



**Bacchus**

# **EDIBLE INSECTS**

An Industrial Analysis Report of Mealworm

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

# Contents

---

**1** Why Insect

**2** Short Overview of the Insect Industry Today

**3** Key Drivers to Grow the Insect Industry

**4** Mealworm Flour as a Solution

**5** Norms

**6** Law

**7** Technology

**8** Market

**9** Supply Chain

**10** Ideal Business Model

**11** Conclusion

Why Insect 1

Short Overview of the Insect Industry Today 4

Key Drivers to Grow the Insect Industry 5

Acceptance among western people to eat insect 7

Legislative security 10

Production cost barrier 14

Focus on mealworms 15

Presentation 16

Academic research in insect nutritional properties 20

Academic research in ecological impact 21

Mealworm flour as a solution 25

Norms 26

Acceptance of mealworm flour 28

Health issues in mealworm flour 30

Law 32

Current Legislation in the main markets for mealworm flour 33

Food safety plus impossibility to rear mealworm on waste at the moment 34

Prospects on legislation for mealworm flour 36

Technology 40

Current processes in insect industry / standardization and industrialization of insect products 42

Potential technologies for insect industry 43

Our own production improvement solutions 45

Market 46

Impact assessment of mealworm flour 48

A competitive analysis of mealworm flour 49

Conclusions 50

# About Us



**Melinda Palit**

The possibility of something new that keeps me going everyday. I like the new ideas about how people interact towards each

**Marie. M**

The possibility of something new that keeps me going everyday. I like the new ideas about how people interact towards each

**Iker Saenz**

The possibility of something new that keeps me going everyday. I like the new ideas about how people interact towards each

**Matthias. F**

The possibility of something new that keeps me going everyday. I like the new ideas about how people interact towards each

**Max Dorr**

The possibility of something new that keeps me going everyday. I like the new ideas about how people interact towards each

**“Describe Bacchus in one sentence. Use some cool words”**

Bacchus is the Roman God of wine and plentiousness, 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!



Our goal is to provide the world with a plentiousness of food, delicious food. Just as the plentiousness and the 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.



