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Master Management, Economics and Consumer Studies

Master Thesis

Edible insects, innovative protein source for a transition in the food landscape

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EI= edible insects

Abstract

Edible insects have been proposed by scientists as an alternative sustainable protein supplement in Western countries as food and feed. The industry developed the idea by system of mass production and processing into innovative insects' feed and food products. Private and public facilitators are involved in the value chain by supporting entomophagy in Western countries. This paper explores the innovation practices of edible insects' rearers, edible insects' food and feed manufacturers and facilitators. Given the high environmental and nutritional potential, the mass rearing production is a valuable input in the food system. However, the innovation introduced directly as food or indirectly as livestock meat have to be contextualized and associated to more sustainable food system where all the aspects of sustainable diets are simultaneously taken into account. Innovation from manufacturers' perspective has to work in combination with traditions and cultural, local food systems, and affordable prices.

Introduction

The growing world population and an increase in food production, consumption and distribution is putting heavy pressure on already limited resources, such as energy, water and arable land (Rosegrant and Cline 2003, van Huis, Van Itterbeeck et al. 2014). Increasing economic growth in developing countries further increases the demand especially for protein-rich food sources, such as meat (Davis, Prescott et al. 1999, FAO 2009).

Edible insects, cultured meat, seaweed, beans, and fungi have been studied for their suitability as meat substitute and sustainable protein sources (Vantomme 2015). In particular, there are at least three reasons why insects are considered to have potential as an alternative to conventional livestock and are good candidates to support food security (van Huis, Van Itterbeeck et al. 2014). First, insects are nutritious with a high protein content, high amount of fats and large numbers of minerals. Second, compared to traditional livestock insects emit less greenhouse gases and ammonia, they need considerably less land and they have a favorable feed conversion efficiency, as they are cold-blooded and have energy-conserving lifestyles (Veldkamp 2012). Moreover, insects can be sustainably reared on organic side streams and waste products (Bodenheimer 1951). Some species and/or their larvae are detritivores, which makes it possible to rear them on almost any substrate including manure and other waste. Third, insect rearing doesn't require high initial investments, being sustainable also in poor conditions providing sustainable diets, but with a bigger initial investment the production can be up scaled becoming a profitable activity (van Huis, Van Itterbeeck et al. 2014). When collected or even farmed at the household level, insects can also provide an alternate revenue for poor families, in particular to women. Roughly 2000 edible insect species that are able to be incorporated into feed or food (Veldkamp 2012).

According to the Food and Agriculture Organization (FAO) of the United Nations, insects constitute already an integral or supplementary part of up to two billion people's diets in more than 113 countries (FAO, 2013). Entomophagy is diffused particularly in tropical and subtropical countries where the biggest variety of species is available. The most common eaten species are beetle, ants, wasps, butterflies, grasshoppers and crickets. Those invertebrates are usually fried, roasted, cooked alone or added in dishes and soups (Gjerris et al, 2015).

It is still now known the potential of edible insects on large scale and how they could fit into the concept of sustainable diets in Western countries. The FAO defined sustainable diets as those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally accepted, accessible, economically fair and affordable; nutritional adequate, safe and healthy; while optimizing natural and human resources (Burlingame and Dernini 2011).

The large scale industry of edible insects is growing especially in Europe and North America with the purposes of introducing edible insects into feed and food. (van Huis, Van Itterbeeck et al. 2014). Governments and research institutes are engaged in the elaboration of a legislative framework whereas the feeling of disgust, fear and strangeness of consumers is an obstacle to the acceptance of insects as food.

This research is meant to give insights on the role of the large scale industry of EI as food and feed for the achievement of sustainable diets in Western countries by analysing innovation practices of companies. The methodology used is the theory building form cases, a deductive approach that allows generating theory propositions from the study of multiple case studies.

The relevance of this research project is the contribution to the literature available on innovation theory and the development of insights into the edible insect sector and its impact on sustainable diets in Western countries which can be of use for the industry and politic maker.

1. Research objective and questions

1.1. Research objective

The objective of this research project is to have insights on the development of the EI industry by analysing innovation practices of selected case studies. Innovation practices are the set of innovation features adopted by companies in order to introduce a product on the market. A consideration on the role of these practices in the achievement of sustainable diets in Western countries is part of the final discussion.

1.2. Research Questions

GRQ: Which innovation practices are undertaken by businesses in the EI sector?

SRQ1: How are innovations in the EI industry related to sustainable diets?

2. Literature review

The following literature review is aimed at building the basis for the empirical part of this research. The first topic researched in this part is the EI industry, including the cultural and legislative aspects; the second focus of the literature review consists in the characteristics of business innovation theory ant the application of those to companies in the EI industry.

2.1. The edible insects' industry (EI)

The edible insects' industry is the reference industry for this thesis. It is intended as the whole of businesses engaged in the large scale rearing and/or processing of edible insects for human or livestock consumption.

This chapter will first give an overview on entomophagy and then to focus on legislative and cultural aspects of the edible insects sector in order to contextualize the industry within its major constraints. Those two topics, in fact, are considered major bottlenecks to the diffusion of insects as food and feed in Western world and relevant for this research in order to have a better understanding of the innovation practices adopted by companies.

The first part of this chapter will briefly discuss the legislative framework in Europe and outside, and the organizations involved in the promotion and coordination of the EI sector. The second section is dedicated to issues to consumers' acceptance of edible insects' products.

2.1.1. Overview

The number of species considered edible are more than 2000 and are diffused especially in tropical countries where insects are bigger thanks to higher temperatures, people have more contact with nature, and harvest is easier because of higher occurrence. It is indeed in these countries where entomophagy, the practice of eating insects, is common. Insects are harvested in the wild and thus subject to seasonality and unpredictability (van Huis, Van Itterbeeck et al. 2014). The orders of insects with more edible insects consumed are Coleoptera (beetles),

Lepidoptera (caterpillars), hymenoptera (bees, wasps and ants), Orthoptera (locusts and grasshoppers), Hemiptera (scale insects and true bugs), Isoptera (termites), Odonata (dragonflies), Diptera (flies), and other (van Huis, Van Itterbeeck et al. 2014).

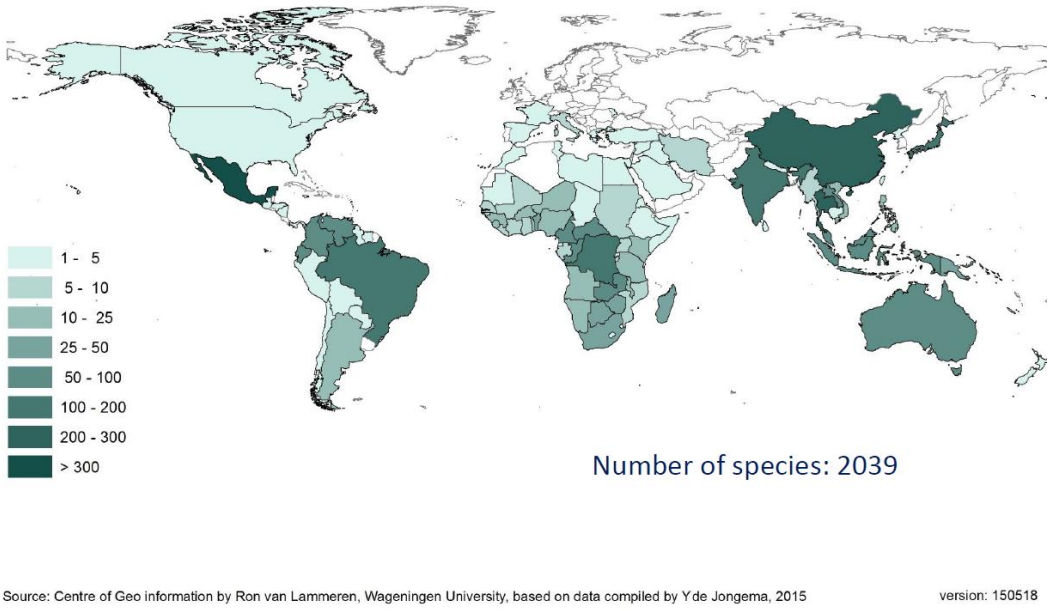


Figure 1Entomophagy by Country (FAO, 2014)

In western countries, modern agriculture, low biodiversity and deforestation and urbanization made industrialization the only way to entomophagy (Van Huis, 2016). The practice of rearing insect on large scale is currently taking place in many areas of the world, including Europe and America. In Asia there are already many farms of edible insects existing able to rear high amount of insects, for example, in Thailand there are over 20,000 insect breeders for insects as human food (De Graaf, 2014).

From 2010 pioneer companies created a market for edible insects' products for human and animal consumption in Western countries. Edible insects' companies have multiple markets, the most important being in terms of dimension the feed and food market. Insects as food are that commercialized in the food industry as flours, as a whole, as paste etc. and considered a meat alternative given their comparable nutritional properties. Edible insects are also part of the feed ingredients market in competition with soybean meal, rapeseed meal and fish meal that are the most used source of protein for livestock feed especially chickens, pigs, aquaculture and pets. Other markets possible for edible insects' products are pharmaceuticals, cosmetics, waste management, dyes oils and biodiesels.

Research about the potentiality of insects for human consumption started long time ago. In the search engine for scientists "web of science" 46 publications are available on human consumption of edible insects only from 2011 to 2015. However other papers are older, as shown in the image below.

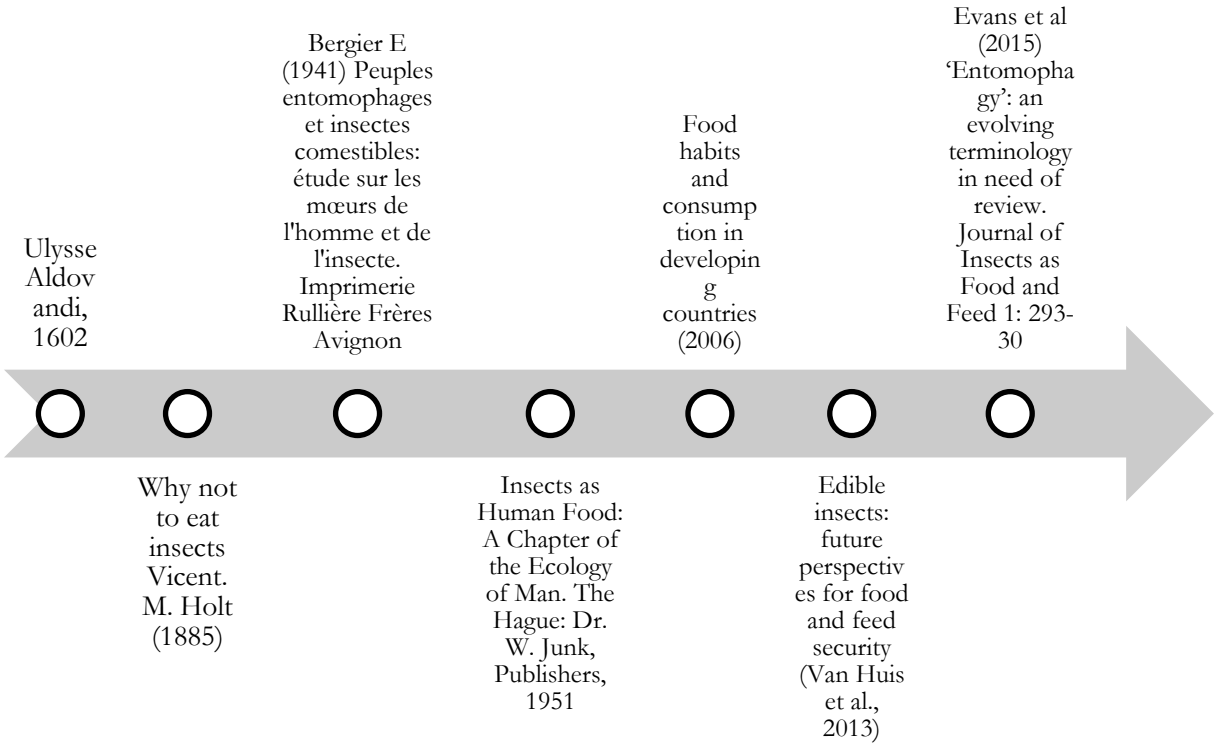


Figure 2 Publication on Entomophagy

2.1.2. Society and consumers acceptance

A wide spread argument against edible insects for human consumption in Western countries is the psychological barrier, or neo-phobia[1], that prevents people from trying an unfamiliar food especially when it has animal origins (van Huis 2013). However, during the last decade, an increased level of peoples' interest on is showed also in the Google Trend. The image (Figure 4) show the number of searches on Google referred to the words "eating insects" indicated with the red line and "entomophagy" represented by the blue line.

