possible health issues and a production cost barrier. To be short, based on our research, we believe flour made of mealworms can become the catalyst product driving the growth of the insect industry. The rest of the report investigates the solution of mealworm flour deeper among 4 dimensions : norms, law, technology and markets. It concludes with a section on how a company can build a supply chain leveraging on this research and gives some possible business models for doing that. In this section, we already give a short preview of the reasons to believe that mealworm flour can become the standard for insect food.

There are thousands of insect's species around the world and more than 1900 species have reportedly been used as food. Globally, the most common insects consumed are beetles (Coleoptera). This is not surprising given that the group contains about 40% of all known insect species. The figure below shows the number of insect species, by order, consumed worldwide (Huls, et al., 2013).

> "We believe powder made of mealworms can become the catalys product driving the growth of the insect indus-

Number of insect species, by order, consumed worldwide



Source: FAO The State of Food Insecurity in the World 2013, adapted from Jongema, 2012

The coleopteran order of the graph above is the same as what we know as beetle. Mealworms are a larval form of beetles. Today, already a lot of articles focus on mealworms. People are doing research about mealworms for food and companies are already producing them for food. That means that they are already somehow recognized as food. The advantage is that this increases the chance that they will finally be accepted as a mainstream food source. For 'unknown' edible insects, this chance is lower. Acceptance enhancement and laws allowing insects will come first for the more known insects such as mealworms.

Off course, this is not a sufficient argument to choose mealworms. Their inherent properties are what makes them so promising. The nutritional value is amazing, comparable to beef in protein content but with less fat inside. In the Norms part, this will be proved in detail. Mealworms also have a short life cycle. From egg to mealworm only needs 2 weeks. Then, they can be harvested and a new cycle can start, resulting in a fast clockspeed of the industry. The production process is simple, as mealworms are small and do not have legs or a hard shell, an attribute of other insects that can make processing more difficult.
Processing the mealworms into flour has some additional advantages. Acceptance is easier when you don't see the original shape of the insects anymore. Furthermore, flour can be processed into a wide range of food products, having the advantage of being a staple food with well-developed processing possibilities. In terms of safety risks, processing into flour makes that you can keep the mealworms fresh for a long time. The nutritional content also becomes more concentrated after making flour. All these advantages will be explained and backed up by research in the coming chapters.

We are using the term mealworm powder and not mealworm flour thanks to Aaron T. Dossey of All Things Bugs LLC. The term flour could make people believe they can just substitute normal flour with mealworm flour. This is not exactly the case as mealworm powder consists mainly of proteins and fat while flour consists of starch.

Therefore, Dossey is trying to put the term 'powder' forward in the industry, and we are following that. Scan the QR code to find Dossey's explanation.

SNAPSHOT

Mealworms Score Better Than Meat

Want to eat sustainably? Then eat bugs.

That's the word from the Dutch, who are doing their best to make a scientific case for the environmental benefits of insect proteins. Reduce greenhouse gases? Check. Produce more edible protein while using less land than more traditional livestock? Check.

That last one's an easy target; livestock take up about three-quarters of the world's agricultural land. And livestock production is also a major source of greenhouse gases, accounting for about 15 percent of emissions caused by human activity.

But no one had run the numbers on bugs as livestock, until now.

The bugs in question are mealworms, actually larvae of the mealworm beetle, Tenebrio molitor. Mealworms are no strangers to Americans; they're common in nature, often used as fishing bait, and sold in pet stores as food for reptiles and fish. But most people don't consider snacking on the wriggling tan larvae themselves.

In order to persuade those of us who still savor a medium-rare steak, Dennis Oonincx, a graduate student at Wageningen University, has been hard at work calculating the environmental impact of meat production from mealworm farming. He measured land use, energy needs, and greenhouse gas emissions, and published his results in the journal PLoS ONE.

When it came to land use and effect on greenhouse gases, the mealworms soundly beat dairy production, pork, chicken and beef. The mealworms needed just 10 percent of the land needed to produce an equivalent amount of beef, including the land needed to grow feed grains and forage. (Mealworms happily feed on grains and carrots.)

But it took more energy to produce a kilo of bug protein than it did to get edible protein from milk or chicken. Indeed, the tiny critters were more on par with pork or beef. That may be because mealworms need to be warm to grow. More than half of the bugs' energy use went for gas heat and electric light. The other half went for production and transport of carrots and grain.

Undaunted, Oonincx and his colleagues conclude that mealworms "produce much less [greenhouse gas] and require much less land, than chickens, pigs and cattle. With land availability being the most stringent limitation in sustainably feeding the world's population, this study clearly shows that mealworm should be considered as a more sustainable alternative to milk, chicken, pork, and beef."

You may not be convinced. But in the Netherlands, at least one restaurant has featured mealworms as part of its bug buffet. The diners gave rave reviews.

And if you're not ready to eat bugs, farmed salmon sure is. Aquaculturists are experimenting with using ranched flies as food in commercial fish farming. They're also under consideration as emergency food for refugees.

An Article by Nancy Shute
http://www.npr.org/

Norms

"Under the wide field of 'norms', we address all issues that affect the behaviour of people towards mealworm-based food products. Also, the desirability of accepting insects as food is investigated, especially with regards to the nutritional value and environmental impact."

Why are Westerners disgusted by insects?

Let us put the currently observed Western disgust towards insect consumption in a historical prospect.

Agriculture was born ten thousand years ago in the Fertile Crescent, a region located in western Asia, before it quickly spread to Europe. From a nomad hunter-gatherer way of life, men started to domesticate plant and animals to secure their food sources, thus became sedentary (Henry, 1997).

The domesticated animals were mainly large ones, not only because they were present in these regions but also because they could supply wool, leather, warmth, milk and strength (for farming or transportation) in addition to meat; what insects cannot. Moreover, the seasonality of insects -especially in these non-tropical regions where most of them hibernate- added to the uncertainty of their supply, made them an unreliable source of food for Westerners, and especially urban areas (FAO, 2013).

In parallel, along with the plant domestication, insects became a pest able to destroy entire harvests. This is one of the reasons why Westerners culturally associate all insects with nuisances. Examples such as mosquitos, ticks, fleas or flies able to transmit illnesses to humans; or termites eating the wood of their constructions only deepened Westerners' aversion against insects. Not to mention the shapes of insects, seen as monstrous and repulsive by many Westerners.

Westerners also rapidly associated insect consumption with some primitive and therefore contemptible behavior inherited from the hunting-gathering times; forgetting pleasantly that the Greeks and Romans themselves ate insects in ancient times (DeFoliard, 1999)

Because of this historical and cultural background, disgust is the first reaction of many Europeans when suggested to eat insects.

Some reasons to hope a change

Just as every social norm, the current observed disgust of insects can be changed within some time. Let us take the example of the Japanese sushi that is now very popular in Europe although the idea of eating crude fish was first considered as disgusting by most Europeans.

"We eat crustaceans, and insects are related to them. We eat shrimp and lobster, which are similar to grasshoppers, as well as mussels, octopus and shrimp."

-See the article by Inez Benitez

-Eduardo Galante, president of the Entomological Society of Spain and director of the Ibero-American Centre for Biodiversity at the University of Alicante, Southeast Spain-

Besides, many people would be willing to try insects. Some encouraging experiments carried out in Belgium (Megido, et al., 2014) showed indeed that on 189 respondents from both genders and different ages, although 46.6% of them had a negative attitude toward insects; 77.7% of them were willing to try it.

This demonstrates curiosity and desire to try novel food (see the focus on this study on next part).

The popularity of insect tasting events such as "Pestaurant" in the UK (Rentokil) confirms this tendency of a growing interest for insects. Even more encouraging: more and more restaurants cooking insects open their doors in the Western countries (Insect Europe)

Another illustration is that there are more and more Google researches in the edible insect fields (see graphs from Google Trends below).

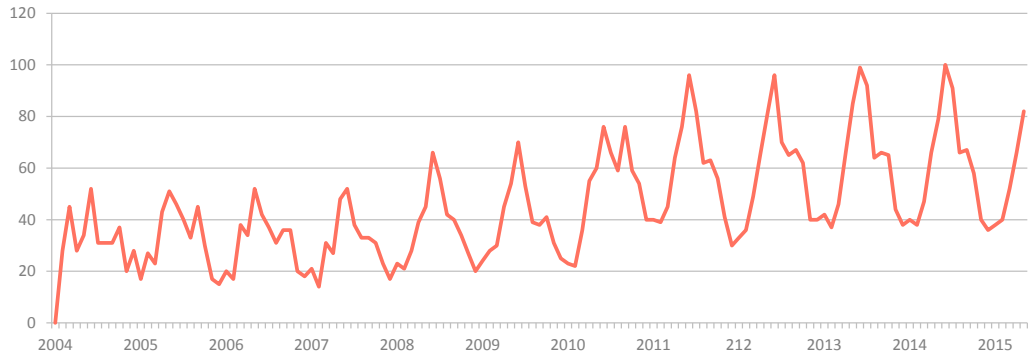
According to a statistical study carried on 368 Westerners (Verbeke, 2014) the likelihood of adopting insects as a substitute for meat is 12.8% [95% CI: 6.1–19.4%] for males and 6.3% [95% CI: 2.8–9.9%] for females; which is not negligible, though can be developed.

What is interesting is that one out of five meat consumers claims to be ready to adopt insects.

As another result, customers who want to reduce their meat intake are 4.5 times more likely to adopt insects. Therefore, the most likely early-adopters of insects as a meat substitute are young males interested in the environmental impact of their food choice, open to try novel food and with weak attitude towards meat. The likelihood that such a person adopts insects as a meat substitute is 75%. This group of people represents our core market.

Last of all, familiarity with entomology multiplies by 2.6 this likelihood; which confirms that communication on these practices is important for the development of this market.

"Google trend" analysis of the key words *eat bugs*



Source: http://www.google.fr/trends/explore#q=eat%20bugs&cmpt=q&tz=
For 100 queries in the USA, 56 were made in Canada, 39 in Australia and 18 in the UK.
Letters represent published papers in the field

"Google trend" analysis of the key words *eat mealworms*

Source: http://www.google.fr/trends/explore#q=eat%20mealworms&cmpt=q&tz=
For 100 queries in the USA, 85 were made in the UK.

Focus on the "Edible insects, acceptance by Belgian consumers" study

Let us go deeper into the "Edible insects, acceptance by Belgian consumers" study (Megido, et al., 2014) which conclusions are that insects associated with known flavors and crispy textures were preferred and that people seemed to be willing to eat and cook insects in the near future.

These results have to be qualified by the fact participants were from Belgium, a country ahead from other European countries in insect consumption and that it offered tastings of only specific preparations of two insect species. The overall acceptance issues require further investigations.

However, this study provides a good base for the acceptance of mealworms. Indeed, these results are consistent with other studies on importance of flavors in the acceptance of food.

Pre-survey

For this study, a pre-survey was made to evaluate Belgian participants' knowledge on entomophagy (see results on table below):

Number of positive answers to the pre-study questions (N = 189)

Age classes (years old)	n	"Are you informed about entomophagy?"	"Are you really interested in eating insects?"	"Do you have a negative feeling toward entomophagy?"
< 13	18	33.33% a	66.67% a	33.33% a
13 - 18	57	24.56% a	77.70% a	42.10% a
19 - 25	32	93.75% b	84.37% a	53.13% a
26 - 45	50	88.00% b	86.00% a	42.00% a
>45	32	71.88% b	71.88% a	53.13% a

Source: Medigo and al., 2014

Remarks: Consumer number who responds "yes" for the three questions. different letters show a significant difference for age classes at $P < 0.05$ (Chi-square test)

A statistical analysis show that the age factor was significant only for the first question (information about entomophagy). 62% of the respondents had already heard about entomophagy, especially the 19-25 year-old class (almost 94%) and the 26-45 yeas-old (88%). 77.7% of the respondents were willing to eat insects although 46.6% of them had a negative feeling toward entomophagy. This demonstrates a certain curiosity toward novel food.

Tasting experiment

Various insect formulations had been prepared from mealworms and house crickets to be tasted by participants. As for mealworms-based preparations, there were:

- Mealworms baked at 200°C for 7 min
- Mealworms boiled for 6.5 min
- A crushed mix (1:1) of baked house crickets and mealworms
- Baked mealworms flavored with a pinch of dried vanilla
- Baked mealworms flavored with a pinch of paprika
- Baked mealworms dunked in chocolate

Respondents were not forced to eat all samples.

A statistical analysis of the results revealed that the global liking of insects only depended on the preparation method. The most preferred preparations were the crispy mealworms with chocolate, paprika and baked naturally. Mealworms with vanilla, house crickets baked naturally and the crushed mix of both species were moderately liked. For mealworms with vanilla, it seemed that the association between both ingredients did not work as expected.

Hedoic test

Last of all, questions were asked to participants after the tasting.

Number of positive answers to the hedonic test questions (N = 189)

Age classes (years old)	n	"Did you taste all the preparations?"	"Are you willing to eat insects in the future?"	"Would you cook insects at home?"
< 13	18	72.22% a	77.78% a	44.44% a
13 - 18	57	78.94% a	77.19% a	35.09% a
19 - 25	32	71.87% a	81.25% a	62.50% b
26 - 45	50	90.00% a	92.00% ab	66.00% b
>45	32	90.63% a	96.87% b	50.00% ab

Source: Medigo and al., 2014

Remarks: Consumer number who responds "yes" for the three questions. different letters show a significant difference for age classes at P < 0.05 (Chi-square test)

The age was a significant factor for the two last questions only. 82% of the respondents tasted all the preparations. After the experiment, 85% of the respondents were willing to eat insects in the future, especially those older than 26 years-old (>92%). They were more than 51% to declare they would cook insects at home, especially the 19-26 years-old (62.50%) and the 26-45 years old (66%). These are very encouraging numbers for the acceptance of insects as food.

Mealworms, fresh or powder?

Acceptance enhancement

It has been proven that the aspect of food is one of the key factors for acceptance. Its preparation is indeed important: food where you can't see the reminders of insects like legs or wings are more easily accepted (Megido, et al., 2014). That is one of the reasons why we want to convert mealworms into flour.

Many other quotations support this theory, like the ones we can find in an article from Terramérica, with a resident of Málaga proclaiming eating insects was disgusting before adding that the idea of eating them after they have been processed and turned into flour was "interesting", because "at least that way you wouldn't see them."

-See the article by Inez Benitez

Better nutriments values

Unsurprisingly, mealworm powder has better nutriments concentration than fresh ones due to the drastic reduction of moisture content (Siemianowska, 2013), with around twice as much minerals in the powdered from than the fresh one and twice as much fat for 2.50 times more protein (see in the following sections).

An ingredient full of prospects

A consumers' preferences survey revealed that insects were more perceived as an appetizer for 37% of the consumers (probably due to their small size and original form). Then, people were found to accept insect addition to their main dish (26%) or as a dessert (23%). To a lesser extent, respondents also proposed addition of insects to salad (7%) or soup (6%), and finally, consumed in their natural shape (1%) (Megido and al., 2014). As the respondents had probably in mind whole insects and were still able to picture them in so many different dishes, it opens very large horizons to process insects into different sorts of food.