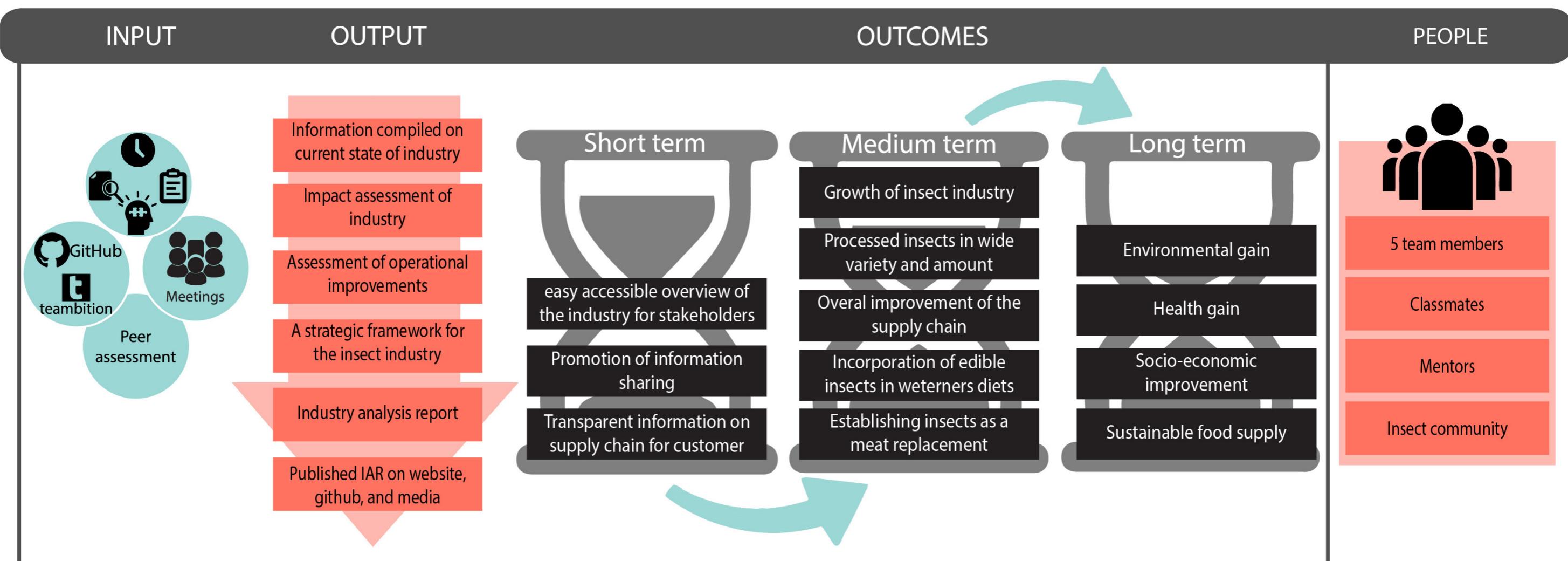
# LOGIC MODEL



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

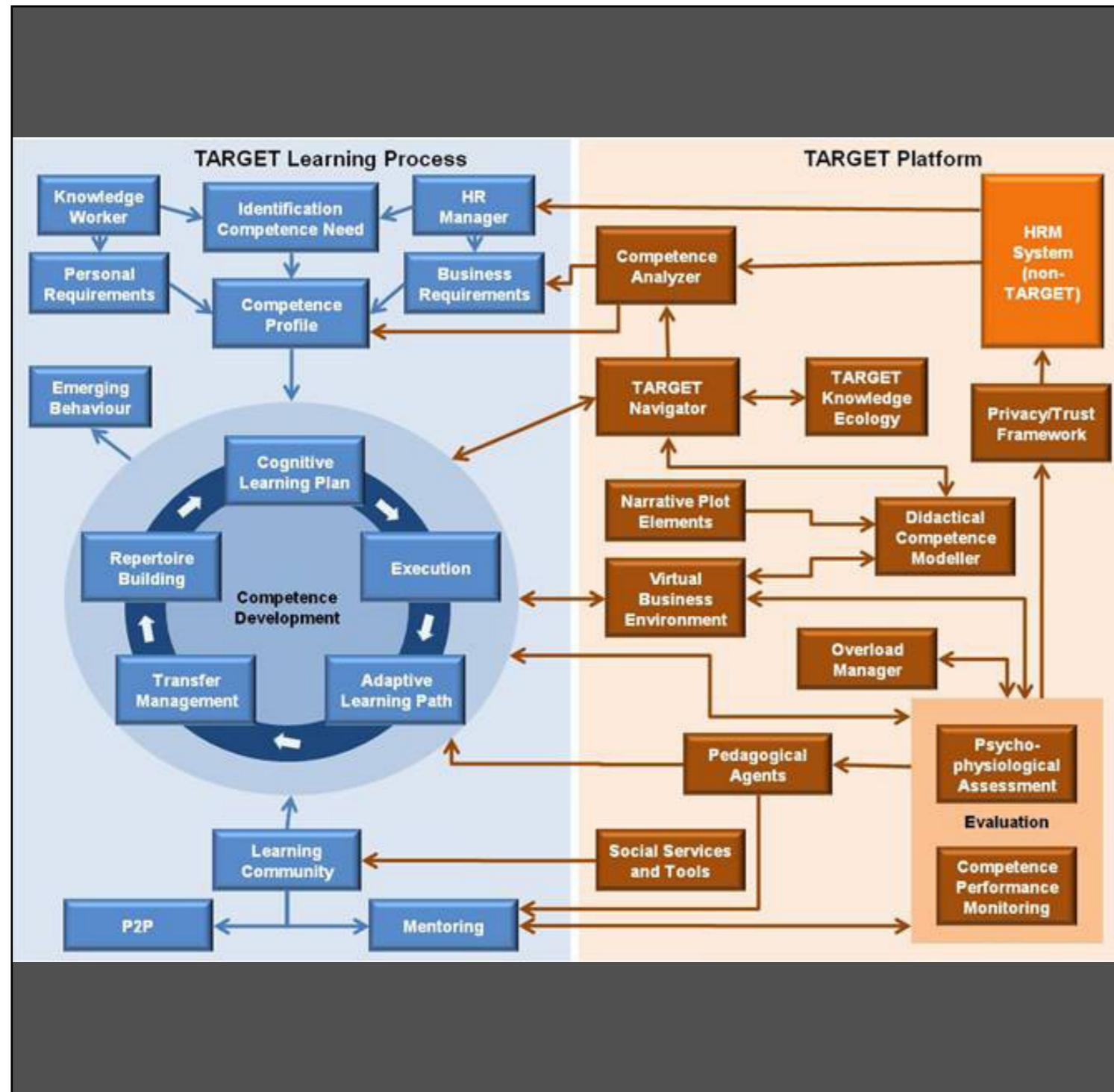


**Problem Statement:** Industrialization of insects as food



Given the trend of population increase, the Earth is expected to be inhabited by more than 10 billion people by 2100. All this population will need food to satisfy their daily nutrient requirements. Considering that 27kg of CO<sub>2</sub> 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. 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!

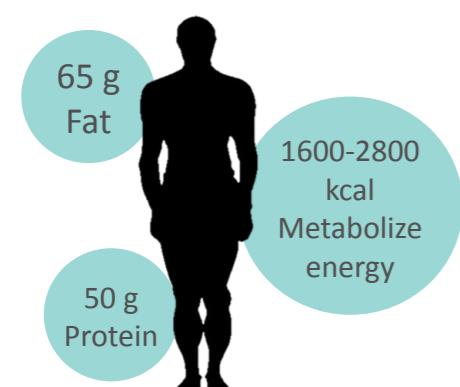
# RESEARCH METHODOLOGY



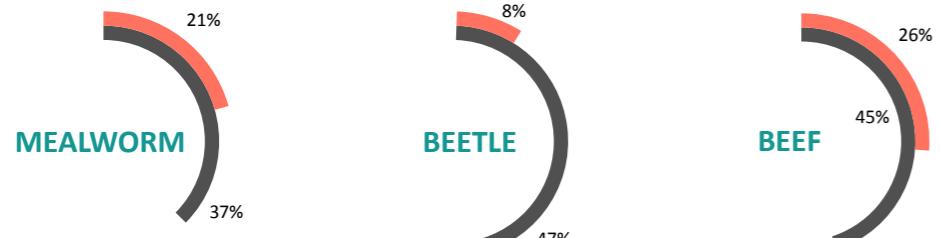
# INSECT AS NEW SOURCE OF FOOD

## Nutritional Value

Human Nutrition Daily Need



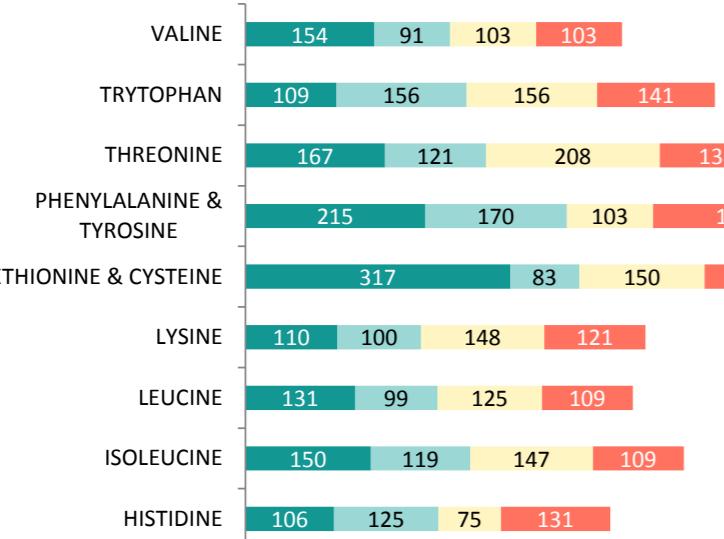
Average ratio of nutrition content with daily recommended value



Source:  
FAO The State of Food Insecurity in the World 2013  
[www.wolframalpha.com](http://www.wolframalpha.com)

## ESSENTIAL AMINO ACID CONTENT

■ Mealworms ■ Soy ■ Whey ■ Milk & Egg



Source: [www.ediblebugfarm.com](http://www.ediblebugfarm.com)

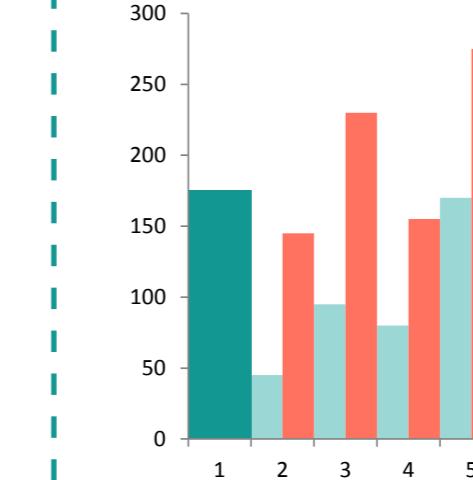
## ENTOMOPHAGY IS FAMOUS!