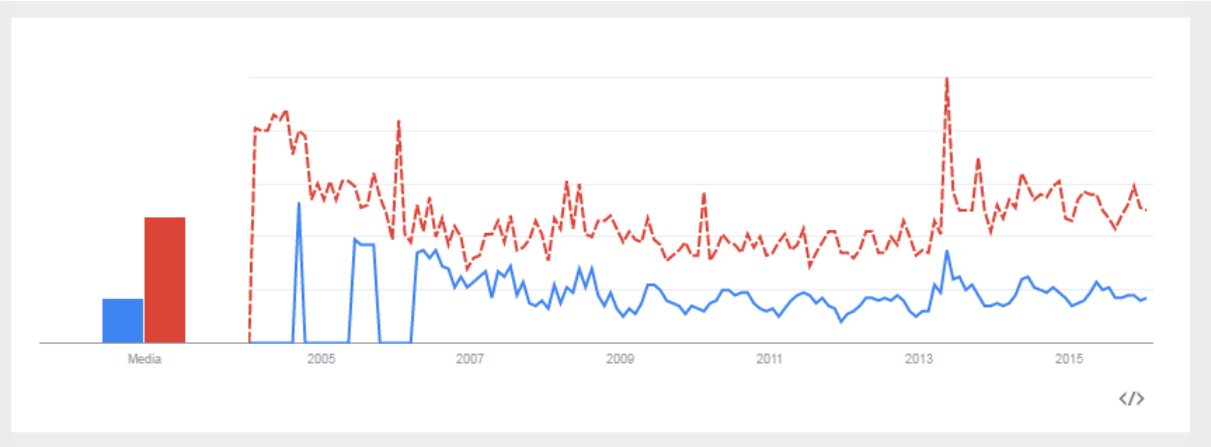


Figure 3 Interest on entomophagy (Google trend, 2016)

Scientists are engaged in understand the reasons why edible insects are not accepted or recognized by consumers as source of food (Röcklinsberg, Sandin et al. 2013).

[1] Neophobia in food consists in the fear of eating something new.

Insects are often associated to waste, dirt, pesticides and diseases leading to a perception of the so called "Yuck factor" and disgust (Anthes, 2015). The concept of "Yuck factor" was introduced by Pennsylvania University bioethicist Dr. Caplan to describe the influence of instinctive attitudes towards new technology (Schmidt 2008). This factor can also be applied to describe the aversion against the introduction a novel food.

The idea that disgust plays an important role in people's everyday behavior and decisions started to be widespread in the scientific world when researchers decided to investigate the interplay between disgust and morality. According to Jonathan Haidt, disgust is sometimes what guides our perception of right and wrong when we follow our gut instead of logical reasoning. In the past disgust has been used against "outsiders" such as lower castes, immigrants and homosexuals. For example, Nazi used to represent Jewish people as rats in the propaganda, making an link between the disgust that is commonly associated to rats to the disgust that in a specific historical period was associated to Jewish. Our disgust reaction protects us from things that might carry parasites and disease, according to "disgustologists" or expert on hygiene and behavior. Disgust, like culture, is transmitted from generation to generation in Western countries (George, 2012).

Disgusts seems to have power in our everyday life, it is possible to overcome it. If we were entirely governed by it, we would never try new things at all. Changing the eating habits of billions of people, is quite a challenge but it has happened before for instance with the introduction of sushi in the West (van Huis 2013) and lobster that used to be so abundant along the east coast of the US and Canada that it was seen as a poor man's food. Today, lobsters are often the most expensive item on the menu and considered a delicious food (Deroy, 2015).

The cultural barrier can be overcome by implementing appropriate processing strategies and by providing customers with information on the products (van Huis 2013). In the study by de Magistris et al.(2015), information can play a crucial role to the acceptance of food made by edible insects in the EU. The visualization of the whole insects induce feelings of disgust in the consumers, however consumers are willing to pay for insect based product with an health claim and a logo on the box. Transforming insects into more familiar foods by for example separating proteins, can be a solution (Mitsuhashi 2010, van Huis 2013) (de-Magistris, Pascucci et al. 2015)Tan et al., 2015).

2.1.3. Ethics

Behind consumers choice there is also a fundamental ethical issue regarding animal welfare. The problem when talking about edible insects is to understand if the rearing conditions are appropriate for their well-being. The European legislation refers to Brambells' Five Freedoms to deal with animal welfare issues. Those include the freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury and disease, freedom to express normal behaviour (within reason), freedom from fear and distress. This framework was invented for vertebrate animals and a more specific to insect should be developed considering also different species (Veissier, Butterworth et al. 2008). Insects are animals, because recognized "sentient" in the biological meaning, but it is arguable whether or not they have a consciousness. The question of welfare remains open in the case of insects because scientists are not sure if they can experience pain or not, but absence of proof is not proof of absence. In addition, although pain experiences and suffering are unlikely to occur, a capacity of nociception has been demonstrated, for example they react to injurious stimulus. (Gjerris, Gamborg et al. , van Huis, Van Itterbeeck et al. 2014)

Since consumers play a crucial role for the development of the sector, it is also important the way communication is managed. Companies and all stakeholders involved have the role to convince people on the reason why edible insect are more and more being referred as food of the future. However, the increasing attention by the public on entomophagy is visible by the increasing number of discussions on the topic. Since the majority of Western citizens are still sceptical towards the consumption of insects as food articles, blogs, conferences websites and informative journals are a primary source of information. Recipes and experiences are also exchanged to persuade people to make use of a more sustainable, healthy and affordable protein source. Famous restaurant's chefs are helping by gradually introducing insects on their menus.

2.1.1. Regulation

The introduction in Western countries of edible insects, given their unfamiliarity, needs to be guided by regulative guidelines that can insure the safety of the process and the correct development of the industry. For this research it is of interest the situation in Europe and America in comparison to the legislative framework of countries in Africa and Asia.

In Europe as a general rule each new substance introduced on the food market has to follow the EC General Food Law and Regulation 178/2002 about health in food and feed. Producers and distributors are also asked to be approved according to 854/2004 concerning food hygiene and 183/2005 on feed hygiene besides the HACCP principles. On one hand, for what concerns feed ingredients the general law about undesirable substances in feed EC 2002/32 applies, but the most relevant is the EU annual By-products regulation 1069/2009 on the requirement to process processed animal protein (PAP). After the BSE outbreak the introduction of any processed animal protein (PAP) has been banned from the ingredient list of feed products with the exception of feed destined to aquaculture. On the other hand, the production of insects as food is not directly regulated but is covered by regulation (EU) 2015/2283 on novel food. The law tolerates the introduction of a novel food if its consumption has been widely spread before 1997 in a third country. Being that regulation is very ambiguous a new novel food regulation is under construction (COM (2007) 872 final) (Proteinsect, 2014).

In the United States the FDA didn't legislate yet on the introduction of insects as feed and food, giving the possibility to companies to produce and trade them (The Future Of Edible Insects, 2014).

In Asia, where the majority of edible insects are reared and consumed, there is no legislation concerning insects in animal feed. China and African countries such as Congo and Nigeria have a long history of producing insects on a large scale for food and insect protein (PROteINSECT, 2013; Paun, 2013). However with regard to legislation in African countries, PROteINSECT indicates that there is currently no legislation covering the production of insects and as opposed to the legislation in the EU, the legislation in China has a passage for "insects and processed insects" in the Feed Material Catalogue (PROteINSECT, 2013). Only dried and crushed insects and de-fatted insect powder from insects are allowed because these do not affect human and animal health. The names of the insect species have to be mentioned in the labeling or packaging to create clarity on the ingredients of the products.

2.2. Edible Insects as innovation for businesses

Edible insects' based ingredients are introduced as innovative products especially in the food and feed industry in Western countries. Companies that introduce EI have to compete for a market share by adopt a certain innovation strategy. The EI industry is characterized by a driver of innovation related to sustainability factors such as the world increase of consumption and production of food. This complex scenario makes innovation theory an important step to analyse practices currently adopted by companies of interest for this research.

The following chapter is aimed to combine the literature about edible insects with insights on the innovation theory. Concepts on innovation are relevant to this research because they allow the analysis in the empirical part of this research.

The first section of this chapter consists in a description of innovation in the food industry, and its contextualization for edible insects, while the following sections deal with concepts typically associated to innovation. Those include radical and incremental innovation, open and close innovation, product and process innovation, supply chain innovation and lifecycle innovation. Each section is first focused on the theory in general terms and then it is applied to the case of EI industry. The last part deals with the sustainable drivers of the innovation and the concept of sustainable diet.

2.2.1. Overview Innovation

An innovation is an invention transformed into a structured and organized business. For a company it represents a way to shape its own future where knowledge, technological competencies and resources are keys to the process (Earle 1997). It has been described by Garcia et al. (2002) as "*an iterative process initiated by the perception of a new market and/or new service opportunity for a technology based invention which lead to development, production, and marketing tasks striving for the commercial success of the invention*" (Garcia and Calantone 2002).

In the food industry, like in many others, the development of innovations is crucial (Winger and Wall 2006). The food sector has to react to the demand for higher quality standards by new formulations of traditional products, product diversification, and new functions of products (Capitanio, Coppola et al. 2010). Each of these strategies is a driver for competition in the food industry that can lead a company to gain a competitive advantage. There are two different views on innovation in the food industry described in literature. In the first view, innovation coincides with technological changes, regarding R&D expenses as major indicator. The food industry being included a low-tech industry (Eurostat, 2015). The second view concerns the market orientations of a company. Innovative products are seen as a mean to fulfil needs and wishes of potential customers. The study by Grunert and Traill (2012) concludes that neither R&D nor market orientation have a positive impact on business performance directly (Grunert and Traill 2012).

Innovation can be developed at derived from food technology level, such as an innovation of product formulation or process engineering or from new consumers needs. Those two are often interrelated. Consumers wishes are a relevant source of innovation. Consumers can be divided into two groups: over-fed affluent and comfortable and the poor under fed underclass. Innovation can have different objectives depending on the economic status of a Country. In this sense innovation at global level is strictly associated to per capita income (Earle 1997).

The innovative process of a company can be analysed on three different layers: the supra-company level, the company level and projects level. In the first the innovation process is

determined also by how the company interacts with networks, clusters and chains. At the second level, the company level, the most important variables that can affect the innovative process are the size of the company, and the degree of vertical collaboration. At last, at project level, a product development strategy, a market focus in the product development process, and the organization of the product development process (degree of formalization) are factors that can influence the innovative process (Traill and Meulenberg 2002).
Innovation is a multidimensional concept made by many variables that define how a company differs from another and so its impact on the environment. Some of the variables are introduced in the following paragraphs.

2.2.2. Radical or Incremental innovation

The degree of innovation is a first discriminant when talking about innovation: an innovation can be radical or incremental. Those two groups can be distinguished according to many criteria. First on the degree of detachment from existing practices (Ducheasneau from (Ettlie, Bridges et al. 1984)). A radical innovation is characterized by the introduction of a technology that is new to the adopting unit and new to the referent group of organizations and market. (Shumpeter,1934 from (Chandy and Prabhu 2011). It usually create a brand new demand unknown by consumers instead of using an existing demand (Garcia and Calantone 2002).
The required changes in both the process and the product are usually much more costly in radical innovation compared to incremental innovations (Ettlie, Bridges et al. 1984). Radical innovations are considered a push to economic growth and an input for better products (Chandy and Tellis 2000). A radical product innovation is a new product that requires a completely different core technology and provides higher customers benefits relative to previous products in the industry. And an innovator is the first firm to commercialize the radical product innovation (Chandy and Tellis 2000). Moreover they foster a major change in cultures and social structures, changing the way people approach a certain product or service (Earle 1997). Radical innovation is more often associated with business model innovation (Crossan and Apaydin 2010).
Companies are influenced in high degree by the surrounding environment on the way technology and the market policy are developed and as a consequences this influence the innovation adoption and new product introduction (Ettlie, 1983). Researches showed a correlation between the size of a firm, market strategy and radical innovation. Radical and incremental innovation strategy and structure are pretty different. For instance, higher rate of new products development came from more complex, decentralized and bigger organizations.
Chandy and Tellis (2000) look in the market of radical innovators to further investigate to what extent the size of the firm can lead to a radical innovation. They distinguish between incumbent and non-incumbent firms and by an empirical study they collect data to test this theory affirming that recently (2000) large firms and incumbents are more likely to introduce radical innovation than small firms and non-incumbents. This because large firms are willing to cannibalize their past investments to introduce radical product innovations (Chandy and Tellys, 1998). Decentralization of units in big firms is a driver for radical innovation. Moreover radical product innovation requires big expenses in R&D, thus small firms in order to acquire them has to make use of spill overs from research or to collaborate with organizations with technological capabilities and financial resources they do not have themselves.
Incremental innovations are marginal improvements of the characteristics or benefits of an existing product in an existing market (Garcia and Calantone 2002). Incremental innovations are

important in a market that is already formed and developed, as competitive advantage and can also warn the company on the existence of a more advanced technology. These innovation are the most widespread, and occur more frequently compared to radical innovation, giving the impression of a continuous change. Companies tend to make use of incremental innovation to maintain a strong position in the market, or to slowly penetrate a new market segment.
Dahlin and Behrens (2005) introduce a classification useful to recognize whether an innovation can be considered radical or not. The authors attempt to put together all the discriminants pointed out by previous works using as starting point the technical content of inventions. To use this classification inventions should be analysed before, during and after their entrance in the market. According to the classification the invention must be novel (it needs to be dissimilar from prior inventions), unique (it needs to be dissimilar from current inventions), adopted (it needs to influence the content of future inventions).