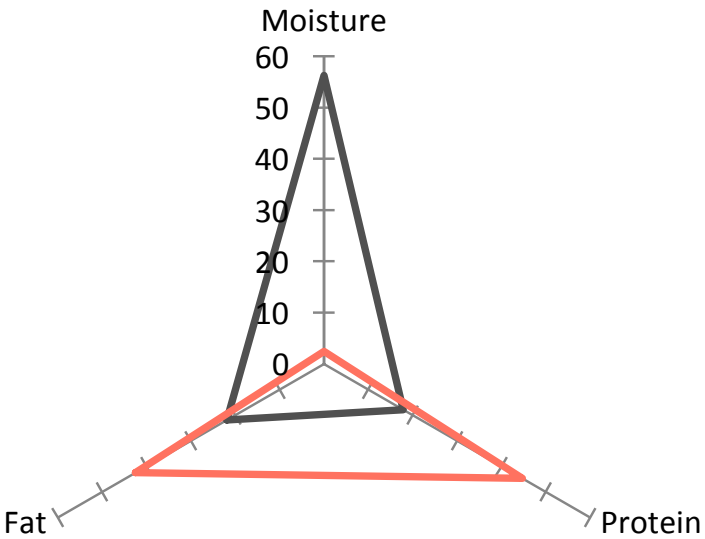
"We wouldn't eat an insect if it looked like an insect. Nor would we eat a cow if it looked like a cow."

-See the article by Ike Swetlitz

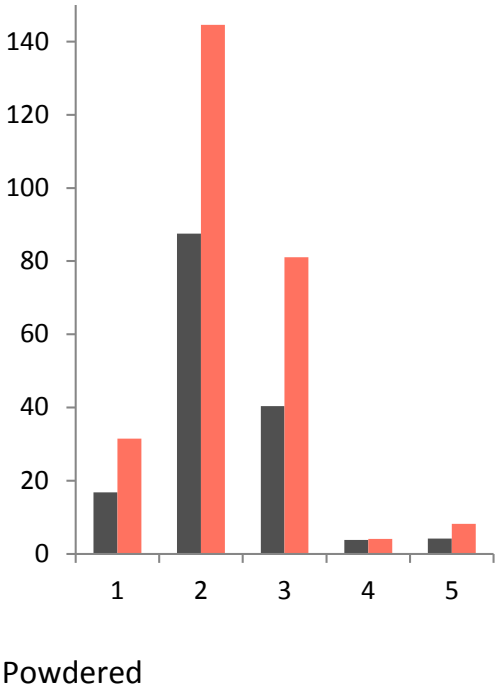
-Kathryn Redford, Canadian co-founder of Ofbug, an ento protein producer in Vancouver, BC-

Flour would just be the staple basis of different derived products. People's imagination will do the rest. There are already many receipts available for cricket flour and whole mealworms.

Composition of fresh and powdered mealworm (%)



Content of minerals of fresh and powdered mealworm (mg/100g)



Source: Siemianowska (2013)

Health issues

Some studies investigated the health effects of the consumption of several edible insects species, including their microbial safety, allergies - some cases have been reported, and nutritional values.

Regarding insects harvested in the wild, another huge source of concern for human consumption is their content in pesticides and heavy metals. Indeed, we do not know what can they absorb. The rearing of insects in a closed area would avoid such contamination risks.

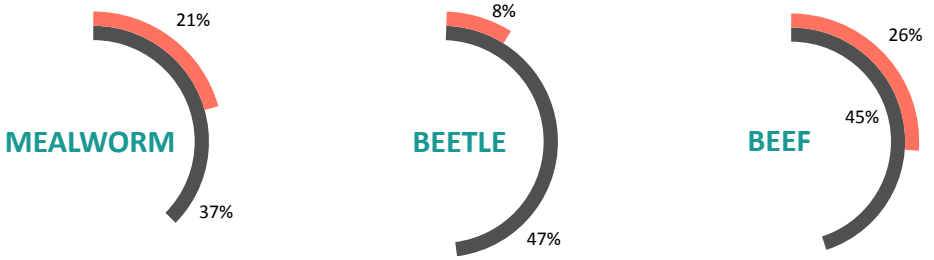
In any case, health issues regarding edible insects have not yet been completely investigated because this research topic remains quite new in the scientific world. Further scientific studies are indeed required to investigate the safety of insects for human consumption and their nutritional contents (ANSES, 2015). The safety of insects as food shall also be ensured by an adequate preservation methods and appropriate safety regulations that have not been formulated either.

There are only very artisanal preservation techniques at the moment and the edible insect supply chain has not adopted yet the Hazard Analysis Critical Control Points (HACCP) system that will probably be crucial to its further development into a real food industry (FAO, 2013)

Nutritional value of mealworms

Mealworm larvae are highly comparable to -and to some extent better than– beef in terms of nutritional content (FAO, 2013) for a lower environmental impact. Complete content studies of fresh and dried powder of mealworms have been carried out (Finke, 2002; Siemianowska, 2013).

Average ratio of nutrition content with daily recommended value



If beef is marginally higher in protein and metabolizable energy than mealworms, mealworms contain proportionally less fat, see the Protein/Fat ratio in the next table.

If we look deeper into the protein or amino-acids and focus on the essential ones (that is to say those that are not synthetized by the body), we can see that beef is higher in lysine, methionine, phenylalanine and threonine and lower in isoleucine, leucine, tryptophan and valine compared with mealworms. Their levels are usually quite comparable, though, as they totally amount for 180.3 grams per kilogram of mealworm and 188 grams per kilogram of beef. Therefore we can conclude that both products are good sources of "good" proteins.

As for the fatty acids, beef contains more palmitoleic, palmitic and stearic acid than mealworms, which are non-essential ones whereas mealworms offer far higher values in essential linoleic acids also known as omega 6. This means that most of mealworms' fat content is "good" fat.

Average approximate analysis of mealworms and beef as a percentage of dry matter

	Mealworm	Beef
Moisture	61.9%	52.3%
Protein	49.1%	55.0%
Fat	35.2%	41.0%
Ratio protein/ fat	1.39	1.34

Source: FAO 2012, [Adapted from Finke, 2002, and USDA, 2012 by D. Oonincx]

Average essential amino-acid content of mealworm and beef (amounts in g/kg of dry matter)

Essential amino acid	Mealworm g/kg dry matter	Beef g/kg dry matter
Isoleucine	24.7	16
Leucine	52.2	42
Lysine	26.8	45
Methionine	6.3	16
Phenylalanine	17.3	24
Threonine	20.2	25
Tryptophan	3.9	-
Valine	28.9	20
Total	180.3	188

Source: FAO 2012, [Adapted from Finke, 2002, and USDA, 2012 by D. Oonincx]

Essential fatty acid content of mealworm and beef on a dry matter basis

Essential fatty acid	Saturation	Mealworm	Beef
Linoleic	Omega-6 polyunsaturated	91.3	10.2
Linolenic	Omega-3 polyunsaturated	3.7	3.9
Arachidonic	Omega-6 polyunsaturated	-	0.63

Source: FAO 2012, [Adapted from Finke, 2002, and USDA, 2012 by D. Oonincx]

As for the minerals, mealworms and beef contain comparable values of calcium, iron, zinc, copper, potassium and selenium. Mealworms contain slightly less sodium and more magnesium than beef.

Last of all, mealworms have generally higher vitamin content than beef, with the exception of vitamin B12 which is almost absent in mealworms

The table below presents more detailed results of the important results of these studies. We put the daily nutritional recommended values for comparison:

Nutritional content of fresh mealworms compared to fresh beef

	Mealworm	Beetle	Beef	Daily recommended value	
General Data					
Protein (g/100g)	18.7	23.7	19-26	50	g
Fat (g/100g)	13.4	5.40	15-19	65	g
Metabolizable energy (kcal/ 100g)	206	138	250-282	1600 to 2800	kcal
Minerals (mg/100)					
Calcium	16.9	23.1	18	1000	mg
Magnesium	80.1	60.6	21	400	mg
Sodium	53.7	63.2	72	24	mg
Iron	2.06	2.18	2.6	18	mg
Zinc	5.20	4.62	6.31	15	mg
Vitamins					
B1 (Thiamin, mg/100g)	0.24	0.10	0.046	1.5	mg
B2 (Rhiboflavin, mg/100g)	0.81	0.85	0.176	1.7	mg
B12 (µg/ 100g)	0.47	0.56	2.64	6	µg
C (mg/100g)	1.20	5.40	0.06	60	mg

Source:
FAO 2012, [Adapted from Finke, 2002, and USDA, 2012 by D. Oonincx]
www.wolframalpha.com/input/?i=daily+recommended+calories#subpod 0200 1 zoom
www.wikipedia.org/wiki/reference daily intake
www.wikipedia.org/wiki/beef#nutrition and health

Remark: It seems that the nutritional content of mealworms can be affected by their diet and environment, just like it affects its growth speed (FAO, 2013).This shall require further study, but possible opens new horizons for their rearing.

As a conclusion, the consumption of mealworms represents an excellent alternative to beef meat as they offer the same amount of protein and minerals than beef with more vitamins (except for the B12 vitamin) and less fat –which on top of that is mostly composed of the essential and healthy omega 6.

Microbial safety

At the moment, it has been proven that a heating step is sufficient to get rid of Enterobacteriaceae and other in mealworms. However, the presence of spore-forming bacteria remains a potential risk that cannot be completely solved by boiling. Further research has to be carried out including refrigerating, drying and acidifying (Klunder and al., 2012)

Allergy

According to some studies, people frequently in contact with mealworms larvae risk to develop allergic reactions such as the inflammation of the eyes and nose (FAO, 2013)

Environmental impact of mealworms compared to livestock

Feed conversion ratio (FCR)

The feed conversion ratio (FCR) for concentrates (kg/kg of fresh weight) for the mealworms was evaluated at 2.2, which means that you need 2.2 kg of food to rear 1 kg of mealworms. This value is similar to those reported for chicken (2.3) but lower than for pigs (4.0) and beef cattle (2.7–8.8) (Oonincx, Itterbeeck, Heetkamp, Brand, Loon, & Huis, 2010)

GHGs and emission: Global Warming Potential

A study (Oonincx, Itterbeeck, Heetkamp, Brand, Loon, & Huis, 2010) was carried on five insect species including mealworms to determine their Greenhouse Gas (GHG) and ammonia emissions. It turned out that mealworms produce far less GHG CH4, N2O, CO2 than pigs and beef, and far less NH3 than pigs.

CH_4, N_2O, CO_2 eq. and NH_3 production (average ± standard deviation) per kilogram of mass gain

Species	CH_4 (g/kg mass gain)	N_2O (mg/ kg mass gain)	CO_2 eq. (g/kg mass gain)	NH_2 (mg/ day/ kg mass gain)
Tenebrio molitor (n = 4)	0,1 ± 0.03b	25,5 ± 7,70 b	7,58 ± 2,29 b	1 ± 2,0 a
Pigs	1,92 - 3,98	106 - 3457	79,59 - 1.130	1140 - 1920
Beef Catle	114	N/A	2.850	N/A

Source: Adapted from Oonincx and al, 2010

A more recent study (Oonincx & Boer, 2012) evaluated the mealworms lifecycle overall Global Warming Potential (GWP), proving that it is far lower than over livestock.

Energy use

The same study (Oonincx & Boer, 2012) evaluated the Energy Use of mealwoms, which is similar to other livestock. This is because in order to reach the optimum temperature to rear mealworms, farms usually have to use heating systems.

Land use

The same study (Oonincx & For every 1 ha of land required to produce mealworm protein, 2.5 ha would be required to produce a similar quantity of milk protein, 2–3.5 ha would be required to produce a similar quantity of pork or chicken protein, and 10 ha would be required to produce a similar quantity of beef protein, according to still the same study (Oonincx & Boer, 2012)

Mealworms use far less land than beef, and less than other livestock animals. This is a particularly important feature since, although we can reduce energy consumption and plant trees to reduce the total GHG emissions, land is definitely limited.

Water use

1 kg of chicken requires 2 300 to 4300 liters of virtual water, 1 kg of pork requires 3 500 to 6000 liters and 1 kg of beef requires 15 400 to 22 000 liters (depending on the sources).

Such data is not yet available for mealworms, but we can try to estimate this value.

As a species used to live in flour and therefore very dry environments, mealworms do not drink water; they just find it in the moisture content of their food. Therefore, the virtual water consumption of mealworms lay almost entirely in the water used to grow the plants they are fed with.
Mealworms are very drought-resistant. However, too little moisture slows growth and reduces size. If larvae are provided with dry food, they can survive and produce one generation a year; but if they are provided with moisture, they will undergo six generations per year and will be fatter. (Sialis website). Therefore, mealworms have a better growth rate if their environment has a satisfactory humidity level –usually 80% in commercial companies - and if they are provided with fresh food.

1kg of potato requires 290 liters of water ; 1kg of lettuce 240 liters; we need 280 liters for 1kg of cabbage, 350 liters for 1kg of cucumbers and 822 liters for 1kg of apples (waterfootprint.org).

Depending on their diet and considering their 2.2 Food Efficiency Ratio, mealworms potentially require between 600 and 1800 liters of water, which is less than all the other livestock.

Rearing on organic side streams

Several studies including a project that involves the European Commission called “DESIRABLE” aim at evaluating the potential of insects as biomass converters by rearing them on waste.

Indeed, it is said that, as they are very efficient at bio-converting organic waste, the yellow mealworm along with the black soldier fly and the common housefly could collectively convert 1.3 billion tons of bio-waste per year (FAO, 2013)

However, rearing insects on organic waste for human presents unknown risks of pathogens and contaminants. In virtue of regulations (EC) n°1069/2009 and (EC) n°767/2009 forbidding animal to be raised on kitchen wastes and manure, it is unlikely that this research project will lead to applications in actual production (ANSES, 2015), although this would unlock a vast potential of biowaste reduction.

Conclusion

Mealworms present a best Feed Conversion Rate, offer smaller land and water uses with less GHG and ammonia emissions than all the other traditional livestock for similar energy uses. They are definitely more environmental-friendly than beef, pig and chicken.

Laws

“In a modern society, laws regulate the boundaries of what is possible.
Most insect food producers today are working in a grey and almost lawless zone, what is seriously limiting the possibility to scale up. We investigate the current situation and prospects for law about insect food in Western countries in this part.”

Legislative security

As explained in the key drivers, the legislative framework regarding the rearing of edible insects for human consumption is unclear, with no national regulations on it. There are no international guidelines provided by the Codex Alimentarius (a database providing international reference standards for food and feed) either. On the opposite, there are laws on maximum permissive levels of insect contamination in food products for humans such as grains (FAO, 2013).

This blurred legal environment is a big obstacle for massive investments to develop their production. Indeed, as long as you do not know about the safety standards you have to respect, it is impossible to make big investments in industrial breeding and transformation processes and you cannot make sure customers will thrust your products.

> "There are no international guidelines provided by the Codex Alimentarius, hence no clear regulation at the moment"

Still, the situation is very likely to evolve in the coming years, with the advances of research in the field of edible insect safety and thanks to the growing attention insects are subject to.

Laws and regulations in Europe for edible insects

In EU, edible insects are considered as Novel Food because they were not consumed to a significant degree by Europeans before May 15, 1997. Therefore, the European Novel Food Regulation (EC n° 258/97) should apply, restricting their trade as long as their safety has not been investigated (European Parliament, 1997). The European Commission is currently financing a scientific study in partnership with China plus other countries in Europe and Africa that aims at better evaluate the potential health risks and advantages of edible insects.