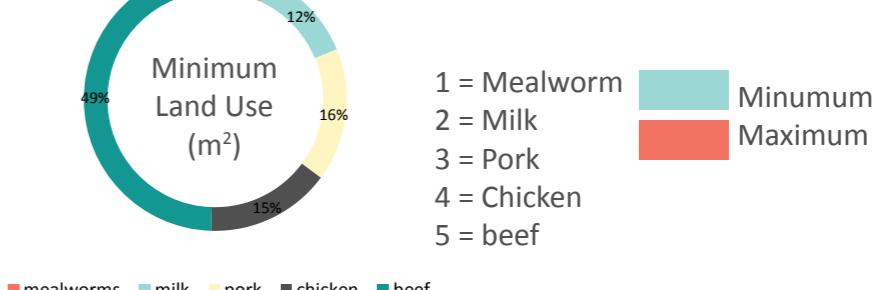
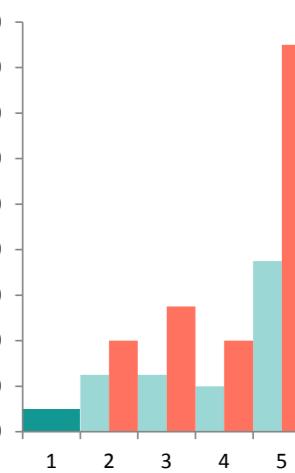
Source: [www.ediblebugfarm.com](http://www.ediblebugfarm.com)

## Ecological Aspects

Global Warming Potential (kg CO<sub>2</sub> -eq)

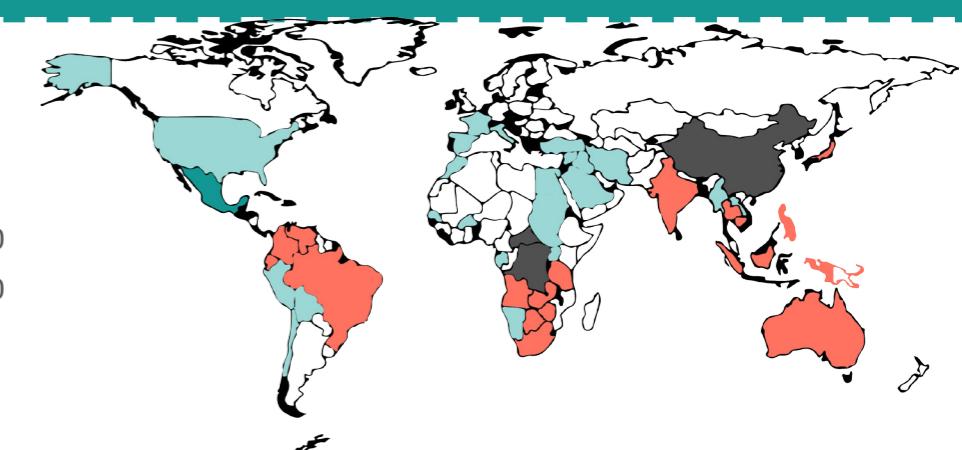


Energy Use (MJ)



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

## Number of edible insect species around the world



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



# Why Insects?

"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"



## Insect as a new source of food

In 2013, the UN Food and Agriculture Organization (reference) 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 delicious 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, why do we choose for these crawling animals most people hate?

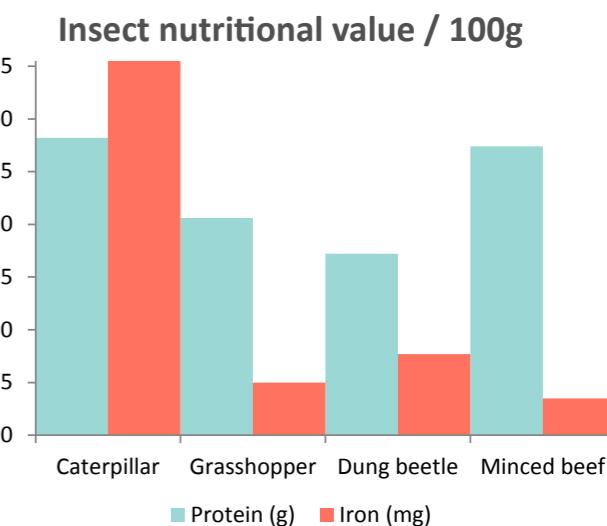
So, why insects? Regardless of its looks that most of people don't fancy, insect as food is not only contain high nutrition (protein, vitamins and minerals) that can be found in fish and meat, but also way healthier as it contains less fat (as for the ratio). Harvesting insect is way easier than harvesting cows, pigs and sheep; they need less food to raise, emit fewer greenhouse gases, and by consuming insect we also help reduce pest insects without using any insecticides. Last but not least, farming insect can become a new form of business that can be done in the developing tropical countries (which usually suffered 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, crick-

ets require only 2kg of feed for every 1 kg of body weight gain. Insect can be reared on organic side-streams (including human and animal waste) and can help reduce environmental contamination. It emits fewer greenhouse gases and less ammonia, require significantly less land and water, and compared with mammals and birds, insect 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 highly nutritious and healthy food source with high fat, 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 formulae for aquaculture and livestock.



Source: Montana state university

# “with more than 10 billion people expected to be inhabited by 2100, we need food to satisfy the daily nutrient requirements”

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 insect family has a great number in terms of species. The figure below shows the number of insect species, by order, consumed worldwide (Huls, et al., 2013).

As can be seen in the graph above, the difference of the insect quantity consumed worldwide is quite big in the coleopteran order. This brings an interest for us to narrow our focus on coleopteran order, which is beetle. Another interesting fact occurs as we learn more about beetle; it turns out mealworm that is already quite famous as an exotic food, is a larval form of beetle. There are quite numbers of information and articles about mealworm as food, which indicating that some people already acknowledge it as food; thus it brings positive advantage to our projects. Not only mealworm wins in quantity and fame, it is also contain high nutrition (dried): 46-53% protein, 28% fat, 6% fiber, 5% water, environmentally safe, simple production process (we

- Processing: 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.

believe so because it's small and have no hard shell like beetle), and better yet- have a short life cycle. This is why we believe that mealworm will be a best candidate for a further study.



## SNAPSHOT

### Can we feed the world?

As world hunger refers to the want or scarcity of food in a country (Oxford English Dictionary, 1971), 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. 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

#### **Undernourishment around the world, 1990 - 2 to 2012 - 4**

#### **Number of undernourished and prevalence (%) 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 & Caribbean	68,5	15,3	37	6,1

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

far been more than sufficient to exceed population growth (Food and Agriculture Organization, 2012). It is because poor people, especially in 3rd world 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 – substitute today's food sources

# Key Driver

"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"



## Acceptance among westerners

A key challenge towards selling insects for human consumption will be people in the West accepting insects as a food source. A better understanding of why most Westerners do not like the idea of eating insects nowadays (FAO, 2013) can indeed help finding creative solutions to improve global insects acceptance.

Let us put the currently observed Western disgust towards insect consumption in a historical prospect. Agriculture was born in the Fertile Crescent, a region located in western Asia, ten thousand years ago before 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- add-

ed to the uncertainty of their supply made them an unreliable source of food for Westerners, and especially urban areas.

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 a Westerner.

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 a European when suggested to eat insects. But just as every

social norm, it can be changed within some time.

Indeed, some encouraging experiments carried out in Belgium (Rudy Caparros

**"Westerners culturally associate all insects with nuisances and see their consumption as primitive"**

Megido, 2014) showed that on 105 respondents from both genders and different ages, although 46.6% of them had a negative attitude towards it; 77.7% of them were willing to try insects. This demonstrates curiosity and desire to try novel food.

Besides, the popularity of insect tasting events such as "Restaurant" in the UK (Rentokil) shows a growing interest of Western people in eating insects. Even more encouraging: more and more restaurants cooking insects open their doors in the Western countries (Insect Europe).