Radical and incremental innovation in the EI sector

Most of the innovations in the food sector are incremental (Capitanio, Coppola et al. 2010). As Earle (1997) notes, "Innovation in the food industry combines technological innovation with social and cultural innovation" (Earle 1997, p. 166). A radical technological innovation in the food industry can cause changes in society, in consumers' cultures, in communities and organizations. For example the introduction of Supermarket drastically changed people's habits and culture or a new product in substitution of fat ingredients require food manufacturers to modify the way they fry snacks. Food is an essential part of social structure all over the world and it has a strong political and economic importance. Citizens ask for cheap, safe and high quality food and politicians held the control for prices and subsidy farmers. Many food innovations were developed also under governmental or regulative request, like preserved food useful to feed army during wars (Earle 1997).
During the last decades some products were perceived as radical innovation. Examples can be nanotechnologies, nutraceutical and functional foods, genetically modified organisms (GMO's) and irradiated foods (Pascucci and Magistris 2013). Those innovations had an impact on companies' behaviour, consumers' way of thinking and food legislations (Pascucci and Magistris 2013). Edible insects sector appears to be following the same pattern because of the involvement of many stakeholders. The radicalness of the introduction of edible insects as new protein source can be evaluated on the basis of the magnitude of the impact that it has on the feed and food industries.
Concerning the feed industry, currently, the most-used protein sources are soybean meal, fish meal and processed animal proteins (Veldkamp 2012) but there are several issues limiting the protein production for animal feed. In the European Union the use of processed animal proteins is prohibited due to the TSE (Transmissible Spongiform Encephalopathy) legislation (Veldkamp 2012). The soybean and rapeseed cultivation is limited due to a lack of available land (Manceron, Ben-Ari et al. 2014). Fish meal, another source of proteins for feed, has significantly reduced in availability due to marine overexploitation of the small forage fish which are used for meal (Belluco, Losasso et al. 2013). In addition, cattle production and the beef consumption are considered as the major source of the greenhouse gas emission worldwide. According to Kyoto Protocol on climate change and EU regulations that followed, there is a need for more sustainable production systems with alternative protein sources (Spiegel, Noordam et al. 2013).

Moreover, the prices of high-protein ingredients for feed in the last five years have doubled and represent 60-70 % of the total production costs. (Taheripour, Hurt et al. 2013).
This reasoning leads to the conclusion that the introduction of insects could shape the feed production scenario for example affecting prices, land conformation and animal welfare.
Edible insects can be introduced in humans diets (Ramos-Elorduy 1998). Although one century of promotion failed to introduce edible insects in the food system, recent studies, present insects as highly nutritious and healthy food source, with an high amount of fat, protein, vitamin, fiber and mineral (van Huis, Van Itterbeeck et al. 2014). Sushi, goji berries, quinoa, kombucha and acai berries are examples of food products recently adopted into (elite) Western food cultures. Insects are well known for the production of silk, wax, dyes, as animal bait but for food the only common used products are bees honey, food coloring and pharmaceutical products such as propolis (Rumpold and Schlüter 2013). The meat substitute market give companies many option to work on because of the comparable nutrient content of the substitutes (de-Magistris, Pascucci et al. 2015). Edible insects, sometimes still associated to pests or to dirtiness, are considered radically innovative by consumers in the West that are not used to find insects in supermarkets shelves (Pascucci and Magistris 2013). Edible insects still constitute a niche in the food industry, but they show environmental and business potential to affect food cultures and landscape(de-Magistris, Pascucci et al. 2015 from Verkerket al., 2007).
Insects can enter the food industry depending on the way those are processed and used by companies and this can have consequences on different levels considering especially the restrictions coming from the legislation and consumers acceptance.

2.2.3. Open or Closed innovation

Open innovation is a term introduced by Chesborough (2003) to define a system where a firm collaborates with partners, scientific institutions, governmental bodies and competitors in order to foster innovation and development of new products or processes. The firm in this way can share the burden of innovation with other parties and at the same time have access to other's results or outputs. Collaboration makes the innovative process faster and more efficient. The mutual need of information and innovation requires the firm to create a balance between the value that a firm can retain for itself and the resources it sells outside. (Omta, Fortuin et al. 2014)
There are risks connected with open innovation such as loss of knowledge, higher coordination costs, loss of control and higher complexity and at the same time organizations face also internal challenges such as the difficulty to find the best partner, the imbalance between open innovation activities and daily business, and insufficient time and financial resources for open innovation activities (Enkel, Gassmann et al. 2009). Ebersberger (2011) showed that open innovation has a positive influence to innovation inside a company.
Two types of innovation are widely spread, an "innovative alliance" is when a firm collaborates only with one partner; a "network collaboration" is a collaboration between many partners. The former is the most common and the easiest to adopt even though less comprehensive, usually lasts the time of a project. The latter on the contrary has a longer term of collaboration. Some examples of network collaboration are crowdsourcing, mass customization, customer community integration, as well as the use of innovation intermediaries. (Enkel, Gassmann et al. 2009)
Enket et al. (2009) distinguish three processes in open innovation. The outside-in process represent the flow of knowledge from suppliers, customers, competitors, etc. towards a company; the inside-out process consist in the action of selling intellectual properties or technologies or

ideas in the outside market (mainly for big companies); the coupled process is a combination of both processes, so the mutual exchange of knowledge between an organization and the environment. However the strategic, organizational, behavioural, knowledge, legal and business perspectives, and the economic implications of an open innovation process are still discussed in the scientific community (Enkel, Gassmann et al. 2009). The development of social networks and internet technologies together with the open innovation based business model push companies to be everyday more open to users inputs.
Start-ups are usually favoured by open innovation because being small companies they can compensate the scarcity of financial, social, commercial and technological resources collaborating with others. The collaboration can occur horizontally, meaning among similar businesses in the same industry, vertically different kind of businesses of the industry at different levels such as marketing firms, research institutes, governmental labs and industry associations (Baum, Calabrese et al. 2000). An higher performance of a start-up is determined by an initial strategic alliance with parties that contribute with diverse information and capabilities (Baum, Calabrese et al. 2000).

Open innovation in the EI sector

Open innovation has historically being linked to new industries such as information and communication technology sector and pharmaceutical industry, but instead many of the characteristics are studied also in the so called mature and traditional food sector (Sarkar and Costa 2008).
Changes in supply and customers' demands and the increased level of global competitiveness required innovative solution in the configuration of the agribusiness. Companies are constantly looking for new ways to improve efficiency and effectiveness of their innovation process. Open innovation can take place in the food industry and can improve the effectiveness of technological and market capabilities while reducing costs (Sarkar and Costa 2008). In an open business model the aim is to create value to customers by integrating ideas external to the firm and cooperating with suppliers or competitors.
Market based transactions are changing towards network of relations between important economic actors. The creation of such a network requires the reshaping of the business model of a central firm and the other players with different assets and competencies (Vanhaverbeke and Cloodt 2006). The introduction of biotechnology exemplifies how a business model can be shaped to compete with a new one.
The dependency on scientific knowledge, legislative restrictions and consumers' behaviour make the food industry appropriate for open innovation. The high number of actors involved requires also coordination along the chain and between different parts. In the case of the edible insect sector it isn't clear to what extent companies collaborates but there is a mutual exchange of information between companies' research canters and governmental institutes to seek for an higher consensus among consumers.

2.2.4. Product or Process Innovation

Innovation has become an important source of competitive advantage for a firm, so that activities that can bring to an innovative outcome are everyday more valuable (Oke, Prajogo et al. 2013). The performance of each firm depends on the strategies and specific actions undertaken to implement innovation capabilities. The source of such an innovative strategies from a

managerial point of view can be a change in the leadership style, top management commitment to innovation, improving people's creative skills, improving technological competencies, or a change in the culture of the firm (Oke, Prajogo et al. 2013). Innovation can be a mean to revitalize an organization and a way to use more efficiently existing competencies (Cheng, Chang et al. 2013). Companies are pushed to produce more innovative products rather than incremental ones, this because really new products are vital to follow the changing rhythm of the surrounding environment (Danneels 2000).

Product innovation is the introduction of any new product or service to meet a market need and to explore new markets (Cheng, Chang et al. 2013). A product or a good innovation is a tangible offering that can satisfy consumers' needs by means of its attributes, appearances, technical specifications, or part of the final product. A product innovation can consist of a brand new product or in a modification of an existing one. It is a process that includes: technical design, research and development, production, management and commercial activities associated with marketing of the new product (Tohidi and Jabbari 2012). New products can be defined along two dimensions: newness to the market and newness to the developing firm (Pullen, de Weerd-Nederhof et al. 2012). The relationship between product innovativeness and innovation performance has been studied as a parameter to distinguish different typologies of innovation.

A process is a specific order of work activities across time and place. Process innovation is a the adoption of facilities and technologies in order to produce new products or to provide new services. It consists of processing inputs into outputs in an innovative way using knowledge and information. Process innovation directly influence the plant layout reducing the burden of production costs, it can be as valuable as financial manoeuvring. There are many occasions that can foster a process innovation in an organization, for example merger can be a good occasion, or an old IT infrastructure system. A process innovation can shape the way the organization works, improve the way the work is done. (Davenport, 1993)

According to recent studies product and process innovation seems to occur at the same time, especially in the service industry. The combination of the two is the structure used to generate value for customers (Davenport 2013).

Product and process innovation in the EI sector

In the food industry innovation can range from a new ingredient and so a new product, to a new way to improve food preservation and packaging and so a new process. In the food industry innovations are mostly process innovations (Capitanio, Coppola et al. 2010).

The introduction of edible insects in the food system can be seen as a product innovation and a process innovation. The first is product innovation in edible insect sector is easier in somehow to identify, it consists in products that are new to the market, for example the introduction of energetic bars, or candies or cookies. Stakeholders are putting a lot of effort in this sense in order to gain consumers acceptance. The less impacting for consumers the better is accepted (de-Magistris, Pascucci et al. 2015). In the food industry, technical details of the product such as perishability or nutritional values can help in defining product innovation. The second one is focused on making the processes of preparation of food and feed ingredients as efficient as possible. Indeed the production of edible insects due to the high manual labour expense required has high costs if compared to traditional livestock. The mass production of edible insects needs to become more attractive by the development of automatized processes in the phases of rearing, harvesting and post-harvesting (including safety and quality monitoring) (Rumpold and Schlüter

2013). Another point where an innovation can occur is on the selection of the species and on the factors that influence the rearing process such as illumination, water, humidity, ventilation, container systems and so on (Rumpold and Schlüter 2013). Going in more details also new technologies are in development like systems to cut legs and wings to the insects, separation of proteins, chitin removal, or the research for cheaper substrates such as waste

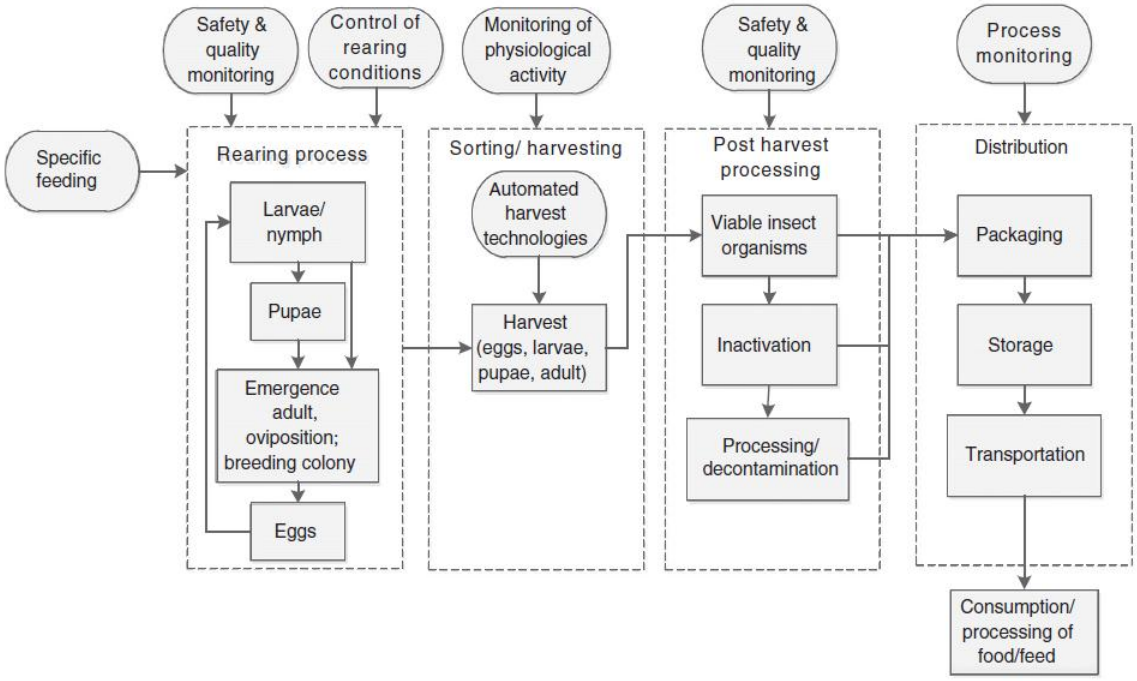


Figure 4Large scale production of Edible insects (Rumpold and Schlüter 2013)

2.2.5. Supply Chain Innovation

A supply chain describes the flow of a product from the production phase till the sail to final consumers. In the between there are steps that need to be precisely managed and coordinated. The main actors in this process are supplier, manufacturer and consumers.

Innovation can occur at many levels of the supply chain. In particular, the relationship between buyer and supplier, according to Roy et al. (2004) can lead to incremental and radical innovation. To have radical innovation, the company should innovate together with its suppliers. (Roy, Sivakumar et al. 2004)

Companies can innovate also on the way they manage the supply chain, the way value is delivered to customers. Soosay et al. (2008) describe how the increasing global competitiveness, the push to reduce costs, the demand for increasing quality, the increased interaction with customers and developments in the information technology are the basis for enhancing the relationships along the supply chain. A better coordination could lead to innovation in the supply chain that goes together with the dynamic environment. In this way partners could benefit the advantages of lower costs, high quality, lower lead time, efficient operations and effective coordination (Soosay, Hyland et al. 2008).

Companies can collaborate ultimately with their buyers. The target market of a company is part of its strategy and also of its marketing plan. It refers to the group of customers chosen by the company to be potential buyers. The goods produced for individual final consumers are those products that don't need any further commercial processing, while business goods are those sold

to other companies to produce products that will arrive to the consumers or will be used internally. Examples of the latter are buildings, equipment, raw materials, etc. The majority of the features that distinguish business from consumer marketing are product or market related. Those two market strategy differentiate on the type of good, the buyer's decision making process, the features of the market, and the nature of marketing activities.