> "In EU, edible insects are considered as Novel Food (EC n°258/97), which interpretation is ambiguous"

It will be finished by April 30th 2016. (PROteINSECT, 2015). One might hope that its completion will accelerate the trade authorization of edible insects for human consumption in the European market. A hope sustained by the coming revision of the Novel Food regulation planned in 2016.

The interpretation of this European Novel Food Regulation (EC n° 258/97) is somewhat ambiguous. Insects as human food are partly –and always unofficially– tolerated in countries where legislation is unclear, like in France or the UK (Day, 2015). At the moment it is up to each state-member to decide for itself on specific cases.

In Spain for example, insects are allowed to be eaten in restaurants who buy them for foreign suppliers, but not to be sold for consumption. Health authorities vetoed indeed an edible insect shop in Barcelona in 2008 (Benítez, 2013).

On the other hand, Belgium became the first European country authorizing 10 species to be commercialized in December 2013 (Flanders Today, 2014).

The Netherlands also have a very permissive attitude towards insects and are probably the most advanced European country in that issue. A Dutch Supermarket called Jumbo decided to put insects on its shelves last November 2014 (Brody, 2014). The Dutch Laboratory of Entomology in Wageningen University is very active. Besides, this university co-organized with the FAO a conference titled "Insects to feed the world" last May 2014.

Law and regulations in the United States

The industry of the breeding and processing insects for human consumption is growing every day. Pitifully, it is facing big problems in the United States because of the lack of clear regulations on the matter. Right now, there is no state in the Union that clearly have specific regulations towards insect breeding or production for human consumption. It seems that the laws and institutions were not ready for this industry to spur out. It is true that the breeding of insects for animal consumption has been widespread throughout USA and there are regulations regarding this as in any other pet food or feed. (Regulations such as the level of waste, pesticide, rat droppings, etc.). Sadly all this regulations are not fit for a human – grade farm. Due to this, the entrepreneur companies that have started in the edible insects market cannot set their process to any regulations. This can bring problems and uncertainty to the customer about the quality of the product they are eating.When addressed directly about the topic of edible insects, the FDA states that even if there is not a specific law that speaks about insects, the FDA does "have" regulations about this industry. This is because the FDA requires by law the following: "All the food must be clean and wholesome (with no filth, patogens, bacteria,

toxins, etc.) and must be produced, packaged, stored and transported under sanitary conditions. Including a proper label of the content". As a consequence they consider that there is a regulation, although not specific, about how to process the insects. The broad statement gives too much space to different interpretations. A situation that could be problematic in the future. On the other hand, the breeding of insects can bring a lot of complex situations. As there is no clear regulation about it, the companies can decide to feed the insects with waste or low quality feed, therefore rendering a possibly not healthy insect. Also, there is no regulation about the workplaces or the farms and the beef farm regulations cannot be adjusted to insect ones. What is clear is that the United States government has to start developing regulations focused on this emerging market. As there is no prohibition for neither the breeding nor the production of edible insects, the industry is going to thrive in the US. However, it is likely that there is going to be huge differences in quality and cleanliness between brands, as anyone is going to interpret the broad regulations to their best interest.

That situation is currently happening in other countries, like Canada. On Canada the CFIA (Canadian Food Inspection Agency) is looking into making insects viable as a feed ingredient. But there is no formal law that regulates the breeding or processing of insects. Inevitability as insects become more accepted and cheaper to produce, this laws are going to be passed. However these legal processes are long and it will take some time for them to be ready.

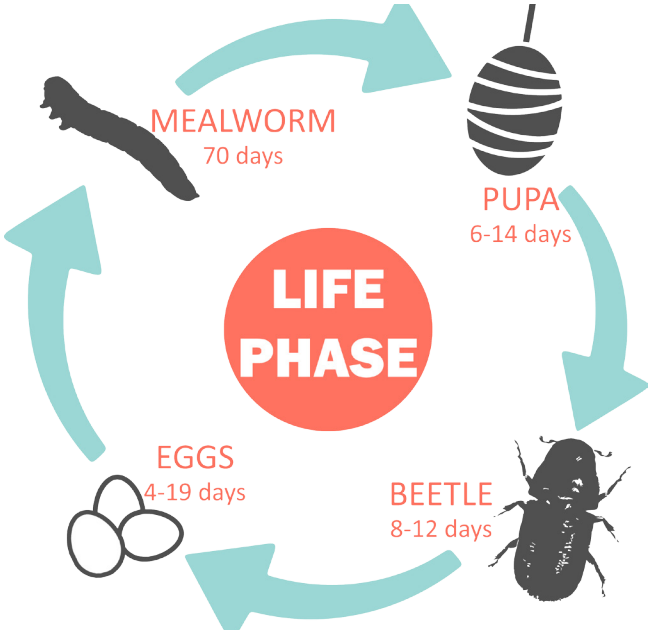
Technology

“Agricultural technology has greatly improved since the industrial revolution, allowing us to feed our fast growing world population. As insects are only considered as a food source in the West since a couple of years, they missed that productivity increase. Innovative startups already pioneered practices to produce insects on an industrial scale. Here, we look at current practices and suggest some improvements, drawn from solutions in similar industries.”

State of the art

The farming of mealworms today is not completely new. It is done on an industrial scale for exotic pet food and other animal feed. The other farming method is home farming, also mainly for pet food. The strict food safety requirements for mealworms for human consumption are not met by those methods. A few startups are trying to fill this gap. Their industrial farming methods are kept as a company secret. The fact that an efficient supply chain or machines for the industrial use have not been developed yet, makes it very likely that the professional farmers also use home methods in their production process. While there is little knowledge about the commercial farming, there are many tutorials online on how to farm mealworms at home. Mealworm is a stage in the life cycle of beetles. Starting with an egg, the egg evolves to a larva which is the mealworm itself (peakprosperity.com, 2013). Then the larva turns into a pupa. Out of the pupa a beetle hatches.

Home farming is usually done in a small transparent plastic box. The first step is to clean the box. This step includes emptying and disinfection of the box in order to kill any pests and sterilize. The sterilization process is done by putting it in an oven. The next step is to put a bedding into the box. The bedding usually consists of chicken feed and oats (peakprosperity.com, 2013). After this the mealworm eggs are placed into the box and some organic food is added. Home farmers usually use carrots, potatoes, celery, squash, and watermelon rinds. On top of providing food, a side effect of these vegetables is the higher humidity in the box necessary for the mealworms. It is suggested to use a 60% humidity by 28-30° Celsius. When they are grown, the process of harvesting is done manually. The farmers pick the grown mealworms out of the box and separate them from the bedding. This step is the most work intense part of farming mealworms. After harvesting, they are fasted in a cool environment (6-15°C) for a couple in order to empty their stomach and intestines (FAVV, 2012). Then they are washed and frozen to -18°. Afterwards they are freeze-dried in order to preserve them for a long time.



This QR code leads to a Wikihow for farming mealworms

Video 1

Video 2

Improvements through industrialization

Our goal for the farming process is to provide a constant superior quality of mealworms while lowering their price. We shall not start from scratch, however: we shall improve the current process of farming mealworms used by private farmers. The major enhancements are done by analyzing the process steps and then improving it. The cycle of mealworms growing from an egg to a beetle has been statistically described. The larvae will not transform from eggs on a deterministic time. So by farming many eggs some will transform earlier and some later. The optimal time for harvesting them is the 7th or 8th week from the initial farming process step. Assuming a normal distribution for that process the percentage of bycatch consisting of eggs, pupas and beetles is shown in the graph.

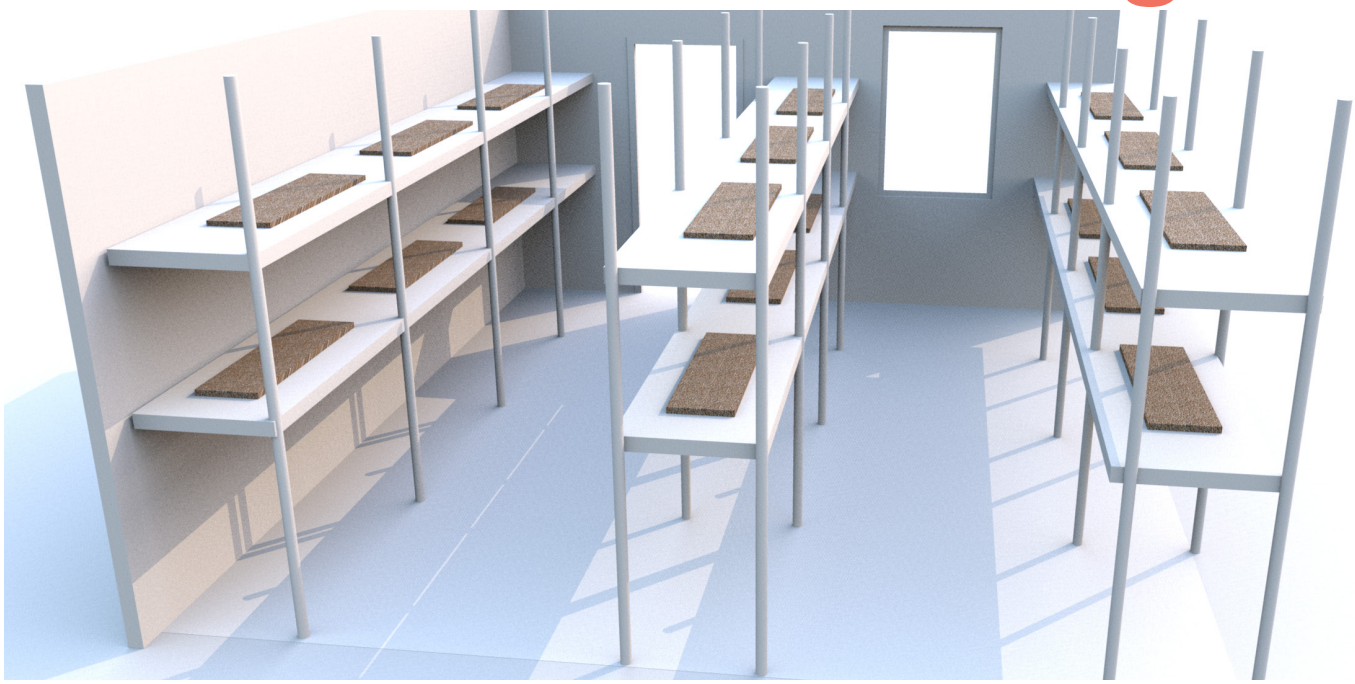
To reach our goal of superior quality, the bycatch, the bedding and scratch must be separated from the product. Home farmers do this process step manually. This step is very labor-intensive which leads to high costs due to wages, even in low cost countries. Secondly, the frequency of repeating the same process step is very high. So, the manual work is potentially automatable. An industrial quantity of mealworms produced per time justifies the initial cost of a purpose-built machine to separate mealworms from the bycatch. There is a high variety of machines for applications like separating harvest goods from waste. Agricultural machines use the different size of the waste and the product to separate them. One application is done by running harvested goods over a grid with gradually differing widths. The gap between two bars is getting bigger. So in the first section small parts fall down between two grids. Then the mealworms are bigger and fall in the next section. The rest that falls of at the end of the machine is also waste. The two exemplary videos show the process for onions.

Due to the fact that the harvest of mealworms is biological and therefore not a completely controllable process, the risk of a failed harvest must be reduced. One way to do this is to farm in separate “fields”. The boxes used in home farming can be kept to achieve this. They provide a good tradeoff between an economic amount and fail safe production. Farming in smaller boxes will decrease the amount of mealworms farmed. With those smaller amounts the fixed costs have to be allocated to fewer products, which will increase the costs for a specific quantum. In case of an epidemic, the risk on spreading the disease is low. Bigger boxes contain large populations, what increases the effect of an epidemic on the production output. Farming in small boxes is a good trade-off to keep risk low.

To make the factory more economical the density in the room available has to be increased. This can be realized in multiple layers and rows. The third dimension must be left accessible for the staff. The picture shows an example for such a layout.

A further improvement is a more scientific approach to optimize the variables of the farming process. The humidity and temperature are crucial variables that have to be controlled and regulated over the whole process. Instead of organic food to provide the necessary humidity, a digital sensor in a control loop with a humidifier is more accurate. Such a system sets up the possibility to evaluate and have an early warning for a process out of control. Hygiene standards in the classic food industries have to be adapted. The legislative requirements in western countries for the farming of food will force the farming companies to set up specific hygiene standards. Moreover, the farmers themselves have an interest in food safety. Collecting all process data can rapidly lead to improvements. Every new mealworm lifecycle, slightly changed input parameters can be used to improve the rearing conditions. With this approach, business interest and the advancement of science go hand in hand.

Proposed layout for mealworms breeding



A Generic Prosess for Farming Mealworms

Front-end		Main Process		Back-end	
Cleaning	Preparation	Start	Wait	Harvest	Preservation
■ Empty the Box ■ Disinfect ■ Sterilize	■ Bedding into the Box	■ Placing the eggs into the Box ■ Add food	■ Wait 7-8 weeks ■ Surveille the mealworm	■ Separate the mealworm from bedding and food	■ Empty the stomach ■ Wash and freeze

Conclusion

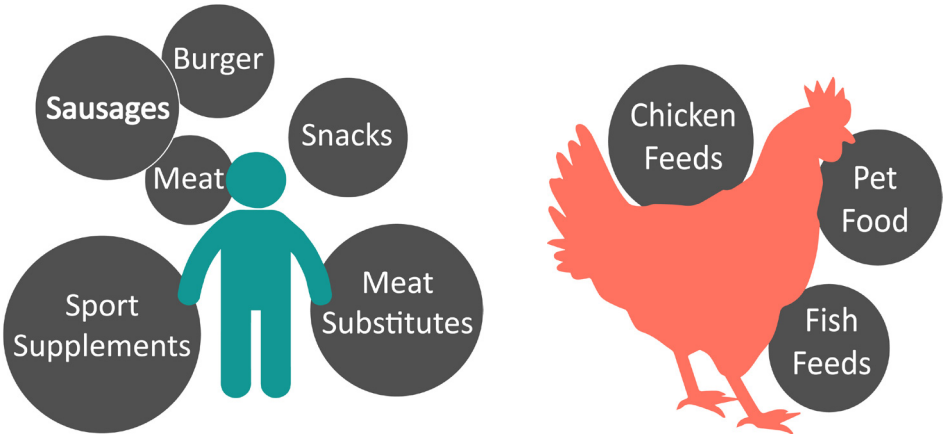
The proposed technique have a strong relationship to ones used in the agricultural and food producing business. Some of the techniques are transferable while other have to be new designed. So even though mealworms are a competitive product they would profit from the development.

Market Study

"Insect based food products can try to address many existing markets.
We quantify the size and price level of possible markets them in order to find opportunities. Then, we assess the competitive landscape with help of Porter's forces.
You can also find an overview of current players in the insect and mealworm food business here."