## Legislative security

In many countries, there is no regulation for insects as food and feed. This is one of the big barriers to insect mass-production as investors fear to put money in a lawless -therefore hazardous- business. Indeed, as long as you do not know about the safety standards you shall have to respect, it is impossible to make big investments in industrial breeding and trans-

lines 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).

In the United States, insects as food do not correspond to any category of the

**“There are no international guidelines provided by the Codex Alimentarius, hence no clear regulation at the moment”**

formation processes and you cannot make sure customer will buy your products. There are no international guide-

FDA (Food and Drug Administration), meaning that there is no legislation on this issue.

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. 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

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

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

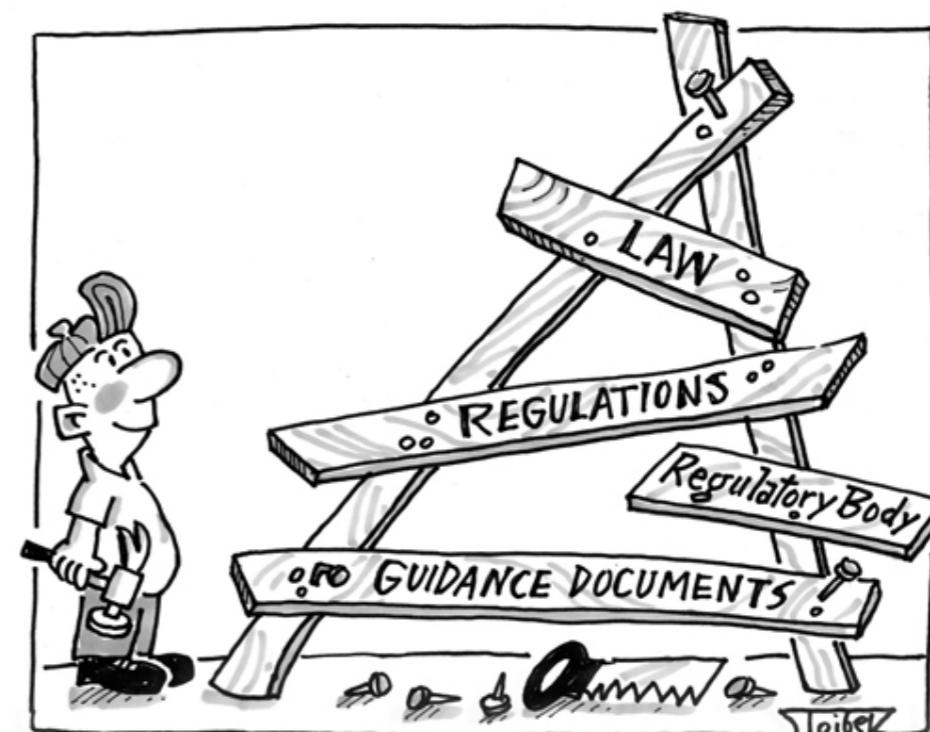
legislation is unclear, like in France or the UK (Day, 2015). At the moment it is up to each state-member to decide for itself on specific cases.

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. The situation is very likely to evolve in the coming years.



# Health issues

As they are cold-blooded and much different from humans than 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).

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 they absorbed. 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 con-

tents (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.

Indeed, 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)



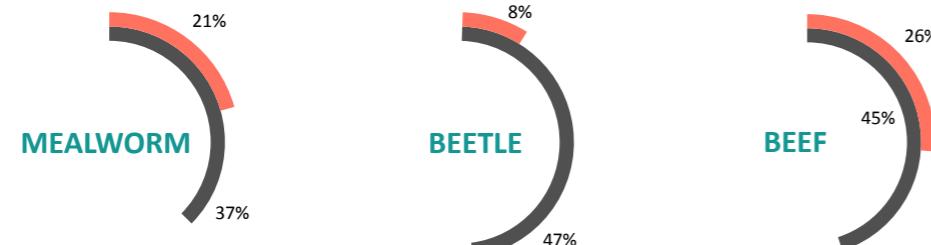
# Mealworms nutritional value

Mealworms larvae are highly comparable to –at to some extent better than– beef in terms of nutritional content

(FAO, 2013) for a lesser 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, as shows 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 (except for moisture)

	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:

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 (H.C. Klunder, 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)



### Nutritional content of fresh mealworms compared to fresh beef

	Mealworm	Beetle	Beef	Daily recommended value	
<b>General Data</b>					
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
<b>Minerals (mg/100)</b>					
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
<b>Vitamins</b>					
B1 (Thiamin, mg/100g)	0.24	0.10	0.046	1.5	mg
B2 (Riboflavin, 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](http://www.wolframalpha.com/input/?i=daily+recommended+calories#subpod_0200_1) zoom  
[www.wikipedia.org/wiki/reference\\_dietary\\_intake](http://www.wikipedia.org/wiki/reference_dietary_intake)  
[www.wikipedia.org/wiki/beef#nutrition\\_and\\_health](http://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 possibly opens new horizons for their rearing.*

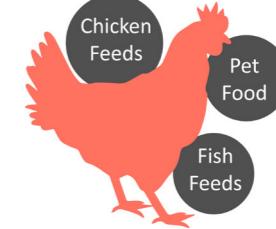
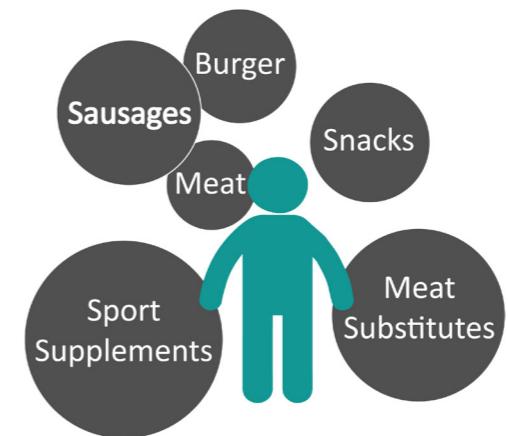
# Market Study

"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"



## 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 and alike. Also, it starts to become popular at 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 is for human consumption and animal consumption:

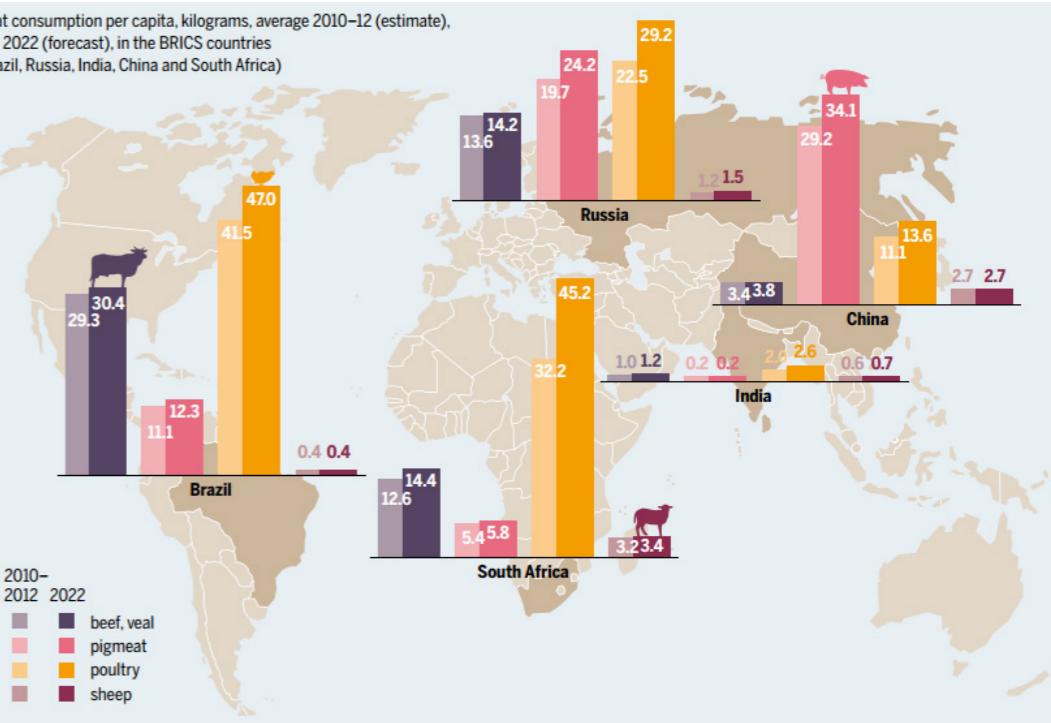


### Human Consumption

#### Meat

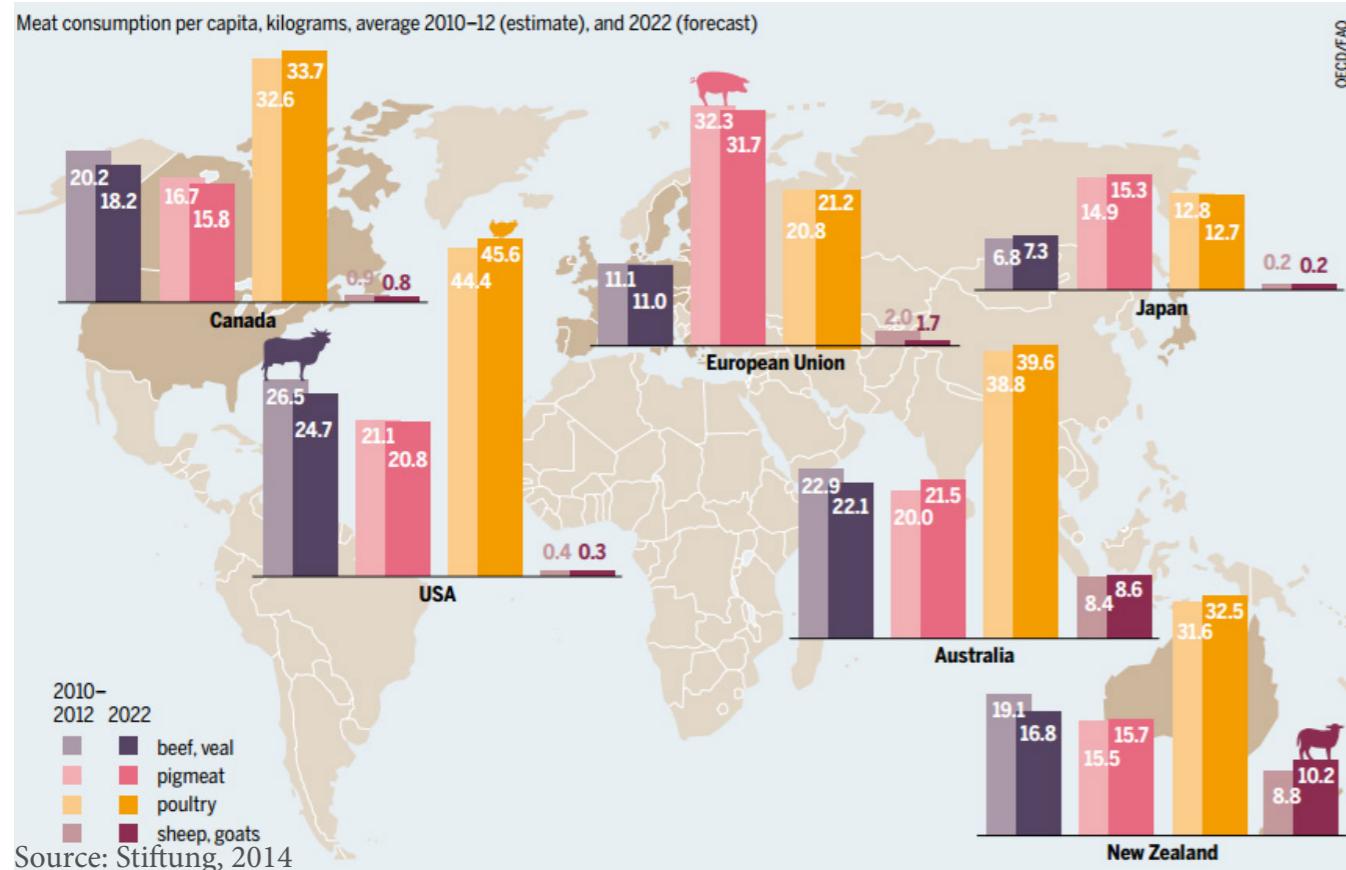
Insects are animals. Therefore, food made out of insects is meat. The most obvious market for insects is therefore the meat market. The Meat Atlas by Heinrich Böll Foundation and Friends of the Earth shows how much meat is consumed per capita in selected countries.

As you can see, this is a huge market. However, although meatproducts made from mealworm flour can theoretically replace any meat, their most direct concurrents 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 mealwormburger. A short overview of the size of two promising processed

Source: Stiftung, 2014



### Sausages

Business Analytic Center calculated the total European sausage production totalling 5,3 million ton at a market size of 19,5 billion euro(BAC). It's a highly fragmentated 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(Dun & Bradstreet). The average price of a kg of sausages in the USA is 9,7 \$ / kg (Wolfram Alpha).

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

### Burgers and Meatballs

The global market for beef is expected to reach USD 2151 billion by 2020(GrandViewResearch). In 2012, 67400 kilo tons of beef was produced.

Of that, 43,9% or 29500 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(MarketWatch). The retail price of a kilo of ground beef in american supermarkets reached 9,15 \$(AGWeb).

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).

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

### 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 Analysis). 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.) (PR Newswire). Market Analysts believe the market will grow with a CAGR of 4.4 to 6.4% up to 6.4 billion \$ in 2019 (MarketsAndMarkets Analysis & RTS Resource). 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).

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).

### Sport 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, more and more this market is 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 (Kathryn Redford). Bug Muscle is a company that will start with the production of insect based nutritional supplements for athletes in middle 2015 ([www.bugmuscle.com](http://www.bugmuscle.com)).