Some market characteristics are different between consumers market and business market. For instance, the relationship between buyer and seller is impersonal in the consumers market while personal between company and sales person. Products thought for business are normally more complex and buyers more sophisticated. The consumer market rely on mass market advertisement while in a business to business market the personal selling has higher relevance. Moreover, firms ask for augmented services at the purchase time (Mudambi 2002).

To sell to a business usually a longer time period is needed in order to establish a relationship with the potential buyer. It is also important to reach the right contact in a company because if multiple stakeholders become interested in the process it might be more difficult to sign the contract (Cohn, 2015). The positive aspect of a business to business is the long-lasting relationship that can arise (Fern and Brown 1984).

Supply chain innovation in the EI sector

The food supply chain describe the process by which goods from agriculture, zootechnics, forestry and fishing activities arrive to the end- consumer with the support of logistics and operations activities (Manzini and Accorsi 2013). There are also external trends that influence the configuration of a supply chain. Those are sustainability, partnership and collaboration, integrated technologies, multi-plant operations and so on. The globalized economy is pushing the supply chain towards a reinforcement of collaboration with supplier and consumers, with the objective to reduce demand uncertainty (Manzini and Accorsi 2013). Lambert et al. start their research on supply chain saying that it is nowadays a matter of chains more than individual firms, supplier, brand and stores are competing as one (Lambert and Cooper 2000).

Vertical integration can foster innovation by the circulation of knowledge of the food system and because it brings new competences in the innovation process (Grunert and Traill 2012). It can be spread along the supply chain from the production stage until the manufacturing and distribution steps. For instance also the relationship between buyers and suppliers has to be taken into account.

The management of the supply chain consists in design, control and coordinate the procurement of products, production, planning activities, demand management and forecasting, inventory, consumers demand allocation, simultaneous facility location, transport planning and demand allocation. Food products are subjected to quality and safety risks that have to be taken into account considering their influence on human health. Foods and raw material are often exposed to physical, chemical hazards such as change in temperature, light, humidity (Manzini and Accorsi 2013).

In the edible insects sector the supply chain is considered circular. The insects are fed on waste to become at the end food or feed ingredients. This configuration would solve in this way two of the problems present in society that are the scarcity of proteins and the disposal of waste. Around insect growers there are NGO's, research institutes and governmental bodies involved in the creation of a larger supply chain focused on providing affordable and sustainable protein

sources to the world population. The environment plays an important role steering the relationship between actors of the supply chain. (van Huis, Van Itterbeeck et al. 2014)

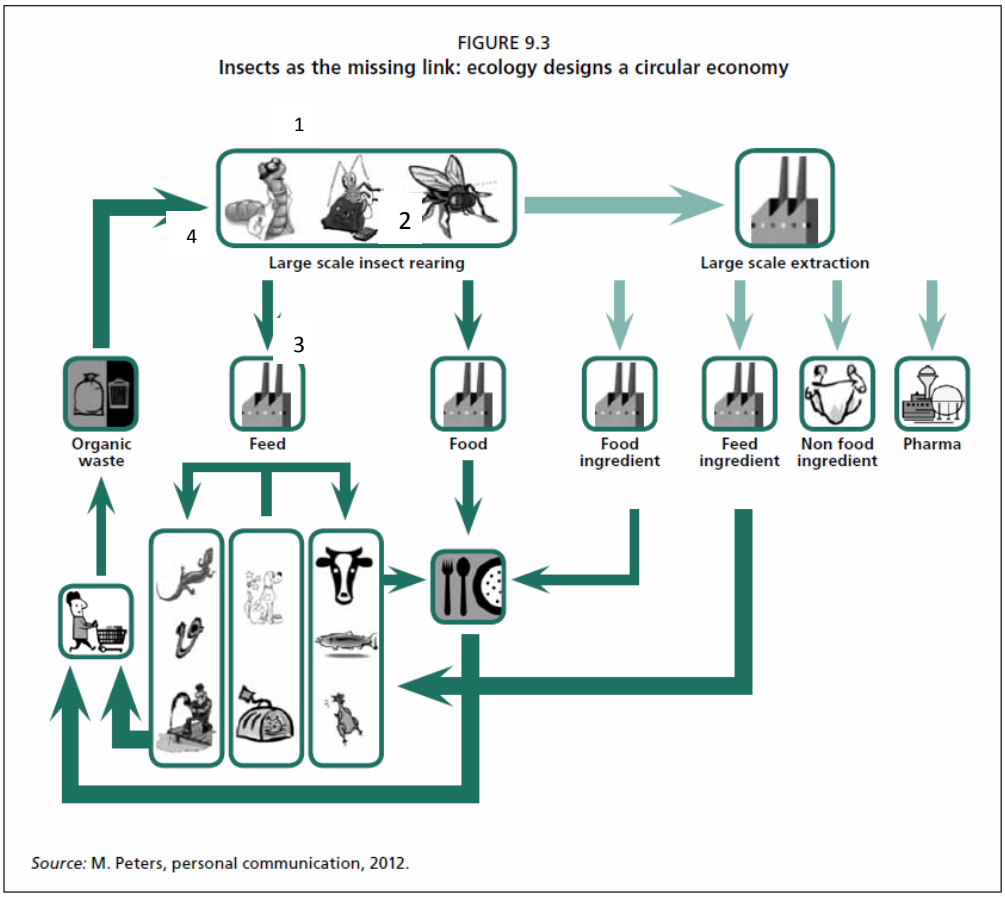


Figure 5 Circular economy in EI sector (van Huis, Van Itterbeeck et al. 2014)

2.2.6. Life cycle Innovation

In the initial phase, many firms enter the market offering different versions of the industry's product, the rate of innovation being high and market share changes quickly. Uncertainty about consumers preferences is also part of this phase. The following stage is characterized by an entry slow down and exit of many firms from the market with a shakeout of the producers. At the same time the rate of innovation and diversity of competing versions of the product decreases. Here firms try to focus on keeping the market share and the production process high. As soon as consumers experiments the product, producers learn how to improve it and so the competition shifts on product quality until a dominant design appears. Next stage is the reduction of competitors, the ones that are not able to produce the dominant design exit. In literature this patterns of entry and exit of firms from the market during time is called product life cycle (PLC) (Klepper 1996). The PLC is a tool that can support marketers to plan and predict the phases of a product's acceptance and success in the marketplace, starting with the introduction of the product, its growth in market share, its maturity, and the likely future decline in market share (Seyman, 2003).

According to Klepper et al. (1996) there are two forces that act on the pattern of entry, exit, market structure and innovation. The first one is that the returns a firm can get from an

innovation depends on its size; the second one explains that firms can reach different types of product innovation depending on the existing characteristic of the firm. Therefore, once they entered the market, firms compete on the basis of their size and the innovative engagement in such a way that the diversity of product and process innovation decrease. The authors argue that the same two forces explain the connections inside the industry, between size and investment in R&D, relative spending on product and process R&D, productivity of R&D, average costs and profitability (Klepper,1996).
The degree of development of an industry can be assessed by the degree of readiness of the innovation. The readiness of an innovation has been assessed with the Technology Readiness Level, a tool used by the NASA to assess the different degrees of readiness of prototypes and then used in other fields of study (Mankins, 1995).

Life cycle innovation in EI sector

Like in all other industry the food industry has a life-cycle that follows a pattern made of different phases. The pattern is determined by the developments of the company's and competitors' products. Introduction, growth, maturity and decline are the stages that characterize the life of a product (Seyman, 2003).
In the case of the new sector of edible insects companies are to be found in different phases previously described. Each of them thus related with a different market, sales, audience, competition and focus dimension.
The production of edible insects is still concentrated in small scale and household organization, although there are some large scale companies (van Huis, Van Itterbeeck et al. 2014). Some of these businesses are already on the market, they have bred insects for use as bait or pet food for many years. Others big players decided to diversify their range of products. (Hoffman, 2014)
But nonetheless the majority of the companies are in their initial/ startup phase, some of them are going through the growth phase while others are stuck in the introduction.

2.2.7. Sustainable innovation

Sustainability has been a driver for innovation in the last decades (Schaltegger, Lüdeke-Freund et al. 2012). In the specific case of the food industry, the push for an increase in consumption and production in relation to sustainability is a major trend of innovation for companies. Indeed, the increasing concern of public and private opinion, in Western countries, on the level of sustainability and especially of sustainability of diets fostered the introduction of new products.
The industry of edible insects presented in this research is theoretically responding to the need of sustainable food by mean of innovations.

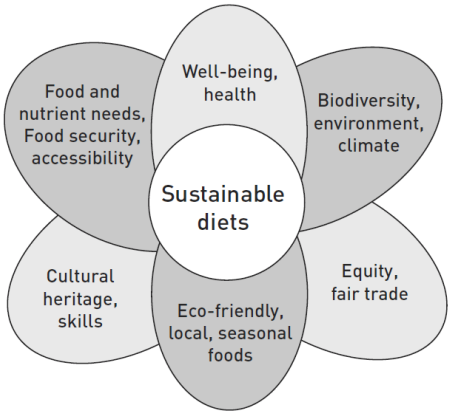


Figure 1. Schematic representation of the key components of a sustainable diet.

Figure 6 "Sustainable diets and biodiversity: the challenge for policy, evidence and behaviour change." Source: FAO 2012).

The conceptual framework for sustainable diet is not regulated yet, it originates from the discussion of politicians, scientists and researchers, and businesses no the practices to undertake in order to increase sustainability levels of production and consumption. FAO defined sustainable diets as those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally accepted, accessible, economically fair and affordable; nutritional adequate, safe and healthy; while optimizing natural and human resources (Burlingame and Dernini 2011).

Summary

At the end of this literature review, about existing research on edible insect related issues and on innovation theory and its application to the EI industry the most relevant information can be used in order to answer the research question of this research project.

On the one hand, the review about the EI sector considers the EI market in Western and Tropical countries and the main differences related to the species grown, the usage and perception. That information is used as research background for the analysis of the companies in order to put them in a context and for the subsequent interpretation the results. Legislation, even though it is in continuous evolution, is included to assess differences inter countries, especially in Europe and America. Consumers' acceptance issues and ethical considerations are important to this research project in order to study the rational for the introduction of new products in the food system.

On the other hand, the review on innovation theory was important in order to highlight which practices of innovation are described in theory and applicable to the EI industry. Whether a company adopts a radical or incremental innovations define the degree of novelty of the innovation. A radical innovation has a big impact on the society while an incremental innovation is more likely to enhance already existing practices.

To explain the forms of an innovation the concepts of product or process innovation can be applied. An innovation performed by a company can be oriented to develop new products or to improve the efficiency of the existing products by making the process more efficient. These two categories tend to overlap.

Open or close innovations are different strategies adopted by companies in order to achieve an innovation. Those two are often structure business model of a company. The identification of this patter enables to assess dynamics in the industry and understand if there is an involvement of different stakeholders and, to a certain extent, to infer on the future direction of the industry.
Studies on lifecycle innovation are used in this research in order to assess the degree of maturity of the industry and to highlight differences in the degree of readiness of companies' innovations.
Moreover sustainability is explored as an important driver in order to define the orientation of an innovation. The concept of sustainability is focused on sustainable diets which is the associated to innovation in the EI industry.

3. Methodology

3.1. Research framework

The research report is structured in three main parts. The first part consists in a literature review on the edible insects' industry and innovation theory. First the EI sector is discussed (Ch.1) with particular attention on issues concerning the legislation and on the consumers' acceptance of insects. Second, innovation theory (Ch.2) is reviewed and applied to the EI sector. This chapter is divided in sections referring to different concepts related to innovation in order to guide the reader to the empirical part of the research. These sections refer to radical and incremental innovation, product and process innovation, open and close innovation, lifecycle innovation, innovation in the supply chain, innovation in the food industry. Lastly, the concept of sustainable diet is explained.
The second part of this report constitutes the empirical part of the research where case studies selected from companies of the EI industry are described and subsequently analysed. It consists in the identification of innovation practices occurring in companies selected as case studies (Ch.5). In the analysis companies are presented divided into four groups made on the basis of their position in EI industry value chain. The groups are insects' rearers, insects as food, insects as feed and facilitators. This chapter gives an answer to the general research question (GRQ).
The last chapter gives insights to answer the second sub research question (SRQ1) on the role of the EI industry to the achievement sustainable diets in Western countries.