Market to seize

The current market for insects in the West is very small. The customers mainly consist of early adopters, foodies, people who like to try new or exotic things. Also, it starts to become popular as a party snack. Because the market is that new, analyzing the current customers and markets says very little about the future market insects as food can seize. We believe, to get an idea of the possible impact of insects as food, we should look at current similar markets where insects, and more in particular insect flour, can be a substitute. For these markets, we want to get an idea of the economic, ecologic and health impact insects can have. We identified the following markets insects can possibly substitute:



Human Consumption

Meat

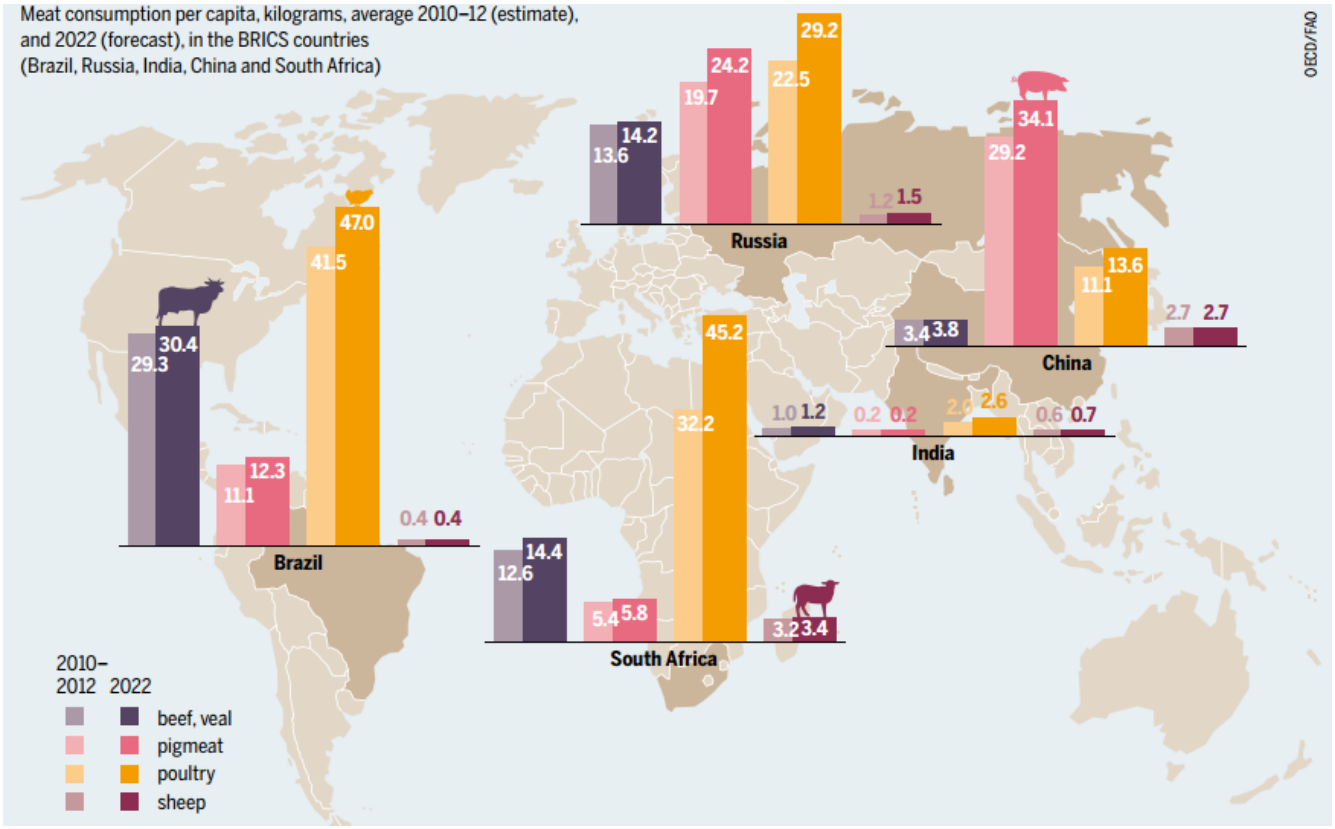
Insects are animals. Therefore, food made out of insects could be considered as meat. The most obvious market for insects is therefore the meat market. The Meat Atlas by Heinrich Böll Foundation and Friends of the Earth shows how much meat is consumed per capita in selected countries (Heinrich Böll Foundation & Friends of the Earth Europe, 2014).

As you can see in the picture in the next page, meat is a huge market. However, although meat products made from mealworm flour can theoretically replace any meat, their most direct competitors are processed meats. A product based on mealworm flour can substitute a processed meat product, while there is still a difference between a steak and a mealworm burger. A short overview of the size of two promising processed meat industries is given here.

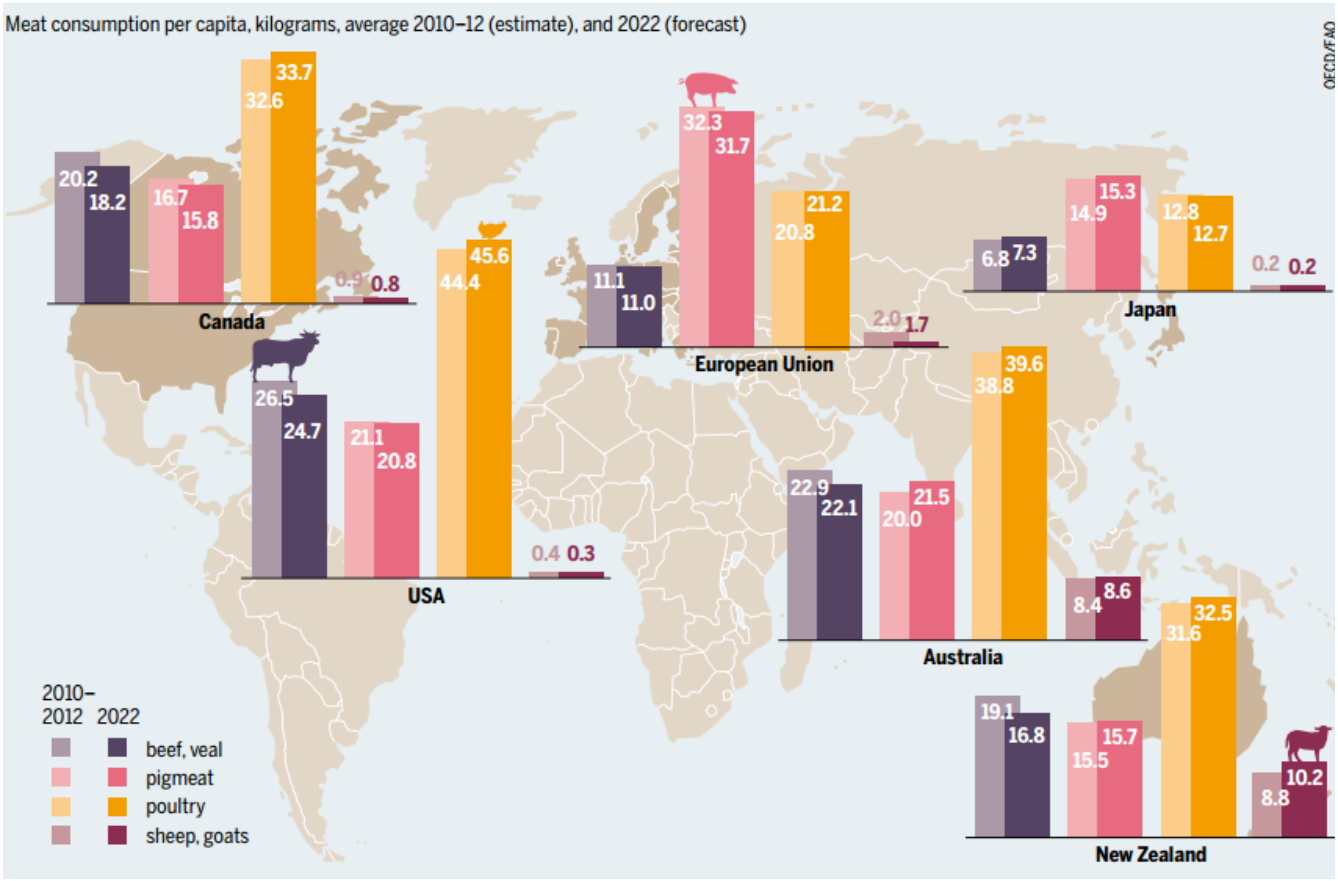
Sausages

Business Analytic Center calculated the total European sausage production totaling 5,3 million ton at a market size of 19,5 billion euro (PRWeb, 2012). It's a highly fragmented market with individual tastes that differ seriously among countries. The US market of sausages and other processed meat products totalled 20,4 billion $ in 2009 according to Dun & Bradstreet (HighBeam Business, 2015). The average price of a kg of sausages in the USA is 9,7 $ / kg (Wolfram Alpha).

Mintel gives the current issues impacting this market : health, product quality, freshness and the search of new flavors and ethnic compatible products (ResearchMoz, 2014). A transparent production process of mealworm flour as main ingredient in a sausage can adress most of these issues.



Source: Stiftung, 2014



Source: Stiftung, 2014

Ground beef : burgers and meatballs

The global market for beef is expected to reach USD 2.151 billion by 2020 (Grand View Research, 2014). In 2012, 67.400 kilo tons of beef was produced. Of that, 43,9% or 29.500 kilo ton was sold as ground beef.

The retail price of a burger in the USA is historically high due to the lowest cattle herd in 60 years and not helped by environmental problems such as the drought in Texas (Hill, 2014). The retail price of a kilo of ground beef in american supermarkets reached 9,15 $ (AGWeb, 2015).

Cheaper burgers, containing more fat and other health affecting ingredients are still widespread. This is one of the main reasons that poor people in developed countries have a higher chance to be fat. However, the general public can react severely when they discover that inferior ingredients are used in their burgers, as the recent horsemeat scandal showed (The Guardian, 2013). Scan the QR code for an in depth article about cheap burgers:

A burger made of mealworm flour with transparent ingredients, nutritional content and production process can be competitive on this market. It will first attract part of the people who eat high quality burgers. If economies of scale grow and price goes down, it can even play a big role on the cheap burger market as it will be a way more healthy alternative for such cheap burgers. An insect company betting on this market in Belgium is Conbuggie.

Meat Substitutes

Meat substitutes in the West are products that are related to meat in terms of taste and nutritional value, but with plant based proteins as the main ingredient. Sustainability and health concerns are the main reasons to eat these products. Therefore, while the market was originally mainly intended for vegetarians, now the average health conscious urban citizen becomes the target. With the apparent health and ecological impact insects can have, it is very plausible that insects will be a viable alternative for the meat substitutes market.

In 2013, this market had an estimated size of 3.2 billion $ worldwide. Today, 80 % of the market is soy based (MarketsAndMarkets, 2014). The main products are tofu, tempeh, seitan and quorn. Lots of small players compete in this market. The 5 biggest players are : Quorn Foods Ltd. (U.K.), Blue Chip Group (U.S.), Vbites Foods (U.K.), Amy's Kitchen Inc. (U.S.), and Cauldron Foods (U.K.) (PRNewswire, 2014). Market Analysts believe the market will grow with a CAGR of 4.4 to 6.4% up to 6.4 billion $ in 2019 (MarketsAndMarkets, 2014) (Foodnavigator, 2012). However, Western market analysts completely underestimate the size of the Chinese market, where tofu is a mainstream part of the diet. The tofu market alone was worth 11 billion $ in 2014 in China and has been growing with a CAGR of 20% a year during the last 5 years. This growth is not expected to slow down as domestic demand is still increasing (Ibisworld, 2014).

In the USA, tofu sells for about 4 $/kg . Vegie sausages sell for 12 $/kg and vegie burgers sell for about 6 $/kg (Indiana Soybean Board, 2015).

Sports supplements

Sports supplements is quite a big market encompassing all bars, powders, drinks and alike that people eat or drink in addition to their normal diet to help their sport performance. Historically, the main customers of this market were young male adults wanting to grow their muscles faster after power workouts. However, this market is more and more becoming diversified and targets now all kinds of people who are doing sports to improve their health. Important in these products is that they contain exact amounts of the additional nutrition people want. This means a simple insect powder would probably not be able to become a resource for this market. But, if it is possible to extract the proteins and omega 3 and 6 fatty acids insects are rich of, they could become a resource for this industry. Another option is to play with the inputs. The nutritional value of insects can be influenced by the food you give them (Redford, 2015). Bug Muscle is a company that will start with the production of insect based nutritional supplements for athletes in middle 2015 (BugMuscle, 2013).

Studying what analysts think about the size of this market gives some useful insights. In 2007, BCC Research forecasted that the total market size would be 91.8 billion $ in 2013 (BCC Research, 2008). In 2011, GIA estimated that the market would reach 67,1 billion $ in 2017 while in a recent report they forecast a size of 61 billion $ in 2020 (Sportika, 2011). It is clear that analysts tend to believe this market will grow way faster than it actually does. Also, almost 95% of this market is sports drinks, a category insect powder probably can't be an input for. The most consumed protein supplement is whey protein, with an average price of about 20$/kg in the USA (Bodybuilding.com, 2012).

Snacks

A lot of the startups trying out insects as food are targeting the snack market. Insects can be seen as a healthy and exotic snacks. Especially for parties this snack becomes popular. Listed below are some companies that sell snacks made out of insect:

www.delibugs.nl
www.mangeons-des-insectes.com
www.sixfoods.com
www. chapul.com
www.hotlix.com
www.bugsworldsolutionfood.com

The global snack market is mainly concentrated in the USA and Europe. It is a very broad term, including sweets and candy, cookies, crisps, nuts, fruit and much more. In total, this market amounted for 374 billion $ in 2014 (Nielsen, 2014). However, with data from Euromonitor we can notice that healthy snacks, without fruits and nuts, have only a share of 3% in that market (Euromonitor International, 2014). Even more, the market share of healthy snacks within the total snack market is decreasing. This raises concerns about the sustainability of the business model of insects as a snack.

Animal Consumption

Makkara et al. state that a 60–70% increase in consumption of animal products is expected by 2050 (Harinder P.S. Makkara, 2014). IFIF believes in an even more spectacular growth : meat consumption doubled by 2050 and fish consumption tripled (IFIF, 2010). The resources needed to supply all those animals with feed will be enormous. In this Industry Analysis report, we focus on producing mealworm flour for human consumption. If more mealworms are eaten, this will substitute part of the traditional meat eaten. But we have to acknowledge that people will not completely change their diet from big animals to insects without any disasters obliging them to do so. Therefore, it is important to assess the size of the market of the feed of the animals we eat and check whether those markets can be penetrated by insects as well. Moreover, with such growth perspectives of an already huge market, completely neglecting animal feed cannot be justified in economic and ecological sense.

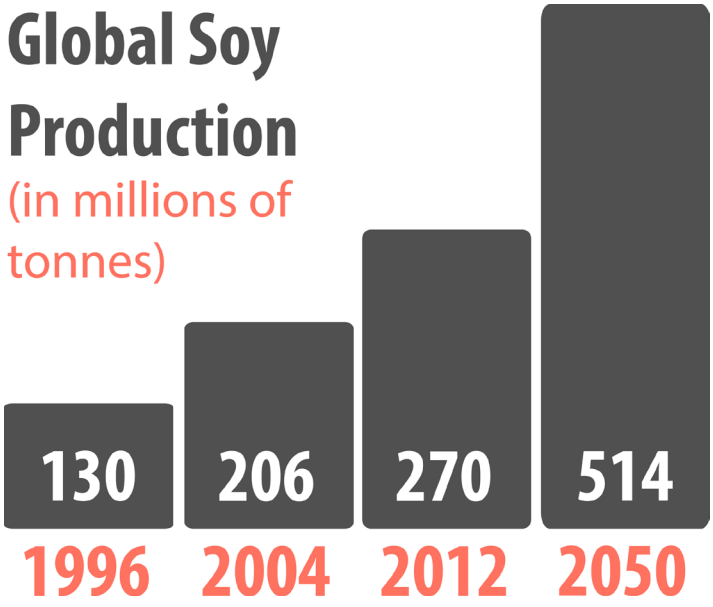
Another possible market for mealworm flour is the use in petfood. That will be breefly covered as well.