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). 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(Global Industry Analysts). 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



## 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

(List of startup snacks)

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). However, with data from Euromonitor we can notice that healthy snacks, without fruits and nuts, have only a share of 3% in that market(bankingbusiness.com). 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

Makkar et al. state that a 60–70% increase in consumption of animal products is expected by 2050 (FAO). IFIF believes in an even more spectacular growth : meat consumption doubled by 2050 and fish consumption tripled (IFIF). 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

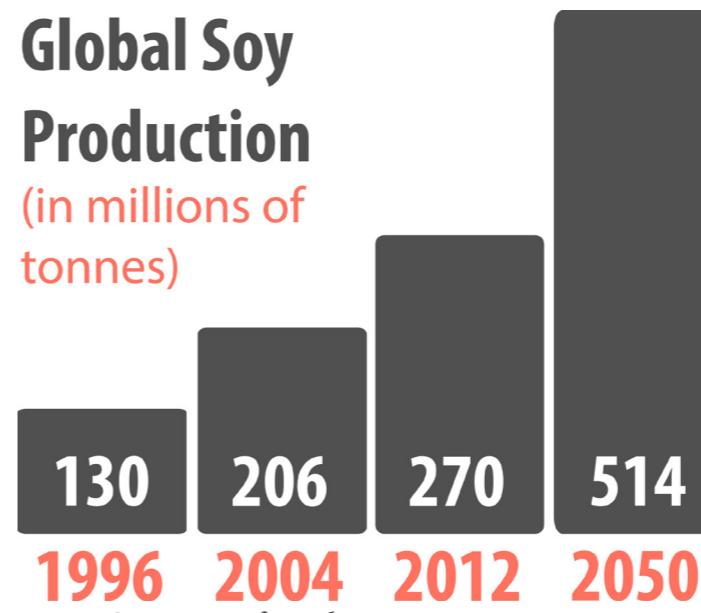
that people will not completely change their diet from big animals to insects without any disasters obliging them to do so. Therefore, it is important to assess the size of the market of the feed of the animals we eat and check whether those markets can be penetrated by insects as well. Moreover, with such growth perspectives of an already huge market, completely neglecting animal feed cannot be justified in economic and ecological sense.



## Animal Feed

The current total global market of animal feed has a size of 370-500 billion \$ per year (IFIF,Alltech). 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). 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 protein 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). Grains for animal feed use 40% of total land use in agriculture(Kathryn Redford). WWF warns for the growth of soy production, as especially in South America the growth of soy farms is already affecting the rainforest.



Insects provide a good alternative for protein 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' (TedX).

Makkar 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 roughly comparable with current soy and fishmeal: black soldier fly larvae, the house fly maggots, mealworm, locusts–grasshoppers–crickets, and silkworm. 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. Of 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 relict of the 1990s BSE crisis (BBC). 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 (Makkar et al.).

## 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 mealworms can be bred by customer (not equally processed)

### Producer of end product:

- The mealworms can be bred by customers
- 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 customer:

- No suppliers

### Farm suppliers:

- Human consumption level suppliers are few (less than 50 worldwide)
- The size of the suppliers is small to medium (less than 50 employees)
- There are a couple similar products (buffalo worm, soldier fly larvae)
- There are not set regulations 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
- Substitute products price tag is high
- Meat is highly available and still preferable
- Vegetables are cheaper and highly available

## 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

## 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 don't include animal meat yet can provide the nutrients to survive. Our product (insect based flour) will face primarily the vegan-grade foods. These 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 haven't provided much protein, 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 our target market is specifically people that prefer not to eat meat while keeping healthy levels of protein in their bodies. Therefore if our 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 supermarket or restaurant, and the prices although sometimes high could overcome the trouble of dealing with flours made from second-rate products.

# Porter 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 is 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. These 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 brands as there is no high brand recognition. A strong merchandising should be made in order to avoid this.

The vegetables, on the other hand, also provide a very important substitute for our products. Our target market if unsatisfied by our product 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 our product.

## Buyer Power

### End Product Buyer

In the current market the customer has a lot of strengths to exploit. Given the option that the e-commerce is widely distributed and accepted, the end user can get in contact with the 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 levels of the innovative products is not as high as a everyday use products. But 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 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's 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 have 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 a considered as novelty food in the 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. Its important to note that even in countries that historically have the habit of eating insects, there are no legal frame-

work 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 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 is a market with very few players at the moment. The companies in this industry doesn't face a great number of competitors therefore making it easier for the companies to grow. On the other hand, even this industry is not “full” with companies yet, the social acceptance highly reduce 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.

# Norms

"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"



## 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 quickly spreading 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 a Westerner.

Westerners also rapidly associated insect consumption with some primitive and therefore contemptible behavior inherited from the hunt-

ing-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 a European 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 many a European.



"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."

*-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-*

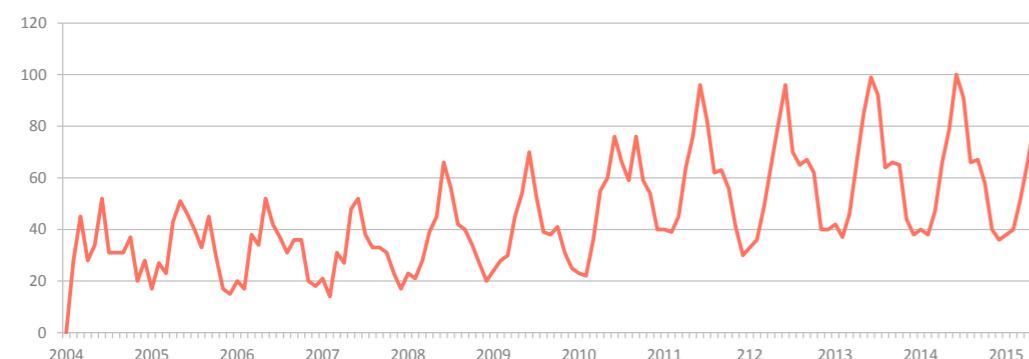
Besides, many people should be willing to try insects. Some encouraging experiments carried out in Belgium (Megido, et al., 2014) showed indeed that on 189 respondents from both genders and different ages, although 46.6% of them had a negative attitude toward insects; 77.7% of them were willing to try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

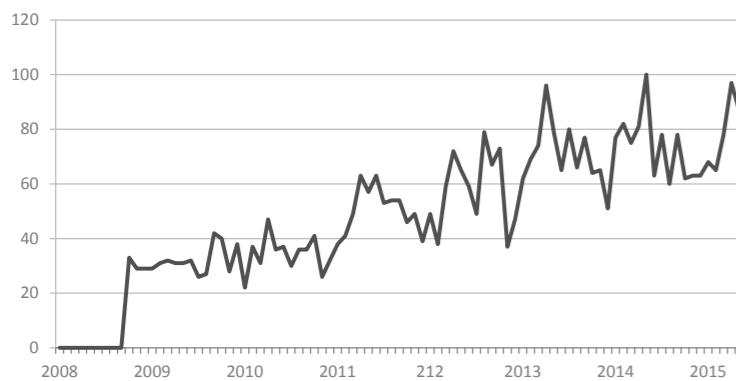
Another illustration is that there are more and more Google researches in the edible insect fields (see graphs from Google Trends below, relative scale).