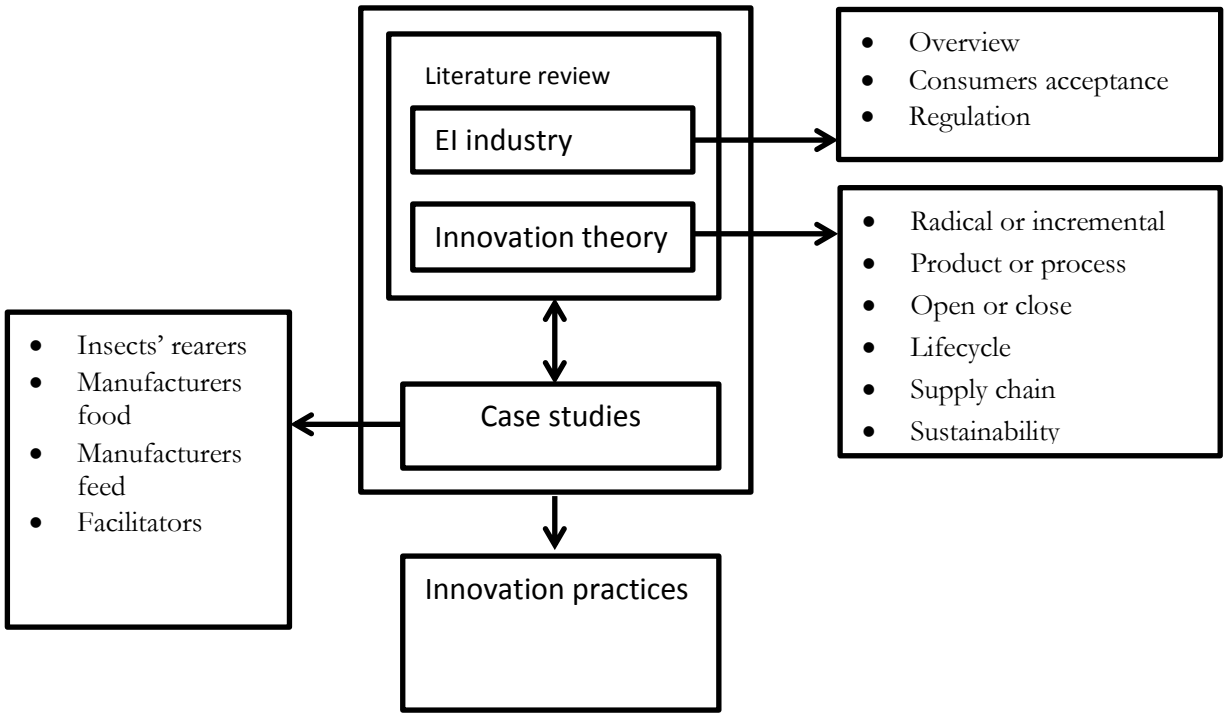


Figure 7 Research framework

The general research question (GRQ) will be answered by using the approach described as theory building from cases. As explained in the paper by Eisenhardt et al. (2007) the theory building from cases methodology is opposed to the traditional theory deduction approach. The theory building from cases indeed is a methodological tool that allows deriving "propositions or theoretical constructs" from the presentation of one or multiple case studies, where a case study is an elaborate description of a phenomenon that can regard a variety of different topics, supported by empirical data (Eisenhardt et al., 2007).

This methodology is suited to this research project given the richness of the sample available, in particular multiple cases are more suited to explain the phenomenon under examination rather than single case. Indeed, the multiplicity of cases gives reason to a robust and generalizable theory that is rich in details (Eisenhardt et al., 2207). The multiple cases theory is presented as a mix of empirical data collected and the emergent theory. Those are addressed in separated sections in order to support one with the other and to allow a comparison among cases (Eisenhardt et al., 2007).

The objective of this study is to build theory propositions in order to have insights on the possible relationship between innovation practices in the new industry and sustainable diets. The research is valuable because it is aimed at explaining a phenomenon occurring in the present society. Indeed, the generation of theory regarding the industry of edible insects is important considering the novelty of the industry and of the implication that can have on the sustainable diets. Currently, there are no studies available with the same objective.

This inductive study can be tested subsequently by a deductive study in order to prove the validity of the theory generated.

3.2. Data collection and analysis

3.2.1. Case study selection

Since the objective of the thesis is to develop theory, the cases are theoretically sampled, that means that they are selected not to test a theory but to explain the logic that relates them. They are chosen because they can be useful in explaining the phenomena taken into examination, by providing extremes cases, unusual cases and exemplars cases. (Eisenhardt et al., 2207)
Cases are selected also by bearing in mind the research questions, which are aimed to connect the edible industry sector to sustainable diets.
The list of case studies is composed by companies operating in the edible insects industry. Companies are considered a case study when the mission of the company includes the production of edible insects for human or animal consumption in the case of insects' rearers, the production of insects' based products in the case of food and feed manufacturers, and the presence of discussions on entomophagy in the case of blogs, NGOs and online shops. The actual production was not a primary focus in the sense that some companies are in the sample even if not in production because the particular case was considered interesting for the research and there are signals that the production will start soon.
Moreover, case studies have been included in the sample if the company correspond to the following criteria:

- The case study concerned a company working in the edible industry sector
- The case study had a corporate website
- The case study offered an interesting example of use of edible insects

Companies have been excluded because they did not match the established criteria.
Those are selected through a desk analysis consisting mainly of data coming from the FAO stakeholders directory, a collection of data on multiple stakeholders in the EI sector (Fao.org, 2016). The list has been updated until January 2016.
Companies on the list have been implemented by a triangulation of sources thus searching on the Web, books and reviews in order to increase the validity of the sample and studied through their official websites, other websites and data obtained via email contact.
Additionally, companies have been contacted via email consisting in a short questionnaire (see Appendix). Questionnaires were used to get information not available on the web and the answers are included in the description if the industry and in the examples.
The questionnaire was sent out to the companies of the samples that fall for the groups which use insects as food, insects as feed and to insects' rearers. On a total of 75 emails sent, the rate of response was of 25%, the majority coming from the food manufacturers group. Three different questionnaires were sent (Appendix) and were structured in the same way. Eleven open questions were asked divided in three groups, concerning technical information (year of foundation, insects and substrate used and quantity produced), information regarding the company (year, collaboration and products information) and the last was an idea about the future perspectives of the industry and expected improvements and innovations.

3.2.2. Case studies of grouping

The objective of the empirical part of this research project is to gain insights on the innovation practices introduced by companies in the EI sector in order to increase the consumption of.

In the following chapter multiple case studies are analysed in groups made according to the role that each company occupies in the food/ feed value chain. The place occupied in the value chain is a discriminant characteristic and thought to be relevant in determining the innovative practices adopted by each company.
Moreover, the division into groups is made reflecting on the similarity of the impact companies belonging to the same group can have on sustainable diets.
The following analysis of each group is structured in several paragraphs. First, a general description of the group, second a description of the innovative practices inside the group and a construct table to summarize most important theory concept found in empirical evidence.
The second sub question concerning the patterns to more sustainable diets is answered in a chapter on the association of constructs made on innovation practices in the case studies to the concept of sustainable diet. The output of the research is the formulation of propositions on the edible industry patterns in relation to sustainable diets that can be tasted by other researchers.
order to find "underlying logical elements" across them.

4. Innovation practices in EI sector- Case studies

This section is aimed to describe innovation practices in the edible insects industry by presenting case studies. Innovation practices are defined by the expression of combined innovative feature described in literature.
The sample of companies is divided in 4 groups on the basis of their position in the value chain. The value chain of insects as feed and food is structured as follows:

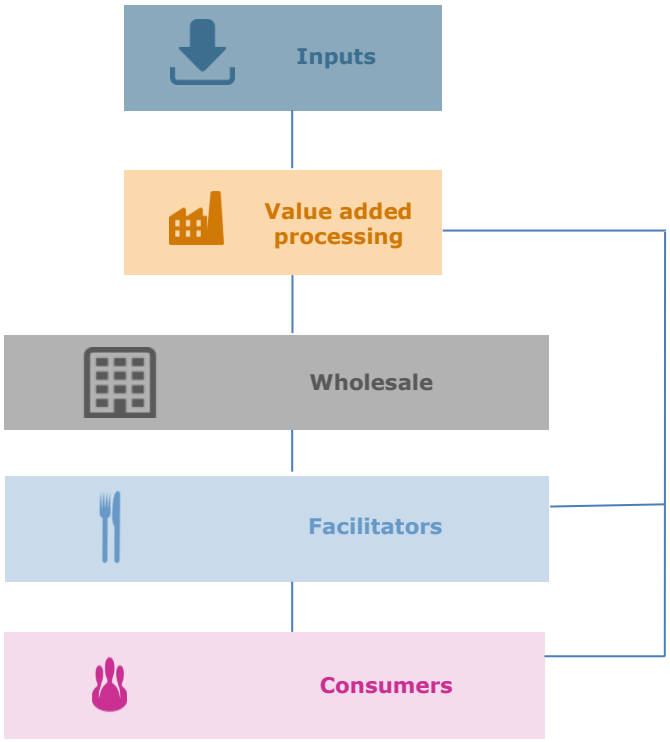


Figure 8 Value chain of the EI industry

The sample includes 104 case studies of which 47 food manufacturers', 17 feed manufacturers', 15 breeders and 25 facilitators. The creation of groups is also made bearing in mind the linkage of innovation practices to the concept of sustainable diet which will be discussed in chapter 6. It is assumed that each group will contribute differently to the objective of increasing insect consumption. The data used are collected from the corporate websites, online journals, online newspapers, books, and other websites and via direct email contact with the companies.
Each group is described first in general terms and the according to the innovation categories described in the literature review. To give a better understanding, one random example for each group is described in more details.

4.1. Group 1: Input-oriented initiatives

The group of input-oriented initiatives includes companies that rear insects and intend to sell the insects, as input for the food and feed industry.

4.1.1. Composition, general traits

Insect breeders are currently considering the idea of breeding for human or animal nutrition because of the recent growth potential of the industry. The production of edible insects can be on large scale systems, which allow the production of millions of adults per day, medium scale production system, which allow the production of thousands of adults per day and small scale systems that produce hundreds of adults per day. According to the MSU Insect Rearing Center the objective of a large scale insect production is to "Effectively and efficiently rearing high quality insects in the numbers needed at the desired times and at the lowest cost possible" (Irc.entomology.msstate.edu, 2016). A large scale farm of edible insects is fundamentally made of a climate controlled rearing facility, insects, resources which include equipment, information, procedures and people, and sanitary controls associated with the wellbeing of the insects and people.
After a preliminary analysis of the companies, fifteen (15) case studies of insects' rearers[2] were considered interesting for this study. The sample is restricted to the information found on the internet.
The majority of the companies that rear insects are located in Europe, 50 % only in the Netherlands and 14% in Spain. The rest are located in the USA (29%) and 7% in Brazil. Information on the dimension of the production has not been found for all the businesses, and thus not reported. Moreover, companies in other businesses like growers of insects for biological control are experimenting secretly the possibility of growing insects for other purposes.
The insects reared for this objective are 33% crickets, 25% mealworms, 21% black soldier flies, 13% houseflies and 8% consists of locusts and others. The substrate used is for the 80% of the cases a feed for insects made of corn or wheat, while the 13% uses organic waste as substrate to feed the insects.

Table 1 most common insects reared

Black soldier fly larvae	Black soldier fly larvae (Hermetia illucens) belong to the family of Stratiomyidae and are native of tropical and subtropical regions of

[2] Term used to refer to insects growers

	America. The larvae can feed up to 500mg of fresh matter per day and the larval stage lasts from 2 to 4 months. The diet can include rotting fruits and vegetables, coffee bean pulp, distillers' grains, fish offal, corpses (they are used for forensic purposes), and particularly animal manure and human excrete. The adult doesn't feed or move. The larva are used for fish bait, pet food, and aquaculture or dried for storage and used for livestock feed. Temperature of the rearing chamber should range between 29 and 31°C and humidity between 50 and 70%. BSFL are used live, chopped or dried and ground. (Feedipedia.org, 2016)
Housefly	Housefly (musca domestica) is the most common fly present worldwide. They feed on organic waste and manure (450 g of fresh manure can feed 1500 maggots). Good feed for poultry and aquaculture. Larval and pupae stage last 5 days each. In order to rarer housefly the humidity of 60 to 75% is required for larvae and the temperature should range from 25 to 30 degrees. Larvae are killed in hot water, then dried and milled. (Feedipedia.org, 2016)
Locust, grasshopper, cricket and katydid	Locusts, grasshoppers, crickets and katydids. Crickets (acheta domestica) are omnivorous and can be feed on organic waste. Temperature should be kept above 20 degrees in good conditions. 2000 crickets can live on 1 m and they self-regulate by cannibalism. They are used for pets and zoo animal and livestock feeding, especially poultry. Can be used live, dried and ground, and sometimes also boiled before drying depending on the animal to feed. (Feedipedia.org, 2016)
Mealworm	Mealworm (Tenebrio molitor) is the larval stage of the yellow mealworm beetle and the smaller or dark or mini mealworm beetle and are originally from Europe but now spread all over the world. The larval stage lasts 18 months and is produced as feed for pets and zoo animals, including birds, reptiles, small mammals, batrachians and fish. They are

	commercialized live, canned, dried, or powder. Mealworms are omnivorous, however in insects farming they are fed on cereal bran or flour together with fresh fruits and vegetables (carrots, potatoes, lettuce) for the moisture and soybean flour, skimmed milk powder or yeast. (Feedipedia.org, 2016)
Silkworm	Silkworm is the caterpillars of a silk moth (bombix mori). The pupae stage can be used as feed for livestock, including poultry, pigs, fish and ruminants. They are processed by drying and grounding. (Feedipedia.org, 2016)