Source: www.protix.eu

Animal Feed

The current total global market of animal feed has a size of 370-500 billion $ per year (IFIF, 2010) (Alltech, 2014). This results in almost 1 billion ton of feed per year. The main categories of animal feed are feed for poultry (444 million ton), pig (243 million ton), ruminant animals (including cow and sheep) (196 million ton), fish feed (40 million ton) and pet food (21 million ton) (Alltech, 2014). The lower amount of feed for ruminant animals is due to the fact that they are still today mostly fed on pasture from grasslands.

Most animals grown for human consumption need a proteine rich diet to grow. Therefore, corn and soy as protein rich grains, are the most popular animal feed. In addition, animals need sometimes animal protein to supply them with necessary amino acids. Fish meal is the most popular animal protein feed. The overreliance on grain-based animal feeds in industrial food animal production has negative consequences for animal health, the environment, and even human health (Sustainable Table, 2015). Grains for animal feed use 40% of total land use in agriculture (Redford, 2015). WWF warns for the growth of soy production, as especially in South America the growth of soy farms is already affecting the rainforest.



Source: WWF, 2015

Insects provide a good alternative for proteine rich grains as animal feed.
A good start to learn something about insects for feed is the Kathryn Redford TedX talk 'what to feed our food' ((Redford, 2015).

Makkara et al. give the state of the art of insects used as animal feed. 5 species of insects are promising as their nutritional quality is rougly comparable with current soy and fishmeal : black soldier fly larvae, the house fly maggots, mealworm, locusts–grasshoppers–crickets, and silkworm (Harinder P.S. Makkara, 2014). The insects themselves can be fed by biological waste. In that case, they help towards a world with less waste while at the same time depleting less natural resources as traditional feed. Off course, a process that can ensure that the waste is not contaminated needs to be developed for such applications. Nowadays, European law does not allow to feed animals on waste. These regulations are a relic of the 1990s BSE crisis (Fleming, 2014). 25-100% of traditional animal feed can be replaced by insects, depending on the insect and animal species. As supply of insects is nowadays still very small, poultry and fish feed will be the easiest to start supplying insect feed to. Other animals require a large supply of feed before they can switch to a new feed source.

Data of mealworms used in animal feed is not yet widespread. It could replace feed for chickens if supplemented with methionine. If only 10% of chicken feed is replaced by mealworms, no supplementary products are needed. A case for catfish is investigated with the result that 40% of the feed can be replaced by mealworms (Harinder P.S. Makkara, 2014).

Price levels to compete on were about 500$ per ton of chicken or pig feed in 2013 (Alltech, 2014). However, especially in the poultry industry, fishmeal is nowadays a very important part of the diet for chickens. 20% of all fish caught worldwide is used in fishmeal. Due to the deterioration of the marine environment, the price of fishmeal is increasing. In 2010, that price was 2000$ per ton, a much more comfortable price to compete on for insects (María-José Sánchez-Muros, 2014).

The industry of insects for animal feed is still small but already more advanced than the industry of insects for human consumption. Some companies are already for years in the business and produce insects on industrial scale. Haocheng Mealworm Inc. is the biggest mealworm producer known and produces 50 tons of mealworms per month of which 200 tons per year are exported (Haocheng Mealworms Inc., 2013). Other companies producing different kinds of insects for animal feed are: AgriProtein(South Africa), Enterra Feed Corporation (Canada), Enviroflight(USA), Ynsect(France), Protix Biosystems(The Netherlands). (BBC)

Pet Food

USA and Europe accounts for more than 70% of the pet food market, for 90% existing of dog- and catfood (PMMI, 2013)). However, with insects in mind, we should not forget about more exotic pets, who already eat large quantities of insects for their diets nowadays. It is a slowly growing market with a worldwide market size between 60 and 70 billion $ (Transparency Market Research, 2014) (Canada, 2010) (PMMI, 2013). To give an example, the price of dog food is about 2$/kg (flagpets).

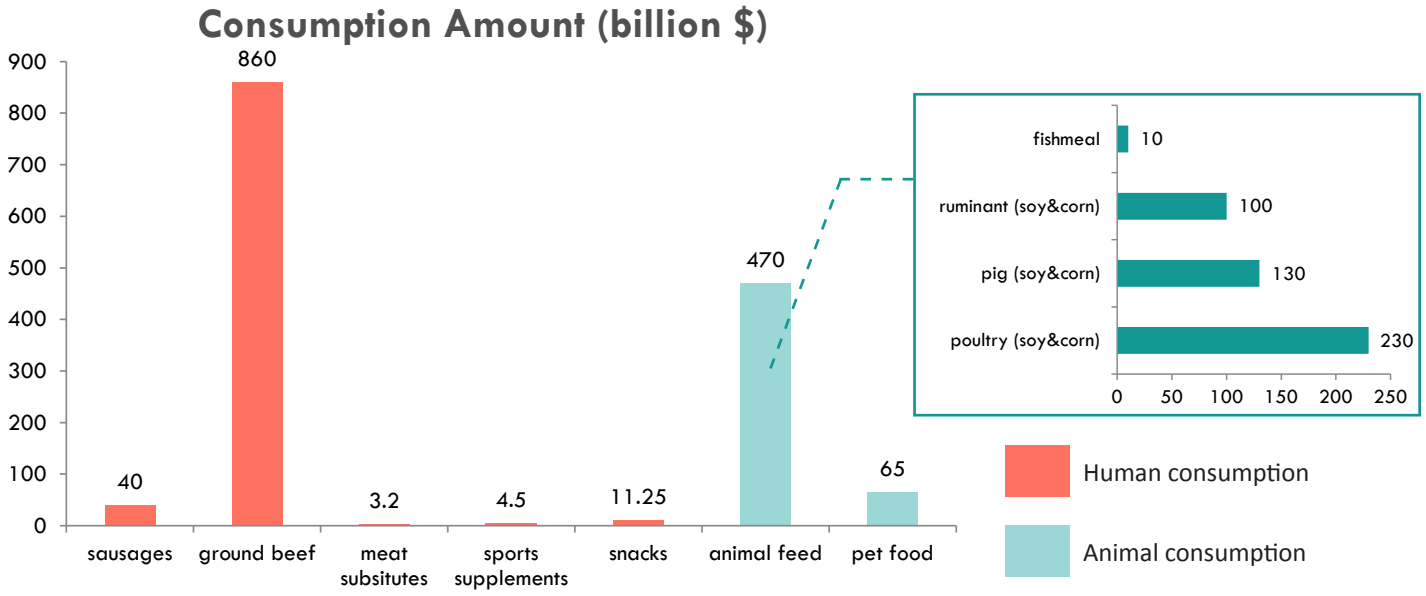
The market is mainly dominated by a couple of big players : Mars, Nestlé, Colgate-Palmolive, Procter&Gamble, Del Monte Foods (Canada, 2010).

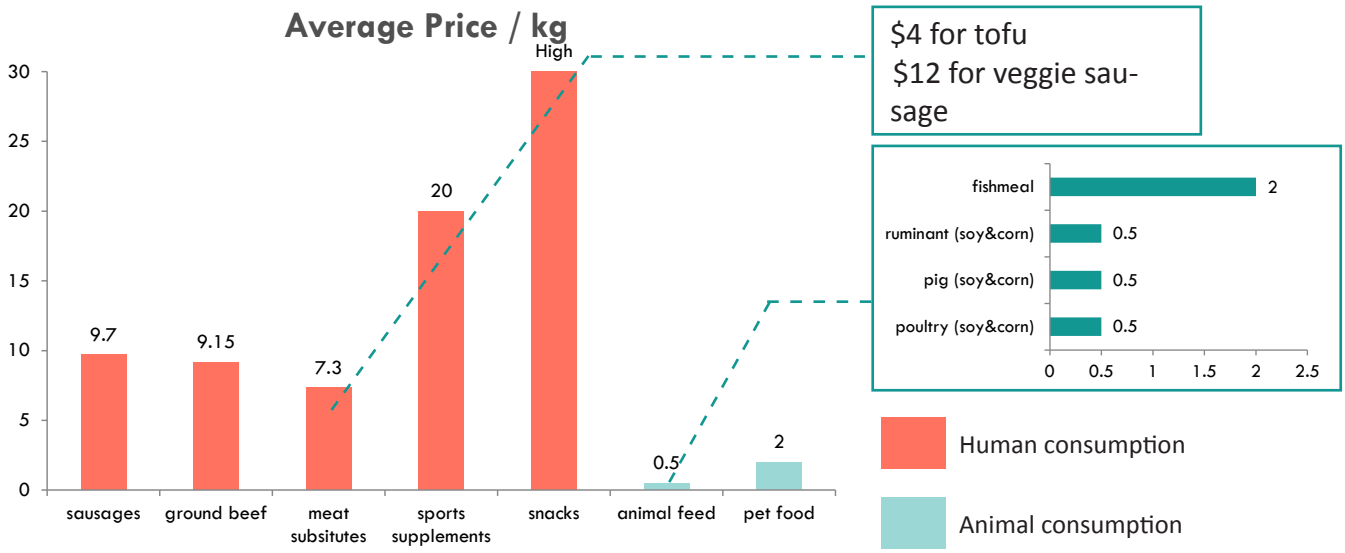
An important market trend in the pet food market is the humanization of pets. Lots of people regard their pets almost as human beings, part of their family. This reflects in the market, where the same trends as in the human food market are seen : a trend towards healthy, organic and sustainable food. Also, in the USA, most customers expect that their pet food is made in the USA and not outsourced to production facilities in developing countries. These trends have both positive and negative implications for an companies who want to start producing insects for food on industrial scale. The trend towards healthy and ecological food can affect insects positively, if proper marketed. The trend towards local production can shield them from low cost competition. This competition can be severe, for example, in China, the company HaoCheng Mealworm Inc. is already processing insects on a vast industrial scale. On the other hand, the humanification of pets also raises questions about the acceptance of people to feed their pets insects (Phillips-Donaldson, 2015). Will people who don't want to eat insects themselves feed their pets insects?

Conclusion: A comparison of the most promising markets

An entrepreneur starting in the insect business should have an idea of which markets are most promising. To help visualize this, we made 4 graphs representing estimates of the market sizes and price levels of the food and feed insects and more specific mealworm flour can compete on. The numbers are based on the referenced estimates from market analysts and other sources as specified in the text. In no case the authors want to state that these numbers are exact or correct, the only purpose is to give a rough estimate that can help with choosing a market.

The graph about the price per kg of food is the one most interesting for insect startups nowadays. Most of them are small scale and the technology is not mature yet. that means they have to offer products that compete with products with a high unit price. Only in that way they can offer a competitive price. Later on, it becomes more important to look at the size of a market, as this is an indicator for the growth opportunities.





It is clear that mealworm flour is not ready to compete on animal feed. The unit price for feed is too low. It makes no sense to try to sell mealworm flour made for human consumption as animal feed. The high standards needed, involving not using waste as a food resource, make it too expensive.

This explains the focus of this report on mealworm flour for human consumption. Right now, the most promising markets seem to be snacks and sports supplements, as they can ask a high unit price. This is partly seen in the current landscape of insect farmers, in which most of the companies sell snacks made of insects. However, clearly there is a gap in the market of sports supplements, where only one company is completely focusing on. If a company can produce insects with the right nutritional amount, this is an opportunity. However, both the healthy/ party snack market and the sports supplement market are rather small. Way bigger and with still a high unit price are the markets of ground beef (burgers) and sausages. Also, the unit price for them is still on a rather high level. If companies can grow to a certain threshold in terms of technology and economies of scale, the burger market can become more lucrative than the snack market. However, companies will have to keep in mind that they market their product as a competitor for high quality burgers. Marketing against low quality burgers result in a too low unit price to compete against, marketing against meat alternatives results in a market that is rather small.

Buyer Power

End product buyer:
- The buyer can buy either bulk size or retail size
- The primary channel for buyers is web stores
- The buyers are less sensitive to high prices (gourmet/ innovative food)
- Low customer loyalty
- The customers can breed mealworms

Producer of end product:
- The customers can breed mealworms
- Low customer loyalty
- The mealworms can be customized by their needs
- The mealworms can be bought online
- Sensitive to high prices

Supplier Power

Self-producing insect farm:
- No supplier

Farm supplier:
- Human consumption level suppliers are few (less than 50 worldwide)
- The size of the suppliers is small (less than 50 worldwide)
- There are a couple similar products (buffalo worm, soldier fly larvae)
- There are no regulation set for breeding in some countries

Competitive Rivalry

- Not many competitors
- Innovative products
- Small target market
- The product offered is different (transparent processes)

Threat of Substitution

- Vegan grade produced food is already positioned in market
- Vegan grade produced food has no negative social acceptance factor
- Subtitute products price tag is high
- Meat is highly available and still preferable
- Vegetables are cheaper and highly availabe

Threat of New Entry

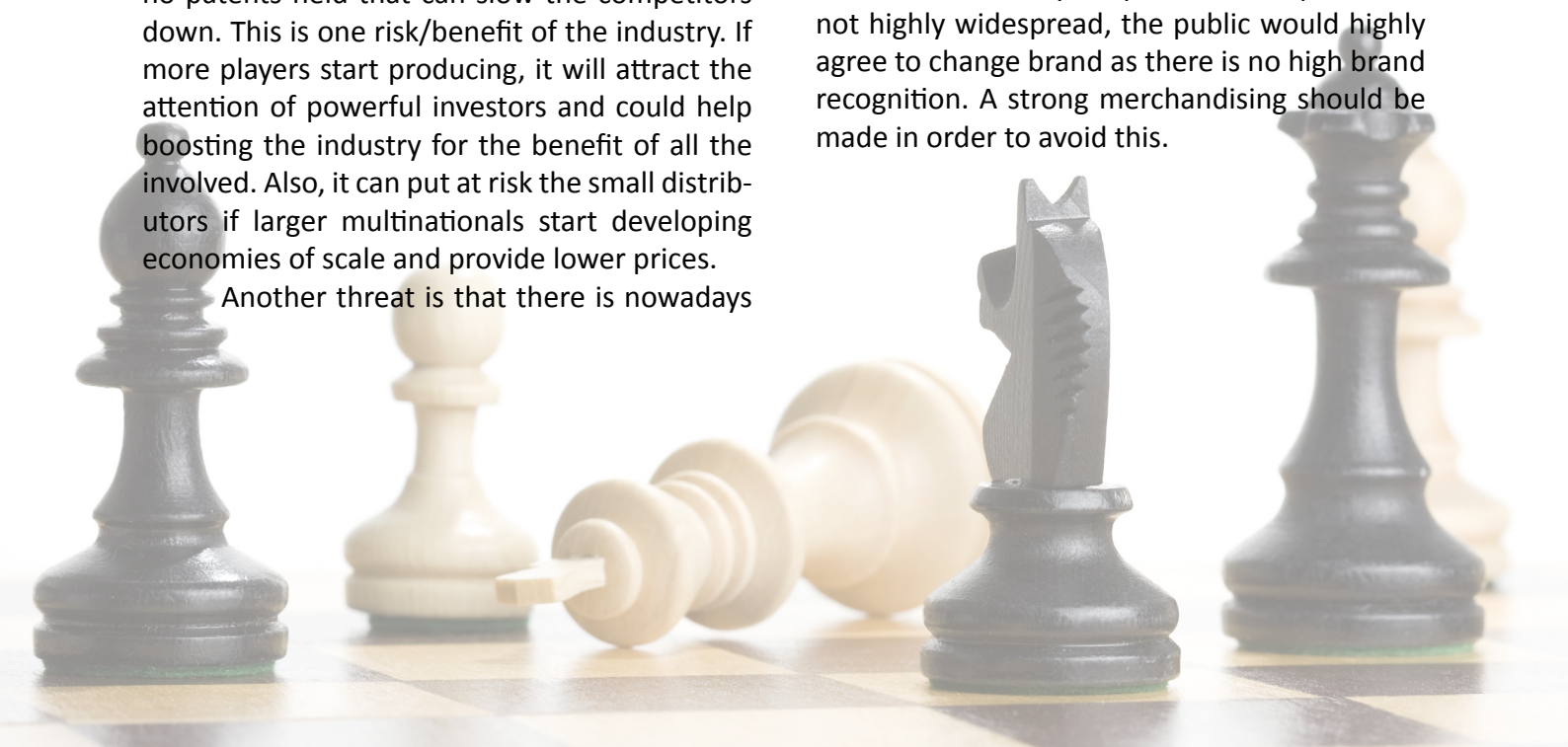
- Pet consumption level producers are moderate high (less than 200 worldwide)
- Pet consumption level producers can adjust their processes and produce human consumption level products
- The product difficulty is low, competitors can be set up overnight
- There is no brand recognition yet
- Processes are easily replicable
- No patents held

Porter's 5 forces

Threat of New Entry

The industry of mealworm products doesn't involve the usage of very complex industrial tasks neither in breeding nor processing the insect. Therefore, it is likely that new companies can enter the market without requiring too large economic investment or time. Also as the processes are not hard to replicate, there are no patents held that can slow the competitors down. This is one risk/benefit of the industry. If more players start producing, it will attract the attention of powerful investors and could help boosting the industry for the benefit of all the involved. Also, it can put at risk the small distributors if larger multinationals start developing economies of scale and provide lower prices.