#### "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.

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 improvable.

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

#### 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

#### 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: <http://www.google.fr/trends/explore#q=eat%20bugs&cmpt=q&tz=>

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)

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 represent 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.

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 years-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

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):

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.

## Hedonic 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: <http://www.google.fr/trends/explore#q=eat%20bugs&cmpt=q&tz=>

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 the more 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.

# Mealworm flour as a solution

## 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." (Benítez, 2013)

## Better nutrients values

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

## 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 R. C., et 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.

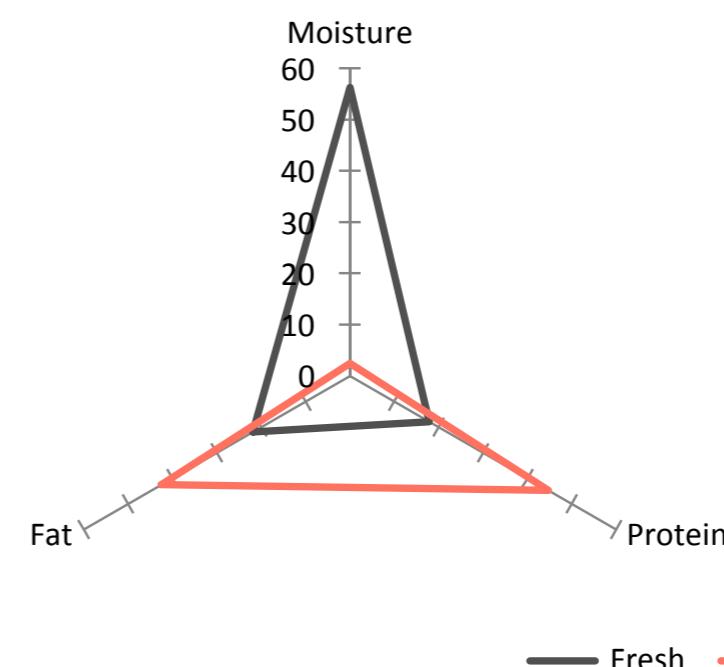
"We wouldn't eat an insect if it looked like an insect. Nor would we eat a cow if it looked like a cow."



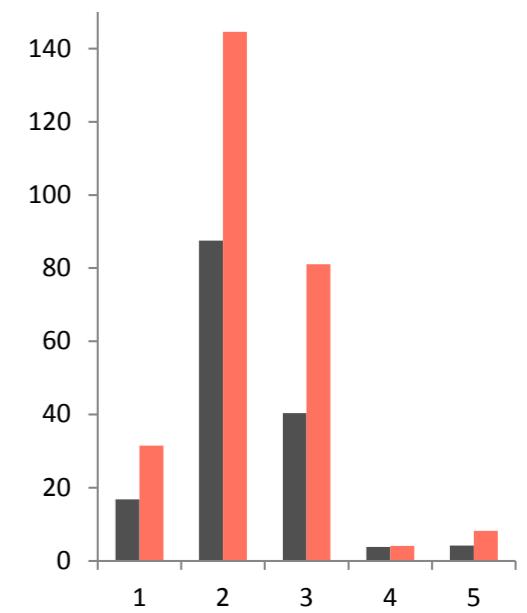
-Kathryn Redford, Canadian co-founder of Ofbug, an ento protein producer in Vancouver, BC-

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)



# Laws



"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"





# Technology



"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"



# Supply Chain

"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"

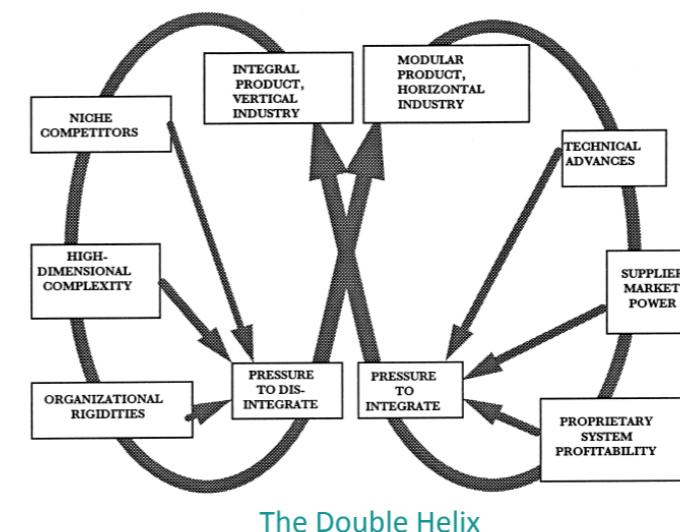


## The supply chain

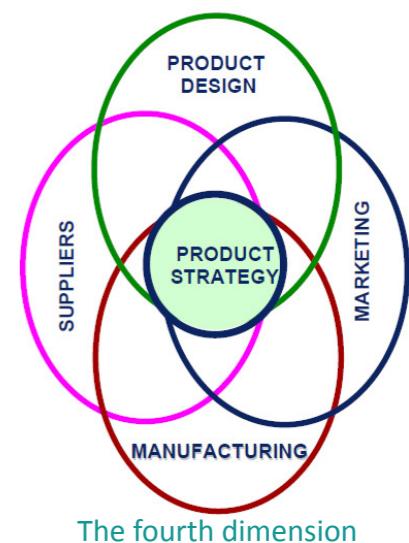
After studying the outside forces affecting the business, which we in this report grouped as market, norms, technology and law, a company can start developing a strategy for a successful business. However, this is not enough. A successful strategy will soon be followed by competitors. A company will 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).

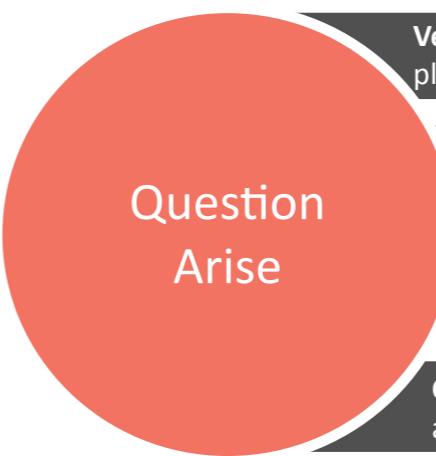
Pradeep Fernandes adds a fourth dimension: Marketing. This is the connection between studying the outside forces and working on internal operations. And that is exactly where a company in a nascent market has to excel in. Therefore, in this section, we assess the dimensions of the extended "4D" concurrent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



The Double Helix



The fourth dimension



**Vertical integration:** where should a company position itself in the complete supply chain from growing insects to selling 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 1980ies, 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.

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
Economic 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 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 supply 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.