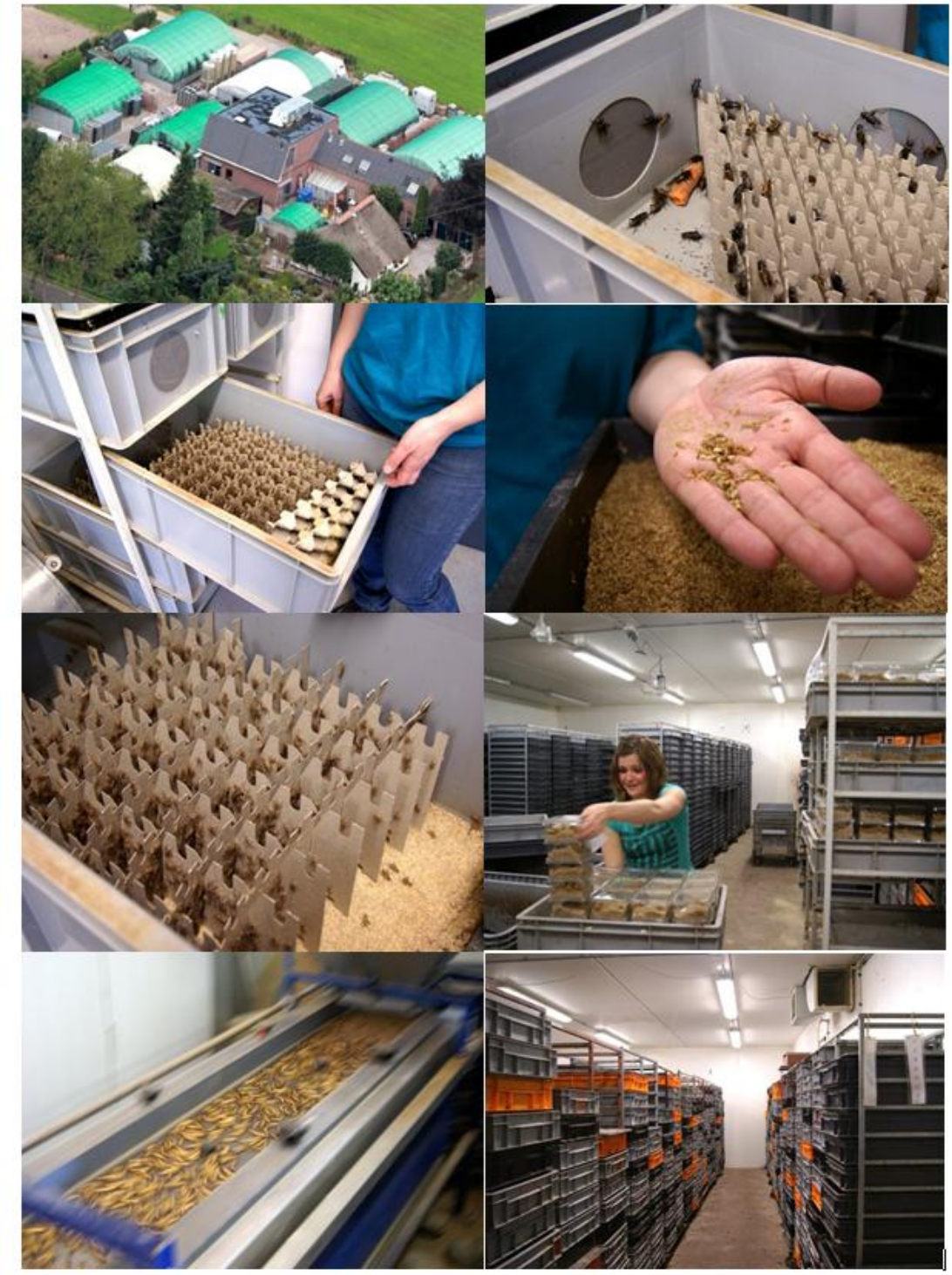


Figure 9Example of insects rearing facility (All About food, 2016)

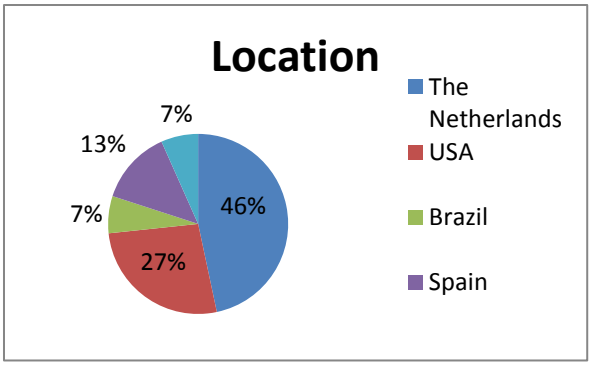


Figure 10 Location, n=15

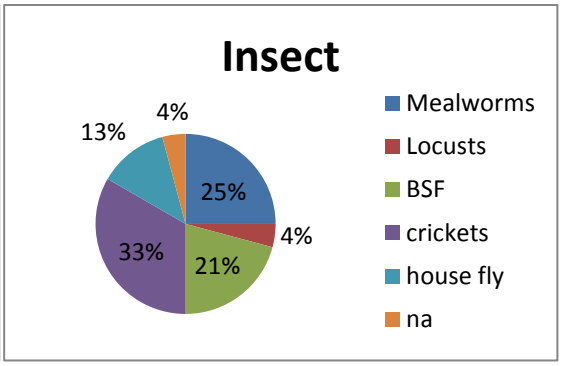


Figure 11 Insects used, n=15

The final products of insects rearers consist 73% of dry insects which is the whole insect preserved with different techniques such as freeze-drying or blenching, 14% of insects raw materials, such as proteins, fats, chitin, or amino acids. Dry insects are sold to the feed and food industry and destined to human or animal consumption, while protein, chitin, fats are used by the feed industry to prepare more balanced feeds.

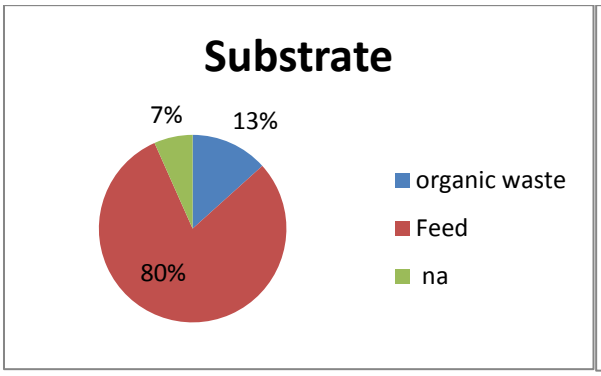


Figure 12 Substrate used, n=15

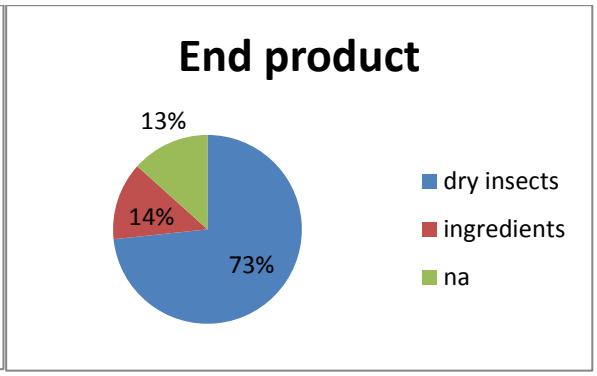


Figure 13 End product, n=15

Purpose and target

The aim of insect growers is to sell unprocessed insects to feed industry, to farmers or to consumers in the case of pet food. In this study the 60% of companies target businesses in the feed industry, the 20% both farmers and industry, the 7% farmers and pet owners and the 13% don't specify it.

Furthermore, the majority of the case studies reported, meaning the 67% of this group state that their main objective is to achieve higher standards of sustainability, sustainability concerns are part of their mission statements. This portion is divided in 7% referred to the sustainability of the environment, 20% referred to sustainable nutrition, 13% to quality and safety issues and 27% generally talk about increasing sustainability. However the 33% of the companies that grow insects don't even dispose of a mission statement.

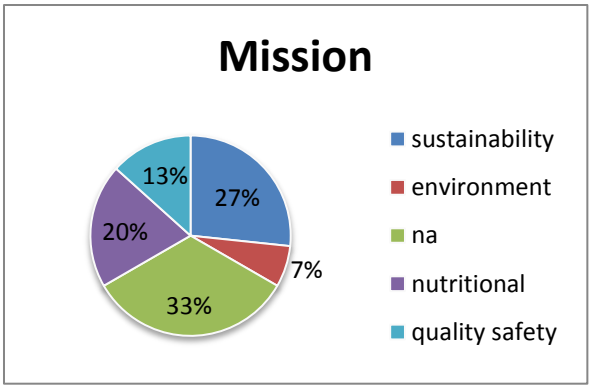


Figure 14 Mission , n=15

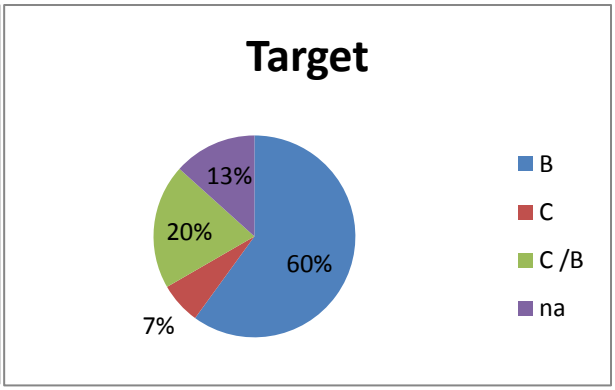


Figure 15 target , n=15

4.1.2. Innovation Practices

Open or close innovation

Innovation in the sector of insects rearing is crucial. The most important innovation however derives from the development of new processes, to increase the efficiency of the production in order to lower the costs and the inputs needed. As a consequence a vital point for insects' breeders is to collaborate with other players of the industry. Explicit collaboration is translated in partnership and agreement. In the case studies analysed the 57% do collaborate with others, the 36% use internal resources and the rest was not possible to obtain data.

The most profitable collaboration is with breeder association and research centres, especially universities because is a source of technical innovation.

Diptera for instance, collaborates not too much with research centres but with private companies (Diptera, 2016). Bitware farms, established informal collaboration, just as friendly collaborators - and donate some things to a non-profit research farm. (Bitware farms, 2016) while BioflyTech collaborates with specific research centers such as Applied Research on Insects Group at University of Alicante (Spain), LEITAT (Catalonia, Spain), Food Industries (Mahou SA, AGSL, Helados Alacant, etc.), Proteinsect project, etc (BioFly Tech, 2016).

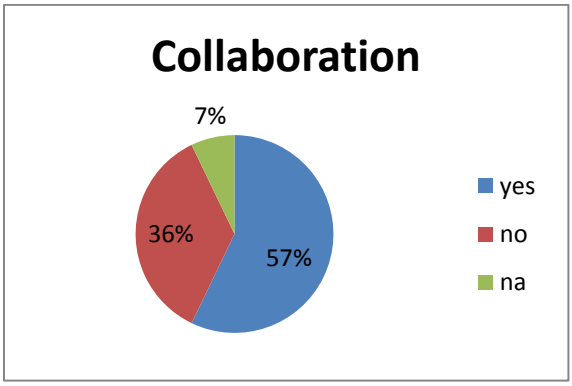


Figure 16 Collaboration, n=15

Product/ process innovation

The innovation in this group consists mainly of processes innovation. Companies engage in process innovation in order to reduce costs such as labour and efficiency. Such innovations, for example, consist in new techniques and machineries for a better automation of the equipment, efficient separation of the insects from the substrate, search for new compositions of feed,

optimal and painless insects' killing techniques. From the questionnaire sent to rearers the need for automation was stressed. Indeed, at the question "what innovation is needed in the industry?" the most relevant answers were: "Automation, that's what we focus on!" (Diptera, 2016) "Reduction of cost of production and more sophisticated and nuanced regulatory systems, as well as international production" (Bitware Farms, 2016), "Design of equipment to allow the industrialization of the production process, improvement of rearing techniques, development of new products" (Bioflytech, 2016), " Automation in equipment" (Insagri, 2016). It is needed for the company to compete with other businesses in the sector.
On the other hand the level of novelty is low for the market because both the feed industry and farmers. According to Entomofarms (2016)"education and exposure are the key tasks to help people understand the value".

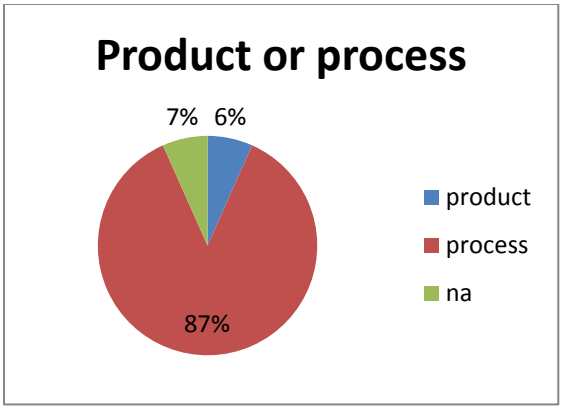


Figure 17 Product or process innovation, n=15

Lifecycle innovation

The 40% of the insects rearing companies have been established between 2003 and 2015 which is the time where most of the food manufacturers started the business. The 27% of companies were founded from 1940 to 2002, meaning before the development of the new market of EI for human consumption. For the rest it was not possible to obtain such information. The development of feed and food made out of edible insects will require an intensive supply of insects. The 47% of the companies of this group of rearers have been established with the purpose of rearing insects for feed and food. Those companies are in the initial phase of the industry, some of them being start-ups and others bigger and more consolidated companies. On the contrary the oldest companies, the 53%, are originally from and more familiar with the market of pet food or live bait and they are already in the mature phase of the industry. For instance Protix is a Dutch company working on finding the best conditions to rear edible insects efficiently and to extract the nutrients from them to be added in animal feed. (Protix, 2016) Whereas, Rainbow mealworms, established since long time marketed its products for reptiles and pets while now entered the market by introducing new species of insects suitable for human and animal consumption.