Another threat is that there is nowadays a considerable (less than 200 worldwide*) number of companies that process and breed mealworms for animal consumption. This companies have already a very structured and organized process. If they were to decide and adjust their methods to produce human-grade mealworm products, then that could make the market more competitive. The last threat would be the lack of brand awareness by the public. As the product is not highly widespread, the public would highly agree to change brand as there is no high brand recognition. A strong merchandising should be made in order to avoid this.



Threat of Substitution

As everyone has to eat, the market for products that satisfy this basic need is swamped with different alternatives. This gets narrowed down when closing in to products that do not include animal meat yet can provide the nutrients to survive. Insect based flour will face primarily the vegan-grade foods. This products are made with vegetables, mushrooms, algae and roots. They use chemicals and sauces to imitate the flavor of common foods like beef or pork. These products have lots of nutrients that the real meat does not, but lack very important others (high content of protein, fat).

Even though vegan-grade products do not provide much proteins, there have been in the market for more than 5 years. Those products are already embedded in the minds of the target market and are highly available in specialized supermarkets and vegan stores. Furthermore, the vegan-grade products do not generate the "disgusting factor" on the buyer, thus making them even a mightier substitute that will be hard to overcome. On the bright side, the vegan-grade products are pricy, so customers could decide to buy our product instead if the price difference is attractive enough.

One of the big problems of entering the food market is that it is highly controlled by the meat products. Even if our target market is specifically people that prefer not to eat meat while keeping healthy levels of protein in their bodies. Therefore if a mealworm product doesn't meet the level of satisfaction that the clients expect, they will probably prefer to go back to eat meat in small quantities rather than continue consuming our products. Meat is highly available in any super market or restaurant, and the prices although sometimes high could overcome the trouble of dealing with flours made second-rate products.The vegetables, on the other hand, also provide a very important substitute for mealworm flour. Our target market, if unsatisfied by mealworm flour, can decide to get their proteins intake from vegetables and plants. Although the amount of vegetables and plants required to satisfy the human protein needs is high, the end user could prefer to do that instead of eating mealworm based products.

Buyer Power

End Product Buyer

In the current market the customer has a lot of strengths to exploit. Given the option that e-commerce is widely distributed and accepted, the end user can get in contact with any of the distributors of the end product with relatively easiness. Then, the customer can decide to either buy in bulk or in small retail orders. But both of this kind of orders (End product) should be issued to the distributor.

The target market of this product is open to innovative products. This kind of market is usually less sensitive to high prices, given that the production level of the innovative products is not as high as everyday use products. But it is important to know that because of this flexibility towards price, the customer is very strict with their quality needs, rapidly changing to another supplier if they suspect quality is not the expected. Also, if any of the distributors meet the desired requirements, the strictest clients could decide to contact directly the manufacturer of the insects, and buy the insects to produce their own customized products themselves. Or even make the decision to breed by their own, customizing their insects to every recipe.

This could really affect the business of the end product producers as every restaurant/small store/insect enthusiast can start trying new inventions swamping the market with different products. On the other hand, this easiness to change of supplier through the supply chain can also boost the business as more people will be open to try new recipes that they can came up by themselves.

Producer of End Product

The companies that decide to focus on the transformation of the mealworms into an end product have also lot of power when deciding where to get their raw materials. The producers can buy the insects from an insect farming company that specializes on the breeding of mealworms. But, the lack of clear regulations as to how to breed the insects in some countries can provide a wide array of insect farms with unclear quality control in their processes. Therefore the producer can be strict when deciding on a supplier and ask for quality controls and regulations on the process.

As any company, they are seeking profit. The producers usually buy in large amounts, therefore they can ask for fair prices or simply change supplier. As the end customer, if none of the suppliers can meet their needs, the producer can opt to breed their own insects and in that way guarantee the price they need with the quality they require.

Supplier Power:

Self-producing customer

The company that decides to breed insects for human consumption has no major supplier. The common suppliers of required services such as electricity, water, gas, etc. are not considered as suppliers. Therefore we can say that this type of company would not work with any supplier.

Farm suppliers

Because consuming insects is still considered as novelty food in Western countries the legal framework to handle with this topic is still new and needs to be improved with time and experiences. That gives a good edge to companies that decide to focus on the breeding of the insects. The companies can exploit the lack of regulations in some countries at least for the foreseeable future. It's important to note that even in countries that historically have the habit of eating insects, there are no legal framework to deal with the industrial processing of them, leaving that as uncertainty for now.

Another edge for the breeders is that currently there are less than 50 companies worldwide doing the same. This means the competitors are few and scattered all around the globe. Each of them have enough market to cover without the need of hard competition, for now. Also, this companies are in their majority startups. As this is novelty in Western countries, the startup companies are mainly composed by young enthusiast. Because of this they can develop their ideas without the fear of a huge corporation entering the market.

In addition, the producers have a couple products with very similar characteristics. Although we are mainly talking about mealworm products, the larvae of the soldier fly and the buffalo worm (another kind of larvae) share lots of characteristics with the mealworms. Therefore, this also gives an edge to the producers that can shift between them based on the requirements of the market or the amount of competitors in each of those.

Competitive Rivalry

The industry of edible insects is still far from a developed state. This means that we can consider this as a "blue ocean" market scenario. This means that it is a market with very few players at the moment. The companies in this industry do not face a great number of competitors, therefore making it easier for the companies to grow. On the other hand, even if this industry is not "full" with companies yet, the social acceptance highly reduces the share of the market to be seized at the moment.

One of the key points in this industry is innovation. As for now this product is not highly appealing, the companies need to find innovative ways to reach the target market. The innovation in the breeding, industrial processing, cooking recipes and marketing should be the biggest competitive strength in this industry. Each one of the companies has to experiment with new ways to convince the market about this kind of products.

Some top players in the mealworm industry

Hotlix

This Company based in California could be considered the older player in this market as they have been selling processed insects for around 25 years. They produce "novelty" products using insects, ranging from candies to snacks. They distribute insects embedded into popsicles or prepared to eat as a snack straight from the bag. Their mealworms are sold whole with flavoring such as BBQ, Cheddar cheese or Mexican spice.

www.hotlix.com

Edible Unique

Edible Unique is one of the companies based in the UK that already have set up international shipping for their products. They have a wide range of products regarding insects. They sell whole insects dried and cooked ready to be eaten from the pack. Their products include no extra seasonings or preservatives being as natural as possible. In addition to their whole insect line, they also distribute grasshopper, pupae and mealworm flour.

www.edibleunique.com

Bush Grub

Another British company that is already venturing on the insects market. Bush Grub distributes whole roasted mealworms with different flavors. They bet that their appealing flavors will convince the skeptic. In addition they also produce mealworms based chocolate bars, being the only company that has started this kind of experiments on the market.

www.bush-grub.co.uk

Green Kow

Green kow is a Belgian company using a very original strategy. They are producing spreads using a mix of usual products as tomato and chocolate with mealworms. Therefore it renders products with a recognizable taste for the customer while packing all the protein of the insects. In addition, they are distributing their products in regular organic products stores.

www.greenkow.be/EN

All Things Bugs

Aaron T. Dossey, Ph.D. Biochemistry and Molecular Biology, started his research about insect based food about 5 years ago. All Things Bugs, his company, really take off after a 100000 $ prize he won in 2012 from the Bill & Melinda Gates Foundation to do research about insect food to stop child hunger in countries experiencing famine. After additional prize from the USDA, he started selling high-quality cricket powder last year. Having sold more than 10000 pounds, he is probably the biggest cricket flour producer to date. All Things Bugs believes mealworm powder can be even more functional than cricket powder and is currently doing research to make mealworm powder the next big thing in the insect food industry!
www.allthingsbugs.com

Other players in insect industry

Other than those four top players, there are some other companies worth considering. Here is a non-exhaustive list of those companies that offer insect-based products for human consumption.

Company	Website
All Things Bugs	www.allthingsbugs.com
Aspire Food Group	www.aspirefg.com
Big Cricket Farms	www.bigcricketfarms.com
Bitty Foods	www.bittyfoods.com
Bug Muscle	www.bugmuscle.com
Bugs World Solution Food	www.bugsworldsolutionfood.com/en
Chapul	www.chapul.com
Conbuggie	www.conbuggie.be
Cricket Flours	www.cricketflours.com
Dimini Cricket	www.diminicricket.com
Ento	www.eat-ento.co.uk
Exo	www.exoprotein.com
Insect Europe	www.insecteurope.com/index.php
Micronutris	www.micronutris.com/produits.html
MIGHTi	www.mighti.co
Next Millennium Farms	www.nextmillenniumfarms.com
Six Foods	www.sixfoods.com
The Farmed Insect Company	www.thefarmedinsectcompany.com
Tiny Farms	www.tiny-farms.com
World Ento	www.worldento.com

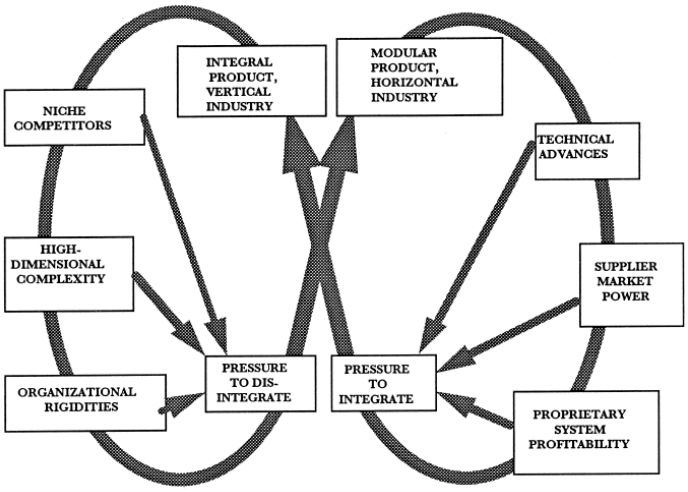
Supply Chain

"The previous parts gave a good knowledge of all forces affecting insect food producers. A supply chain strategy decides about the long term profitability of those companies. In this part, we take into account all the outside forces, or the revenue side of the profit equation, to answer decisions about the operational design of mealworm food companies, the cost side of that same equation."

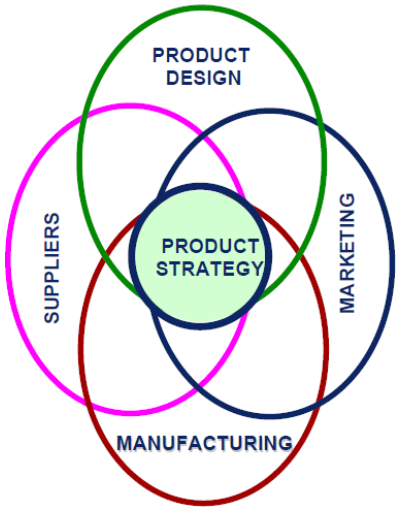
The supply chain

After studying the outside forces affecting the business, which we in this report grouped as market, norms, technology and law, a company can start developing a strategy for a successful business. However, this is not enough. A successful strategy will soon be followed by competitors. A company will get a competitive advantage when it can deliver the best products, at the fastest rate, the best quality and for the lowest cost. MIT professor Charles Fine puts it clear in his clockspeed paper (Fine, 2000). Supply chain is a strategic weapon. The model he proposes to think about and design a company is 3D concurrent engineering. It is the overlap of 3 disciplines: product (design and architecture) process (technical capabilities and manufacturing system) and supply chain(architecture and the logistics and coordination system).

Pradeep Fernandes adds a fourth dimension: Marketing. This is the connection between studying the outside forces and working on internal operations. And that is exactly where a company in a nascent market has to excel in. Therefore, in this section, we assess the dimensions of the extended "4D" concurrent engineering in the insect business.



The Double Helix



The fourth dimension

Questions Arise

Vertical integration: where should a company position itself in the complete supply chain from growing insects to seling them to customers?

Marketing: how to use the supply chain process as a strategic weapon in making customers buy mealworm products?

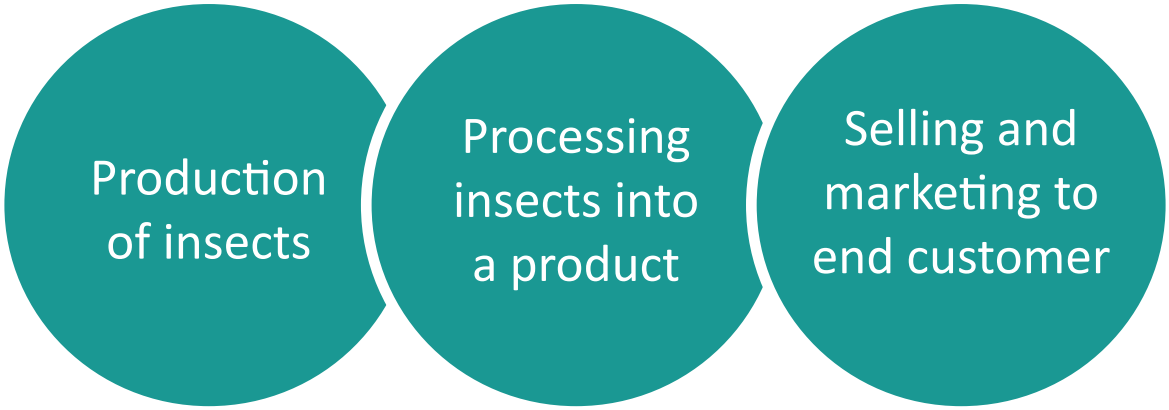
Global supply chain: should a company produce and sell globally or locally?