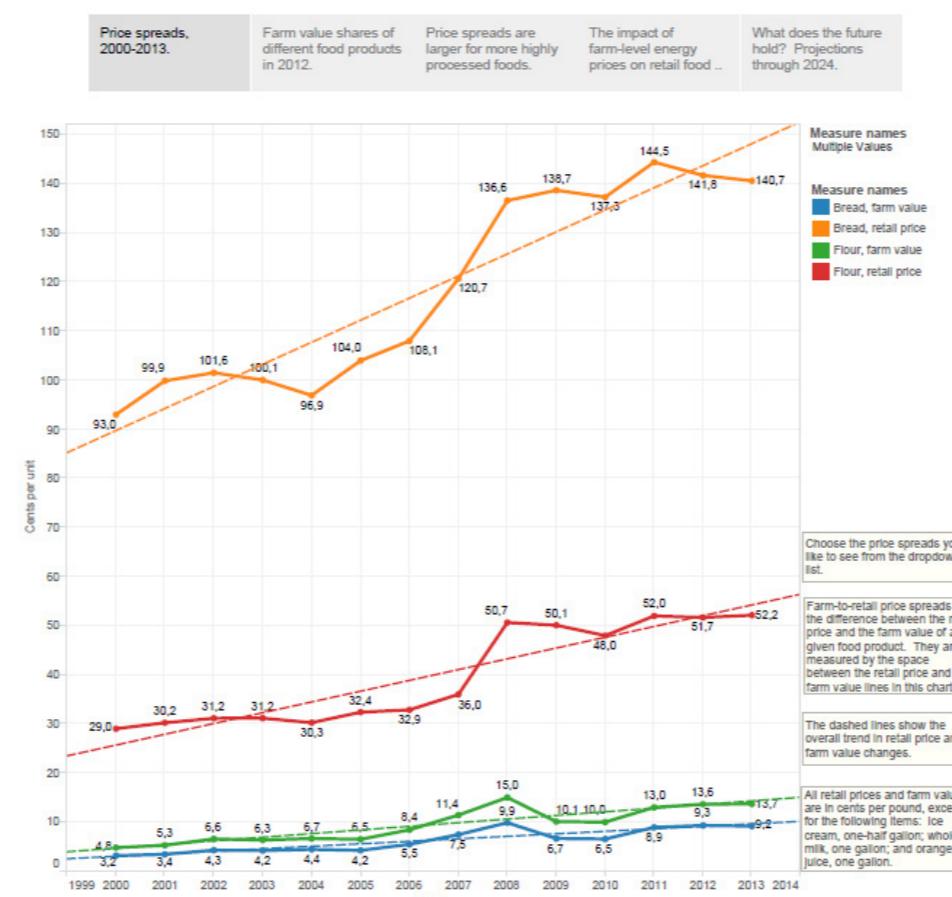
**Restaurants :** Can be an easy way to distribute insects. Also, cooks who like to work with an insect provider will express their creativity and find new ways to cook with mealworm flour.

**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 organizers 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.



Source: Still need to create a better graph ad to add its source (-\_-)

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

## 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 blog 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 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.

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. Thrust : with time and place that can be verified, a customer will be more likely to trust 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 tailored 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 understand 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 parameters.

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 thrust mechanism between two parties without having the need of a third party to make the transaction trustworthy.

It works as follows, explained through bitcoin : Ev-

eryone 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 spent 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, thrust 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. Time-stamps 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?

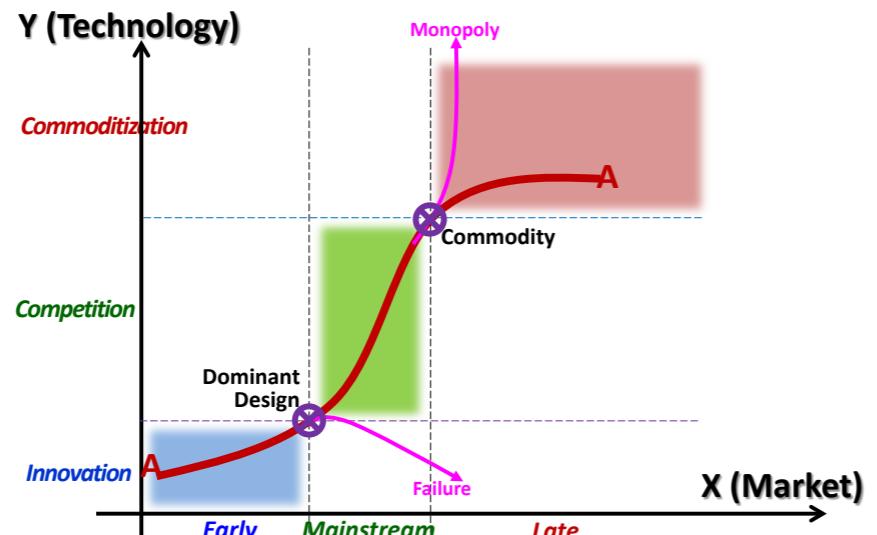


How exactly to implement this is a tough question. Right now, still lots of startups are in the developing phase of developing blockchains for other uses than online money. What can be done for sure is using a blockchain internally, to make all people involved in the process of making one batch accountable 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.

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 centra 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, thrutable and healthy. A strategy burger restaurants use to get rid of the fast food image is exactly that their burgers are mad 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 off 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 4 to 19 days, 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 a 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.



# The business model

## Business model canvas

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.

### 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 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...

ny 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.

So by all that we have gone through so far, listed below are the 7 step that we considered necessary to grow a mealworm food business:

## 4 Improve nutritional content and ramp up production



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

## 4 Working 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.

### KEY PARTNER



Supplier of mealworm powder

Community

Researchers

Restaurant: creative cooks

Event organizer

### 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 transparency
  - 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 PROPOSITION



Provide delicious, healthy & environmental friendly food

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

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

### CUSTOMER SEGMENTS



Creative class in big cities in Europe or USA

Young, urban, health & environmental conscious

### CHANNEL



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

### COST STRUCTURE



Value Driven

Production process high cost

Manual labor

R&D

Promoting a new food source

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

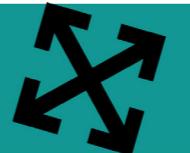
Income from giving workshops and speaking on events

## 5 Quality matters



Concentrate on bringing great-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 Channels



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

## 7 Market insect food as equal, or better, compared to 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.

### KEY PARTNER



Supplier of mealworm powder

Community

Researchers

Restaurant: creative cooks

Event organizer

### 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 transparency
  - 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 PROPOSITION



Provide delicious, healthy & environmental friendly food

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

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

Young, urban, health & environmental conscious

### CUSTOMER SEGMENTS



Creative class in big cities in Europe or USA

Young, urban, health & environmental conscious

### CHANNEL



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

### COST STRUCTURE



Value Driven

Production process high cost

Manual labor

R&D

Promoting a new food source

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



# References



"we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either. we will write a overview or the conclusion of this chapter. other than conclusion or anything is also oka, as long as we can talk a lot about it. perhaps needs 2-3 paragraph. I'm not sure either"