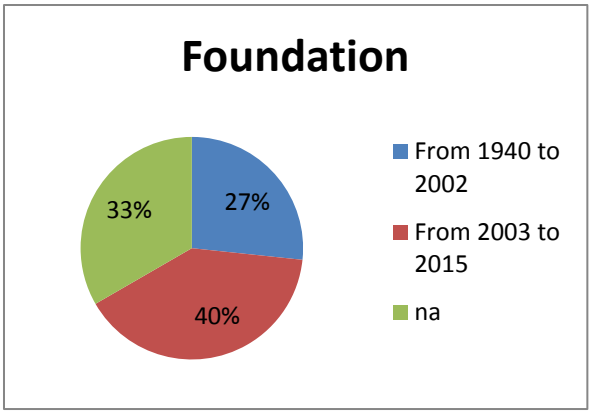


Figure 18 Foundation year , n=15

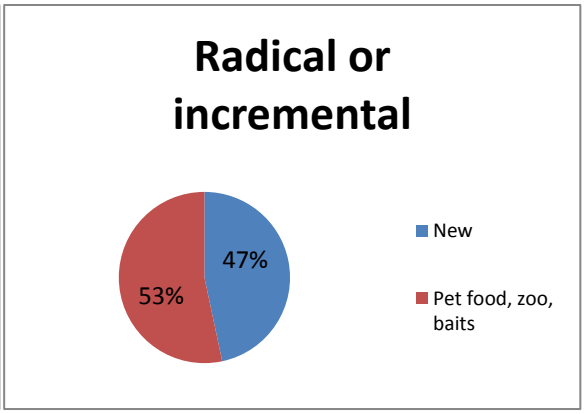


Figure 19 Radical or incremental innovation, n=15

4.2. Group 2: Output (food) oriented initiatives

4.2.1. General information

The group is aimed to include companies output oriented companies in the value chain of the edible insects industry. Namely, foods made out of edible insects and destined to human consumption. Insects are being introduced as a new ingredient in the food processing industry. Case studies studied are forty-seven (47) of which two are not in production yet but were considered interesting to this research for the innovativeness of the products.

The production of edible insects based foods include an initial minimal processing, drying or freezing/grinding into flours and a subsequent process and formulation of more elaborated products that reflects consumers' preferences. Researchers are exploring the possibility to separate and use isolated nutrients contained in the insects, such as lipids (20% of the insect), proteins (20% of the insect) and micronutrients (minerals, vitamins 10% of the insect) (Veldkamp 2012).

Insects' derived products, such as honey, colorants, are consumed daily and are part of traditional culinary products, however, entomophagy is still considered a taboo in Western countries however. An example is the "casu marzu" a cheese from Sardinia which contains cheese fly (van Huis 2013).

In the food industry, companies started the production of new foods for human consumption using insects based ingredients. According to literature, the species used from the food industry are honeybee, silkworms, crickets and mealworms (van Huis, Van Itterbeeck et al. 2014). The case studies studied in this research show that the majority of companies produce food using as raw material mostly crickets (47%), mealworms (21%) and buffalo worms (5%) while only a minority process other insects like scorpions, locusts, ants and cockroaches. (Figure 19)

The reduction of variety is mainly due to the suitability of those invertebrates to mass rearing. In fact, in countries where entomophagy is a common practice the species eaten vary depending on what is available in the wild. In tropical countries the harvest is subject to the seasons, the environmental conditions, the climate and the biodiversity. There are 2000 edible insects however each community eats certain species of insects while considers others taboo (van Huis, Van Itterbeeck et al. 2014).

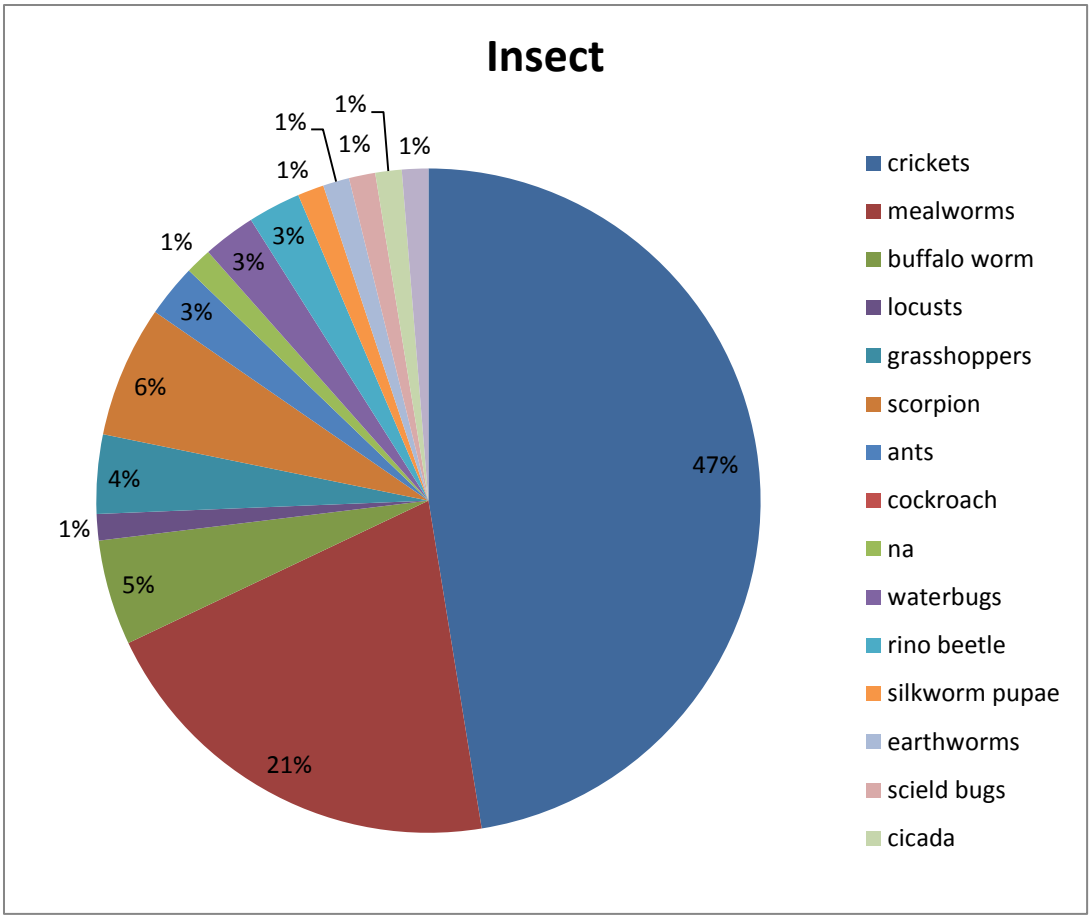


Figure 20 Insects used, n=47

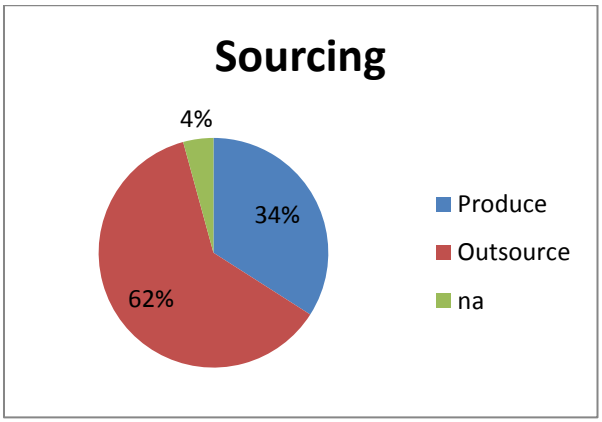


Figure 21 Sourcing, n=47

The insect used as raw material influence the outcome product. Case studies show the 19% sell insects dried or grilled. Those are sometimes added with seasonings to meet consumers taste and packaged in an appealing way. An example is Jimini's a French company commercialize ready to eat insects in a box. The 13% of the companies transform insects' derived ingredients into snack bars trying to enter the market of healthy bars to target sportive people and consumers concerned about nutrition. This market is constantly looking to ingredients with high proteins content and nutritional properties. The 9% of the companies is dedicated to the production of flour that can be used as a substitute of the most commonly used wheat and corn flours. The 8% of companies studied produces granola and another 8% burgers. The rest of the products include crackers, biscuits, candies, chips, protein mixes for gym and sauces. In the 62% of the cases,

companies outsource the input, the 34% of the companies rear the insects in their own facilities. For the cases of companies that are not selling yet, data were not available.

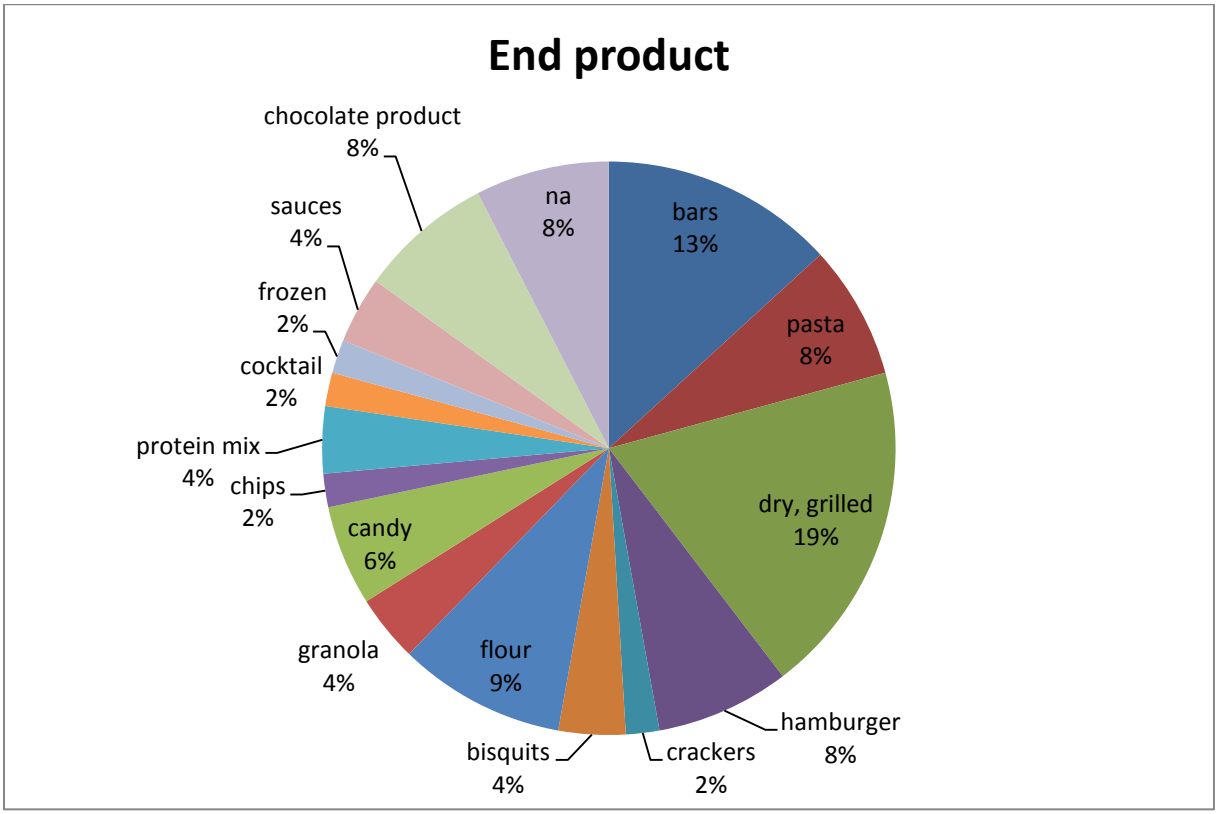


Figure 22 End products, n=47

Companies of this group of edible insects' food manufacturers are located all over the world. The 32% of case studies are located in the USA, the 19% in France, the 11% Belgium and 9% in The Netherlands (Figure 17).

The geographical position is an important element to consider when studying the outcome products. In fact, those need to be conformed to the legislation and traditions of each country which set different requirements in order to introduce a new food on the market. In Europe the new "...food consisting of, isolated from or produced from animals" falls under the definition of novel foods in the final version of November 2015, and so all products produced with insects are regulated according to the communitarian law. However the application of the law can be heterogeneous among member states and thus might affect the goals and the production of the companies. Contrarily, in USA there is no clear regulation on the topic. This ambiguity has an impact on the innovation produced by companies, because on the one hand it gives more freedom to come out with new products and on the other hand regulations are needed to establish quality standards and so barriers to entry.

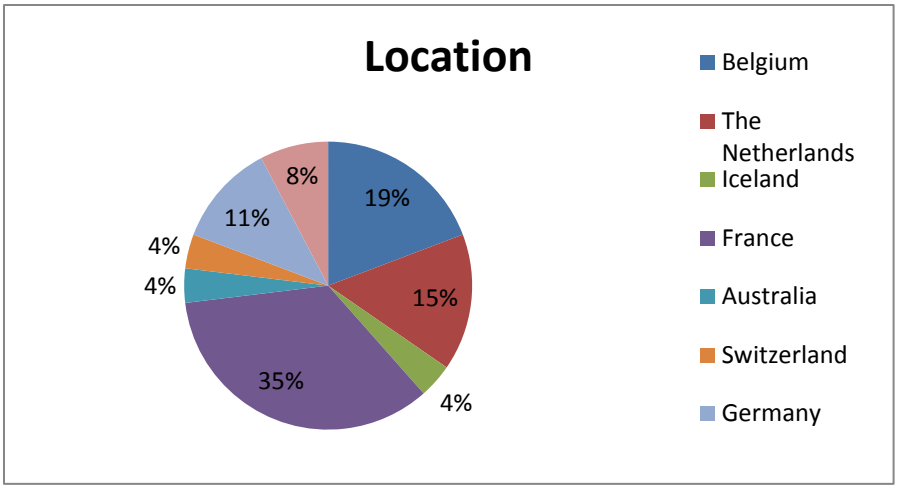


Figure 23Location, n=47

4.2.2. Innovative practices

Purpose and target

Companies studied through their website and via direct contact, are engaged in explaining entomophagy in a way understandable for consumers by referring to scientific sources, talks, news or reviews. A section on corporate websites is, in most of the cases, entitled "Why eating insects?" and is aimed to explain benefits coming from eating insects in comparison to traditional livestock with the visual support of images and videos. The increasing world population and the scarcity of animal proteins are mentioned by citing The FAO report "Edible insects: future prospects for food and feed security".