Clockspeed: what is the clockspeed of the industry and how does this affect innovation in the industry?

Vertical integration: positioning

In the 1980s, IBM, completely dominant in the computer industry, launched the personal computer. They chose to make it a modular system and outsourced parts such as the processor (Intel) and the operating system (Microsoft). This choice was made to increase the speed to market and simplify the task of setting up a supply chain. They got it wrong. The modular PC they built became just a standard box, while 'Intel Inside' and 'Operated by Windows' became the reasons to choose a PC for most of the customers. In 2004, IBM had to sell its PC division to Lenovo (Spooner, 2004).

This story, again by Charles Fine, reveals the strategic impact of make-buy decisions. It is not just about lowering costs. A company has to carefully choose and develop its core competencies. Only then, outsourcing decisions can be made. To help with choosing the right core competencies, we break the vertical supply chain for mealworm based foods down into 3 parts :



Production (breeding or rearing) of insects

Production is nowadays clearly a key competitive advantage because the knowledge of breeding insects is not yet fully developed. Much is done by convention and not yet backed by extensive research. Doing production in house is the only way to collect all information about processes and to implement continuous improvement.

However, once production processes are developed and the insect market starts to take off, production with as goal the intermediary product of mealworm flour will endure fierce competition. This both from existing pet food insect companies who want to tap into an additional market or other previous startups who developed their production processes as well. Mealworm flour will become a staple food that competes on price. Once this stage of competition is reached, a company needs to make the choice between staying in production or focusing on processing. If they stay, or they will have to develop the lowest cost processes or they will have to diversify. Diversifying is possible by working on the nutritional content of the flour and producing different kinds of flour meeting the nutritional needs of different market segments.

So far, we assume that production will be done in large factories. Another possibility is distributed production of insects. In developing countries, a mini livestock of insects can improve the live hood of people as it provides an additional source of income and food(FAO report p.125). In the West, urban farming is growing popular. Due to space limits in developed cities, nowadays it only supplies 5% of the urban food consumption, according to Future Directions International (Corbould, 2013). Concentrating on species such as insects, who require less space than other animals can be a strategic decision for urban farmers.

To help with a choice between traditional big factories and distributed production, we provide a list of advantages and disadvantages.

Big Factories		Distributed Production	
Advantages	Disadvantages	Advantages	Disadvantages
Economies of scale.	Large investment, large financial risk.	Less financial risk : you don't have to invest in a factory.	High coordination cost : logistics and subcontracts contracts require a substantial effort.
Control of product safety and nutritional content and collection of all process data to make fast improvements is possible with modern technology.		Less demand risk : it grows an insect community that probably becomes a loyal customer base.	High quality cost: tracking of production practices needed to ensure quality. With modern technology this should be possible.
In house development of production competencies and capabilities, development of optimal and automated production processes.		More liquidity : costs are more variable as it is easy to stop buying from some people when the demand is low due to the contracts that are small in quantity and duration.	
No complex supplier coordination system needed.			

Processing into insect products

Here economies of scale are very important. Only a fully automated process that can process insects continuously is viable in the long term. Therefore, sourcing insects from different breeding plants will involve lower risks. The cumulative capacity of different mealworm plants can be needed to suply a continuous mealworm based food product. Pests breaking out in an insect population is another risk that can be minimized with multiple supply plants. If a pest is breaking out in one plant, there can still be sourced from another plant.
Again, extensive data collection in order to reach continuous improvement is a need for a successful company. A key competitive advantage will be inventing products that have a delicious taste and good appearance. These will be needed to grow the market from almost zero today to a serious alternative for traditional meat. In parallel, the processes to make these food products will have to be developed.

Selling and marketing to the end consumer

Very related to the end product, this last part can create an enormous value if it can make people believe in the products. This will make the difference between being able to ask a relatively high price or having to compete with cheap products, such as for example frozen burgers. The next part will go in more detail about strategies to build a brand as insect producer. Here, we limit the discussion to the different possibilities in sales channels.

Supermarkets: have a high buyer power but it is the most convenient way to buy food for Europeans and Americans. Therefore, it has to become a sales channel once the mealworm product market becomes big enough. Will require to deliver high volumes with constant quality, not very suitable for a startup.

Specialized shops: shops specializing in bio- and organic food can be a good base to start selling the products. Typically, products sold there have a higher price, but they will ask to proof that the food sold is healthy/environmental friendly.

Online: Currently, this is the way most used to sell insects. However, a startup will very likely have to make use from external package delivery companies. This has some limitations. In China, delivery of food is normal, but in Europe and the USA not really. Fresh food, apart from ready meals, is almost not possible. An alternative is that a company sets up a delivery system by itself. That is risky with unsure future sales of the insect based products.

Restaurants: Can be an easy way to distribute insects. Also, cooks who like to work with an insect provider will express their creativity and find new ways to cook with mealworm flour.

Festivals-party: Tapping in the event-sector with snacks by selling on festivals or parties is another way to reach the consumer. Moreover, it is a marketing tool you get paid for. A startup only has to convince the organizators and can showcase its product to all participants of the party.

Key competitive advantages : recommendation

In the short term, with the lack of reliable producers of insects today, combined with the advantages of learning from process data, a complete vertical integration of the supply chain can be advantageous. The following graph, provided by the US Department of Agriculture, gives an indication that this strategy is probably not the best in the long term. There is a huge difference between what the farmer gets for the food he produces and the ultimate retail price the customer pays. That money goes partly to the food processors and distributors and partly to the marketing and sales channels or retailers. The more processed the food is, the bigger this difference. For complex food products based on insect flour, a big difference can be expected. Therefore, most of the generated value lies in the more downstream activities.
Still, producing of the insects itself will stay an important part of the supply chain. An analogy can be drawn with burgers, in which the best working marketing tool for the past years is using locally grown fresh beef for the burgers. The same will be true for insects.

An insect producer can make it a strategy to grow them organically and make the processors and marketeers use his high quality insects as a sales strategy.

For the processors and marketeers, a strategy can be to work closely together with suppliers and license them for products while helping them to develop the right capabilities in terms of health and nutrition.

Marketing & Supply chain as a strategic weapon

The highly educated, middle class, young urban population of the creative class in Europe or North-America are most likely to adapt to insect food. They can spend a premium on food that is delicious, healthy and environmental friendly. That insects can fulfill all these requirements is likely the best marketing tool to make them accept and embrace insect based food.

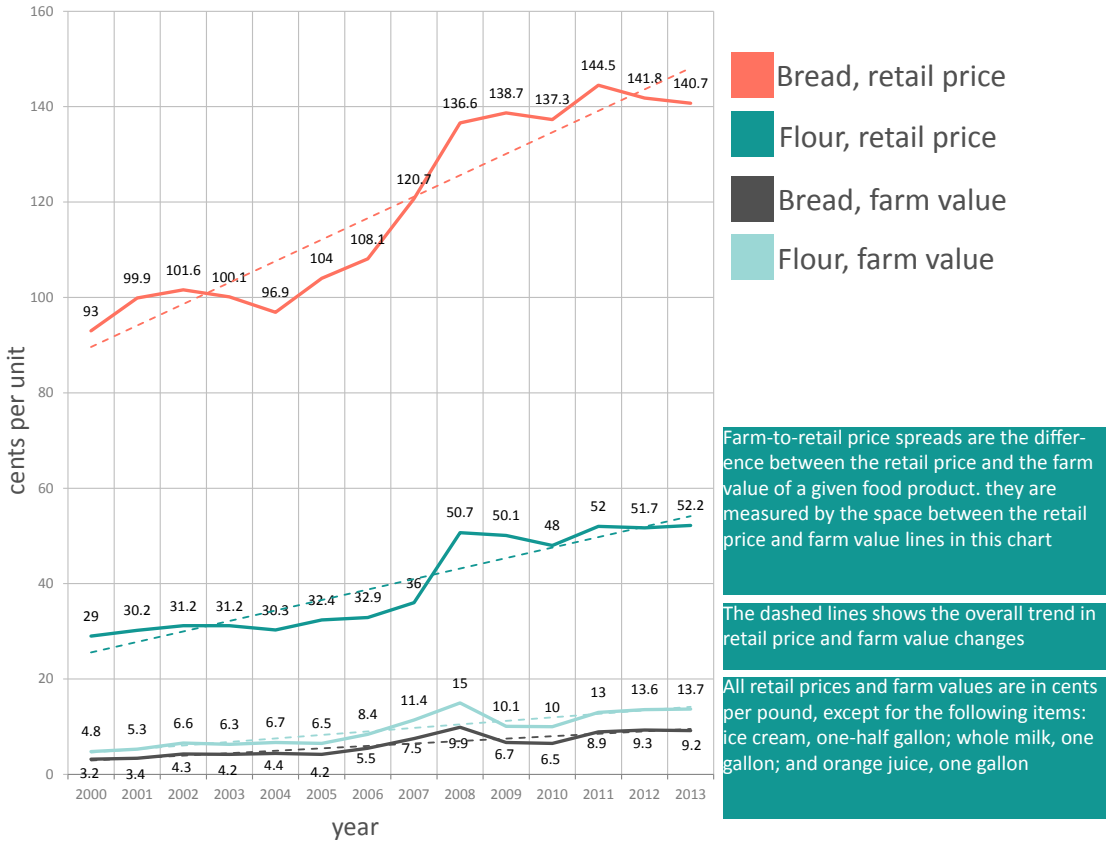
Nowadays, most startups use crowdfunding and an active bog linked to their website to grow a community. This involves a high degree of transparency of what they do. Even better in this are open source companies, in the beginning only for software, but today open source hardware companies also start operating. The advantages of this business model include pre-financing, attachment of the customer to the brand through a community and

USDA's Farm-to-retail price spreads:

Farm value shares of different food products in 2012

Price spreads are larger for more highly processed foods

The impact of farm-level energy prices on retail food



Farm-to-retail price spreads are the difference between the retail price and the farm value of a given food product. they are measured by the space between the retail price and farm value lines in this chart

The dashed lines shows the overall trend in retail price and farm value changes

All retail prices and farm values are in cents per pound, except for the following items: ice cream, one-half gallon; whole milk, one gallon; and orange juice, one gallon

Source: USDA, 2015

customer involvement in new product creation among others. An in depth article of the benefits of such a business model is written by Simone Cicero (Cicero, 2013). Would insect food companies benefit from such a business model?

Large, traditional companies are still reluctant to give away information about their products and processes. Insect food companies can make use of this lack of information for consumers who want to be informed about what they eat. Transparent information about the supply chain leading to the final product, easy accessible to the consumer, will contrast against the fuzzy origin of other processed foods. That's how the creative class can be convinced that insect food is delicious, healthy and environmental friendly.

Transparency, the strategic weapon of the supply chain.

In this part we will explain a strategy for improving acceptance. The basic idea here is that a consumer should have as much information as possible available about the complete process the final food package went through. Therefore, every package should have a unique ID with which the consumer has access to a webpage listing information about exact nutritional value, environmental impact, ingredients and production processes. Adding time and geographical stamps to the different stages of the production process and supply chain is the last important feature. It serves 3 goals:

1. **Trust:** with time and place that can be verified, a customer will be more likely to thrust the information you provide.
2. **Anti-fake products:** Having to fake a bunch of data for every fake food package will make it more difficult for companies trying to fake your products.
3. **Improvement coordination:** providing all data to the consumer also means that the company has all information of its production processes centrally available, a huge advantage in an industry that still has room for improvements.

This gives people the ability to fully understand what is inside their food. The usage of locally sourced, natural ingredients will be encouraged. Moreover, when something is wrong with the product, a unique ID makes it easy to trace it back. Spillage is also reduced, as exact information about the process parameters can be used for taylored information of how long the food product can be kept fresh.

First, we give a more detailed overview of what kind of information can be useful to attach to the product. Then, possible technologies to implement this are discussed. The information should consist of 3 big parts.

The first part is a map following the complete trajectory of the food package, from the moment the insects are born to the package ending up in the store.

Every part of the trajectory can be clicked on and then shows the time , the process done during that time (breeding, transport...) and inputs (the feed for the mealworms...) or process parameters (temperature during transport).

The second part is a table giving the exact nutritional content, comparing that content to the average nutritional content of the mealworm based product and to a substitute product not based on mealworms.

The third part is a table giving the environmental impact of the product and comparing it to substitute products. All of them involve making a base study of the nutritional content/environmental impact and then adjusting the model with the exact process parameters for every batch.

Technology : IPv6, blockchain and RFID

Currently, some existing but not yet very known or understood technologies could help with this information collection and display. The easiest way to present the information of a package to consumers is to add a QR code to the package. After scanning, consumers will reach the webpage of the package.A webpage for every package sounds crazy. Until recently, this would not be possible.

However, the new IPv6 internet standard allows for enough unique IP addresses to provide every atom in the universe with its own IP address.

Another action that would greatly improve the information storage and collection of data is attaching a chip to every package.The best would be a chip where every partial process in the supply chain writes information to. Automatically, then it can be tracked that all processes are done and under the right paramaters.

RFID is a promising technology to achieve that. Passive high frequency RFID tags can be written and read multiple times and now store up to 65 kb of information, what can be enough to store the raw process data (RFID Journal, 2005). One problem is that the price of RFID tags today starts with a couple of cents but can quickly rise to several dollars with additional functionality (RFID Journal , 2015). A more in depth research of the possibility to use the tags in this field is needed.

A last promising technology for making the entire supply chain more transparent is blockchain. Blockchain is the technology where bitcoin is based on. It provides a way to institute a trust mechanism between two parties without having the need of a third party to make the transaction trustworthy.

It works as follows, explained through bitcoin : Everyone who owns a bitcoin has a public and a private key. When you do a transaction, you need your private key to approve the transaction from one person to another. The public key of the bitcoin is handed over. That transaction of the public key is added to the blockchain. Basically, the blockchain is a long list of all transactions done since the beginning of bitcoin, stored by everyone in the blockchain network. Every 10 minutes, a new block is added to the chain, updating the blockchain of every user with the latest transactions. Now, when someone wants to spend the money again, the blockchain will notice that the person already spend the money as his version of the blockchain is not the same as the blockchain of all other users.

This very short explanation cannot cover the whole working principle and the applications possible because of this working principle. For that, we can refer to the original bitcoin paper by Satoshi Nakamoto (Nakamoto, 2008) and the book *Blockchain: Blueprint for a new economy* by Melanie Swan (Swan, 2014).

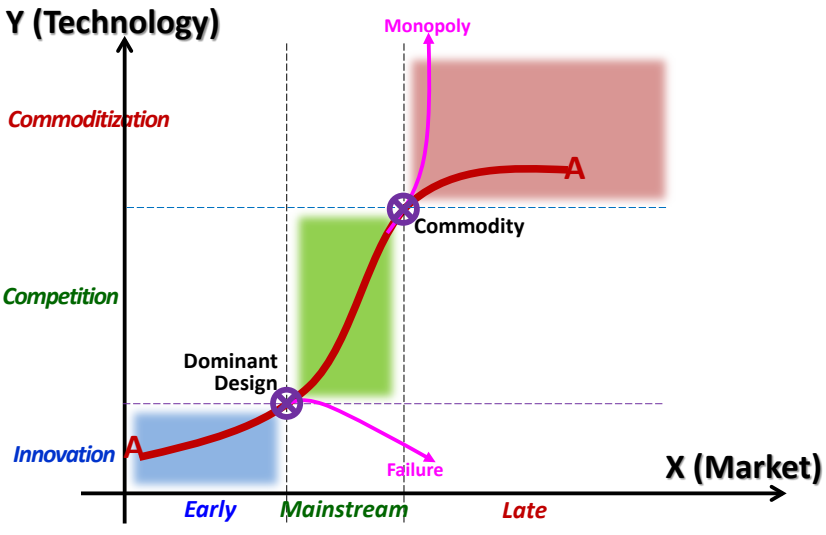
What is important is that from what you know with the explanation given here, you can start thinking about how it can be used in a transparent supply chain. Using a blockchain with a public key attached to every batch of insects resulting in a package of insect food can implement the idea of adding timestamps, trust and unambiguous information to a supply chain. It will be an easy way to control suppliers. With the blockchain publicly available, the company is accountable for the different process steps. Timestamps make sure the process cannot be faked or changed.

How exactly to implement this is a tough question. Right now, still lots of startups are in the developing phase of developing blockchains for other uses than online money. What can be done for sure is using a blockchain internally, to make all people involved in the process of making one batch accountable for their process step. Making use of such a high level of internal control and information sharing can then be used as a marketing tool to assure people that the quality standards of the company are very high. Even better would be the complete public available blockchain, but this needs more research and raises another question. Is it dangerous to reveal that much information about your processes in public?

It is true that competing companies will try to make use of the information you share. However, in a starting industry, having lots of players in the market is good. Most of the people still never heard of eating insects, so the more small companies promoting it, the better. On the famous S curve, we are still in the early market. Lots of small companies are growing the market, not really competing for the same customer. What they try to do is setting the standard, making their product or design the product people expect in this market.

Once a couple of companies can set the standard, the industry will reach a strategic inflection point as Andrew S. Grove, CEO of Intel pointed out in his book Only The Paranoid Survive (Grove, 1999). From the moment that dominant design is set, the market really starts to take off. Lots of companies fail and the ones that stay grow big and start competing with each other.

The S Curve



Source: Principles and practices
of global innovation by professor Stephen Lu, USC

This short introduction in early market economics makes clear that the biggest threat for a company in the beginning is not competition. The biggest threat is not being part of the companies setting the standard. Using modern technologies to collect all information and making that transparent can become a high quality standard all companies have to follow. Another important advantage is that only the company producing the data will have access to all data. With all this information about processes, it will be possible, together with the short life cycle and fast clockspeed (see further), to improve the production technology very fast and iteratively. That means that once the market is big, the company already has such an efficient, high end or cost effective production process that this sets a barrier for other companies to start competing.

Reach the consumer

As discussed before, online sales is the most popular medium nowadays. It seems to be that this is the general case for startups. Therefore, companies do not think a lot about how to sell their products and just assume the best way is using the internet. However, it should not be forgotten that other channels can make the difference between becoming successful or not. Having a stand selling products on festivals, selling in specialized shops, selling in fitness centers or sportsclothing shops when sports people are targeted... Every company should think about alternative ways to sell in order to pick the best one.

In a later stage, once the product becomes successful, supermarkets should be targeted. Not trying to do that, is knowing that you will only be able to compete in a niche market, even when insect food becomes mainstream. In some cases, products can even be jump started by supermarkets. A supermarket pushing insect food could greatly improve the initial acceptance. In Belgium, this is already the truth : mealworm products are sold in the supermarket since the end of 2014 (Reuters, 2014).

Sourcing & Supply chain: global or local?

A company starting today cannot afford anymore to regard the border of its home country as the border of its economic system. The world is flat, and companies need to be ready to accept the opportunities and risks of a global economy. Starting mealworm companies have to decide whether or not source and or sell abroad. Also, knowing what competition they can expect from companies abroad is very valuable.

First the last question. Competition from countries with cheaper labor can become an issue, as the high cost of producing insects right now is because of the high degree of manual work. Also there are already bigger companies producing insects in such countries. In the markets part we already talked about Haocheng mealworm inc., a Chinese company producing mealworms for animal consumption on industrial scale.

A strategy could be to start sourcing from them once they become a threat. However, 2 facts shield local production in Western countries from this threat : perishability and consumer acceptance. The last one is a big argument against sourcing abroad or being afraid from outside competitors.

Perishability: part of the food to sell will be fresh food, putting an extra barrier to companies who produce abroad. For mealworm flour in itself this is not a barrier.

Acceptance: Consumers will most likely start accepting insects when they see the benefits of delicious food, produced organically and environmental friendly, thrustable and healthy. A strategy burger restaurants use to get rid of the fast food image is exactly that their burgers are made with natural beef from local farmers.

Especially the cheap labor countries will not be regarded as the right source for healthy and environmental friendly food. Moreover, often, they will indeed not meet the quality standards set by Western countries.

At the market side, European or American companies can of course try to target other states or countries than their own. For this, first they will have to wait for more extensive regulations backing this up. Developing countries are a market for insect food as well. They already eat them so there is no barrier of acceptance. However, the business models described in this report, are focused on the West. They involve high quality processed food. This is too expensive to apply in developing countries. They have less people of the creative class and will not pay a higher price for food. A mealworm flour company will not be able to use the same business models there. Therefore, it is left out of the scope of this report.

Pleurette in Paris and Rotterzwam in The Netherlands are growing mushrooms on coffee waste in containers and other small spaces in the middle of the city. They are inspired by *The Blue Economy*, a book and movement started by Gunther Pauli (Pauli, 2010).

Insects have similar properties as mushrooms : they can be grown in small spaces or inside, could be grown on waste (if the law would allow it), target an urban population and benefit from local production. Therefore, the blue economy business model seems more appropriate than the mainstream global market model. Keep it simple and local!

Clockspeed & Innovation

Clockspeed is a concept defined by Richard Fine to compare the speed of the innovation cycle and market change between different industries. High tech industries have a high clockspeed, they can be considered the fast dying and continuously evolving fruit flies of an industry. Established global food companies are working in a much slower clockspeed, they can almost be considered as the turtles of industry clockspeeds. We believe mealworm food companies can become the fruit flies of the food industry.

First of all, there is a need. Insect companies need to innovate in their production processes to make them more cost effective and in their final products to make them more appealing. Otherwise, they just won't survive. Also, there is no ballast of existing practices and big established organizations. Creativity and innovation can still thrive. The collection of process information from the beginning will also give a competitive edge against traditional companies. Mealworms are like fruitflies. The lifecycle of a mealworm goes fast, after 7 to 8 weeks, eggs become a mealworm. Companies leveraging the fruit fly abilities of a mealworm will advance faster than all other companies.

Innovation through the continuous collection of data about breeding process. Recording all process data during every short mealworm lifecycle will spur innovation. Constantly working with slight variations in the processes will become the base for experiments that lead to insects containing the optimal nutritional content made at the cheapest price.

Today, much of the breeding is still done without the full understanding of the best parameters. Companies just use conventions. Don't stick to them, or you will definitely fall behind in the fast clockspeed mealworm food industry.

Business Model

"The business models presented here can be seen as the capstone of this project. It represents the direction of all the research done in this project is pointing towards. Feel free to discover how an ideal mealworm food business looks like in our opinion!"

The business model

Here we want to present the business model of the ideal insect for food company. It is a fictitious mind exercise, not pretending to give a waterproof strategy to win the market. However, it will help to give an understanding of all the concepts we touched throughout the report and show the direction that our research is indicating.

Business model canvas

The business model canvas will visualize and summarize the ideas we have about organizing your complete supply chain.

Two of them are presented. One focusses on good business models for startup companies. The other one is more applicable for a company that is already for a while in the business. More detailed analysis of the concepts listed together in one canvas can be found throughout the whole Industry Analysis Report. The two canvases can be found at the last page.

Growth Strategy

Based on our research, we give you a present to end with. A plan to build your own mealworm business in 7 steps:

1 Start a crowdfunding campaign

Test the market and get money at the same time. An explanation of crowdfunding goes too far here. For the why and how of crowdfunding, we refer to an amazing article on TechRadar (Sharma, 2013).

2 Start Production

Produce your own insects to have a learning curve of what is possible with insects breeding. Only in a later stage you can specialize in only processing and sales. Record all information about your processes and make this information transparent.

3 Sell small quantities through specialized channels

Focus on products with a high price, niche market like snacks, party food, food for sportspeople, selling to restaurants…

4 Improve nutritional content and ramp up production

With the learning curve from producing, testing and collecting data this should not be difficult.

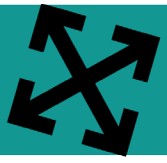
4' Work with upstream producers

It's even better to work with the upstream producers of insects and teach them the standard. The benefits: economies of scale, avoidance of competition from those upstream producers... You implement your standards in terms of transparency in your suppliers.

5 Quality matters

Contentrate on bringing great and high quality products to the end customers. Start specializing in the processing with flour as raw material into a product and selling the final products

6 Upscaling of channels



Change your sales channels to more scalable channels such as supermarkets.

7 Market insect food as a better alternative than traditional meat

Products best produced in this stage are meat replacements. The markets for burgers, meatballs, sausages and other meat products are way bigger than the markets for meat replacements. A failure in targeting against real meat will limit the market size.

Business Model Canvas for a Startup Company

KEY PARTNERS

Community

Researchers

Restaurants: creative cooks

Event Organizers

Media

KEY ACTIVITIES

Vertical integration of supply chain:
- Production of mealworms
- Processing of mealworms into powder
- Inventing & producing snacks based on mealworms
- Selling the snacks

R&D:
- Establishing a model for transperancy
- Invent new products
- Improve production
- Open process information

KEY RESOURCES

Talent:
- To invent new food product that appeal to consumers
- To establish an industrial scale production process

Technology:
- Blockchain and other new technology to make the process transparent

VALUE PROPOSITON

Provide delicious, healthy & environmental friendly food

Provide a novel food source: insect based snacks or sports supplements

Transparency: the customer can follow the history & nutritional content of the food in detail

CUSTOMER RELATIONSHIPS

Community creation

Providing them with complete & transparent information through scanning and app or website

CHANNELS

- Events
- Restaurants
- Online
- Bio- or organic shops
- Fitness environments
- Outdoor sports shops

CUSTOMER SEGMENTS

Creative class in big cities in Europe or USA

Young, urban, health & environmental conscious

COST STRUCTURE

Value Driven
- Production process high cost
- Manual labor
- R&D
- Promoting a new food sourcee

Cost will quickly go down with experience
Cost of transparency

REVENUE STREAMS

Crowdfunding
Sales of mealworm based snacks and sports products: high price
Sales of intermediary mealworm powder: low price
Income from giving workshops and speaking on events

Business Model Canvas for a Food Processing Company Selling Mealworm Products

KEY PARTNERS

Suppliers of mealworm powder

Community

Researchers

Restaurants: creative cooks

Event Organizers

Media

KEY ACTIVITIES

Build transparent relationships with suppliers

Create a strong brand name

R&D
- Establishing a model for transparency with suppliers
- Invent new products
- Track all process information

KEY RESOURCES

Talent:
- To invent new food products that appeal to consumers

Technology:
- Blockchain and other new technology to make the process transparent

VALUE PROPOSITON

Provide delicious, healthy & environmental friendly food

Provide an alternative for meat, especially burgers: insect based snacks or burgers

Transparency: the customer can follow the history & nutritional content of the food in detail

CUSTOMER RELATIONSHIPS

Community creation

Providing them with complete & transparent information through scanning and app or website

Let customers co-create new products

CHANNELS

- Supermarkets
- Events
- Restaurants
- Online
- Bio or organic shops

CUSTOMER SEGMENTS

Creative class in big cities in Europe or USA

Young, urban, health & environmental conscious

COST STRUCTURE

Value Driven
Cost of R&D
Cost of promoting a new food source and building a brand
Cost of inputs: mealworm powder
Cost of transparency

REVENUE STREAMS

Crowdfunding
Sales of mealworm based snacks and burgers: high price
Income from giving workshops and speaking on events

Our Story

"Here's the brief summary of the path we followed to write down this report. It also provides you with a very quick overview of the collaborative platforms we used to coordinate our efforts all along the process."

Everything started in the Global Manufacturing Strategy class of the English Master in Management Science and Engineering Program of Tsinghua University, Beijing, China. We were required to write an IAR, shortcut for the so-called “Industrial Analysis report”.

Our multinational team was brought together by our love of food. The choice of the specific topic of edible insects came quickly, as a very promising alternative of meat. The original idea was to investigate cricket flour as it was becoming famous in Western countries. However, after we got more familiar with the edible insects world, it turned out that cricket might not be the best choice. After further investigations, we decided to shift our main focus on mealworms.

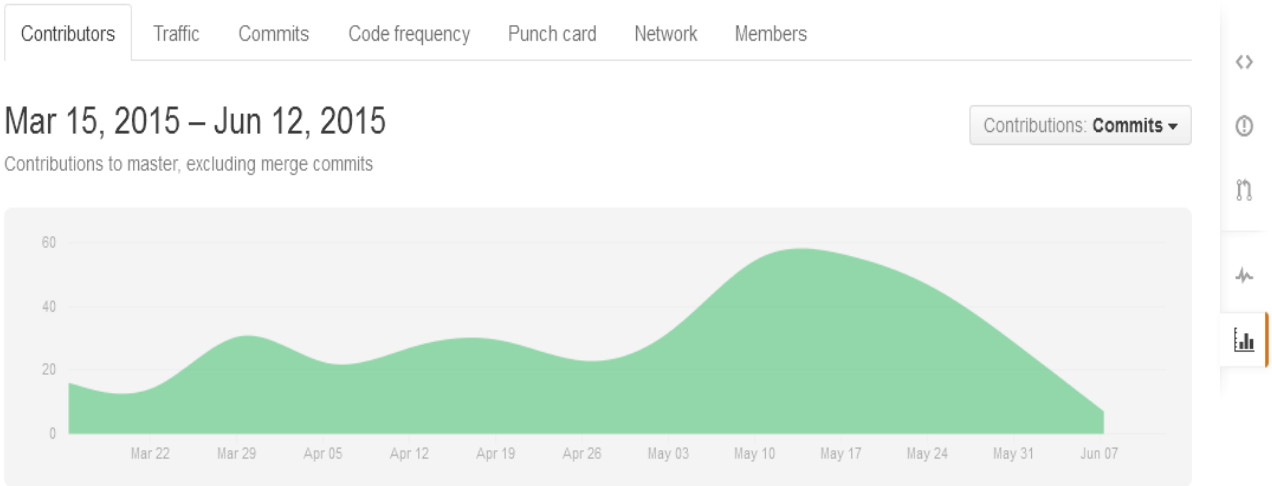
In order to complete this work, we did not only meet very frequently but also used online collaborative tools such as GitHub (a platform where you can create a repository where commitments from team-members can be tracked, merged and modified; visitors are also able to leave modification suggestions) and Teambition (a super DropBox with an additive blog function and organizational tool).

You can visit our Bacchus repository at: https://github.com/ikerito7/Bacchus-R1. As a way of illustration, here is a graph of our team-member’s contributions on GitHub along the length of the project.

QR Code towards our webpage

QR Code towards our Github Repository

Bacchus Github Performance



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"All the cited references in the report can be found here. If you want to know more, go back to the research methodology on page 7 and 8. There you can find a link to a more exhaustive list of articles we used to get an overview of the insect industry without citing them explicitely in the report"

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