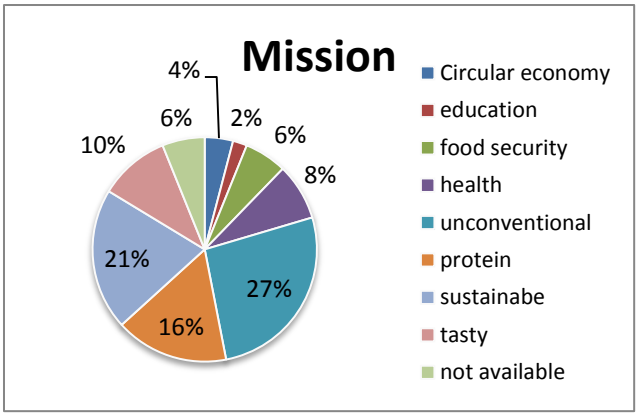


Figure 24 Mission, n=47

The mission and vision statements of the companies refer to those broad categories. More specifically 27% of case studies researched are willing to sell their final products in order to offer a new, unconventional experience to consumers. Their objective is to stimulate the curiosity of customers. The 21% aim to stimulate practices of sustainability; 16% aim to the solution of protein scarcity. The 10% stress in their mission statement the taste and palatability potential of the insect derived product. The rest of the companies are concerned about educational purposes, circular economy implementation, health issues, food security (6%).

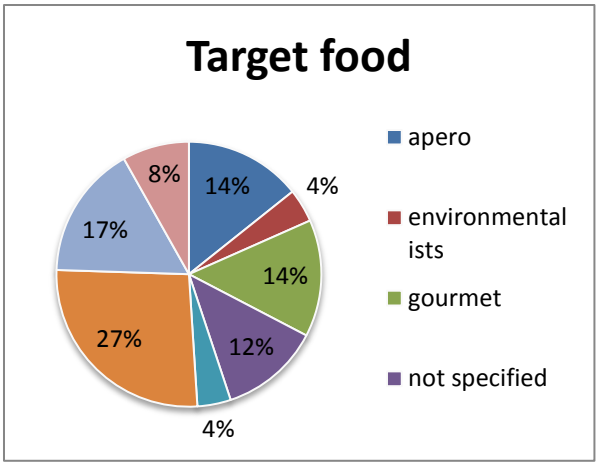


Figure 25 Target, n=47

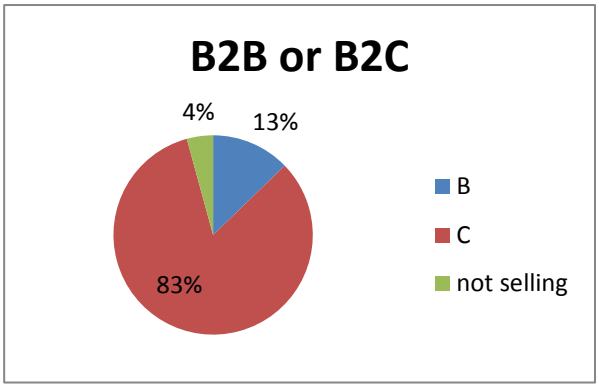


Figure 26 Business or Consumers, n=47

In the 83% of the cases studied companies that produce insects as food target mainlyconsumers. Only the 13% of the companies sell product to other businesses for further elaboration (or cooking). Concerning the target of the companies according to what is mentioned in the website it is possible to derive three main target groups: technology consumers, life style consumers and mass market consumers.

- Technology consumers are those who chose foods because of its functionality. In the case studies sportive people are target market for 17% of the companies, paleo friendly market accounts for 4% of the companies while 8% of the companies are willing to produce a product aimed to supply essential nutrient. Environmentalists are target market for 4% of the companies and would eat insects for its lower impact in the environment.
- Lifestyle consumers are those who are fascinated by new trendy benefits. Gourmets are mentioned as target group by the same percentage of 14%. Those consumers are willing to try new products supporting healthy benefits.
- Mass market consumers include those who follow the trend once it becomes more popular (late adopters). The majority of the companies' studied are indeed targeting those consumers that don't fall in any specific classification.

Products are in most of the cases available online. However, retailers are beginning to accept and sell insects based products, where allowed by law.

Lifecycle innovation

The majority of the companies that produce insects as food are start-ups. This is to say, established recently (Figure 20). In fact, the 21% of the companies that is now manufacturing insects as food were founded in 2008, the 17% in 2013, and 17% in 2014. The rest were founded starting from 2004.

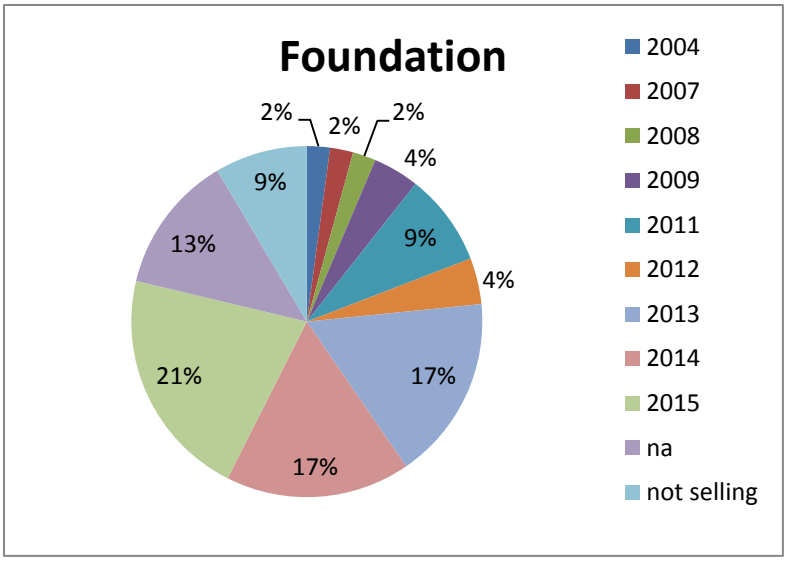


Figure 27 Foundation years, n=47

Another trait typical of start-ups is the way in which they raise the funds needed to transform an idea into a company. The 36% of the companies used crowd funding system to finance their idea, and the 11% business angels or prizes or grants (Hult prize, climate kick). The remaining 49% of the companies either used private finances or the information was not available.

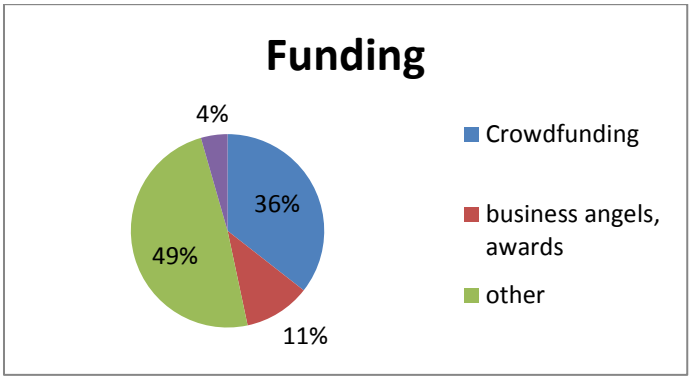


Figure 28 Funding, n=47

Moreover the character of the founder is an element that can influence the classification of a company. The industry of edible insects as food presents recurrent figures of founders. Recently graduated and motivated young entrepreneurs which by accident or for the affinity of the studies developed an interest on the topic. The team is in average formed by an entomologist, a financial analyst a market person and a chef. Chefs are key characters that contribute to the development of the company, they are highly evaluated because the competitive advantage of the sector seems to be to find the most palatable solution for consumers.

Open or close innovation

The edible insects industry is now in its initial phase and so it is very difficult to estimate the degree of sharing of ideas. However, the presence of collaboration addresses partially the question of open and close innovation. In fact, the basic knowledge is shared while details on the production are still kept private.

The 26 % of the case studies show collaboration with a private or public partner. Collaboration means that there is a partnership agreement between the company and the research institute, the government, with competitors or (NGO or an association).
Ronzo, a new Polish company, replied to the question about collaboration "Yes we collaborate with reaserchers, shops, and breeders. Not always we make coperation but we talk a lot" (Ronzo, 2016). Essento stated to be working close with different universities and private sector experts, which are part of the board. (Essento, 2016). Tasty bugs collaborates with other foreign and domestic companies and with universities such as the University of Wageningen, and with breeders. Moreover, Sanne van Erp from Tasty Bugs added to the answer "we have the same goal so we should help each other. I'm sorry to say that not everyone thinks the same about that". (Tasty bugs, 2016) Aspire is collaborates with NGOs, breeders, researchers and other interesting parties (Aspire, 2016). Cfu food defined the need for collaborations in specific terms. The company needs to know more on the impact of feed to sensory attributes and the impact of feed to protein/fat and other nutritional compositions, and thus is willing to establish scientific collaboration (Cfu foods, 2016).

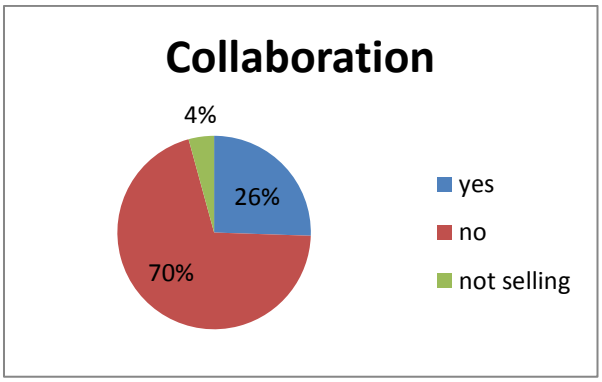


Figure 29 Collaboration, n=47

Product or process innovation

The 83% of the innovations introduced by manufacturers of insects as food are product innovations. The effort made by those who develop the idea is mostly focused on creating a product with new features. New formats (bar, pasta, and powder), new ingredients, new combinations and new recipes are examples of product innovation used by companies, with the objective of targeting a variety of new markets. For example the Dutch company Tasty Bugs wants to show "how diverse insects are and how many things you can do with them, so we use as many products as we can" and "inform people and show them the process that an insect goes thru before it is on your dinner plate" (Tasty bugs). Furthermore, Essento, besides food is also working on a cookbook with plenty more insect-meals (Essento, 2016).
Opinions on what innovation is needed were collected via email questionnaires directed to manufacturers of insects as food.
Gabe Mott from Aspires stated that "insect consumption is an ancient tradition while the modern industry is extremely novel to most of the world and thus innovation in production, processing, product design, marketing and just about any other area you could think" (Aspire, 2016).
Max Kramer believes that "it is most important to create attractive products. So product development is our number one topic (Bug Foundation). Things can be sustainable and healthy,

but you will always want to eat delicious food" (Bug foundation, 2016). On the same line Eli Cadesky from Cfu Foods, thinks that "major innovation is needed from chefs. Our raw ingredients provide a template, a blank canvas if you will. We need chefs (read: artists) to paint masterpieces. Insect flour has done great job of opening consumers to the category but from conversations wth chefs, insect flours lack of functionality impedes its abilities to actually displace meat products. Chefs, armed with the right tools, are the best asset at inspiring sceptic consumers to opening their minds and mouths. Experiential marketing will also be a valuable tactic too. (Cfu food, 2016)

Other opinions deal with communication issues. For example Raphaëlle Browaeys states that "people need to be reassure about the insect consumption and that is why we choose known flavors, use fun and jokes to communicate, have colorful packaging, and finally we participate to lots of events and meeting to make people taste our products" (Jiminis, 2006). And according to Sanne van Erp of Tasty Bugs, better PR is needed on local and global scale. People are ready to eat insects, but where can they get them? What can they do with them? How much does it cost? She continues saying that "people are scared of not necessary from the insect, but of the price it costs. It's like caviar and oysters. If the price goes down people will be more inclined to buy them and therefore eat them. Products are not correctly placed in the store when products are in stores people can't find them because there is not enough PR behind it. For instance there is a spread for toast available in Belgium but when a "normal" person wants to buy it to, of course, walk towards the shelf that has other kinds of spreads on them but then the find out that it's not there. They don't know where to look and so the give up and buy something else. We have to educate the supermarkets where to place the products and how to sell them" (Tasty bugs, 2016)

The idea of costs reduction is stressed by Tamara Koller of Entomos that argues that "Everything must be more professional f.e. the breeding. This is necessary to be competitive (price and efficiency) with conventional meat. It is also important to combine these rational aspects with emotional aspects" (Entomos, 2016)

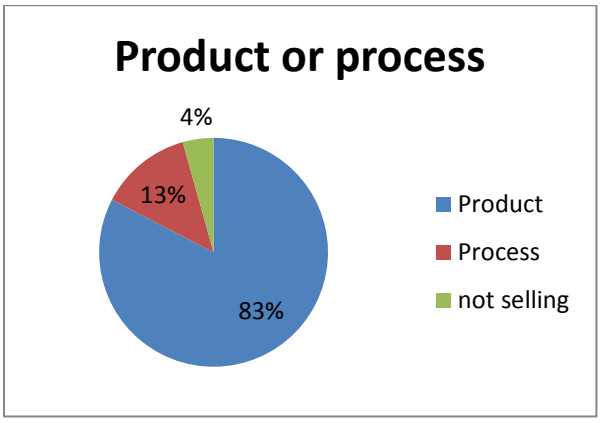


Figure 30 Product or process, n=47

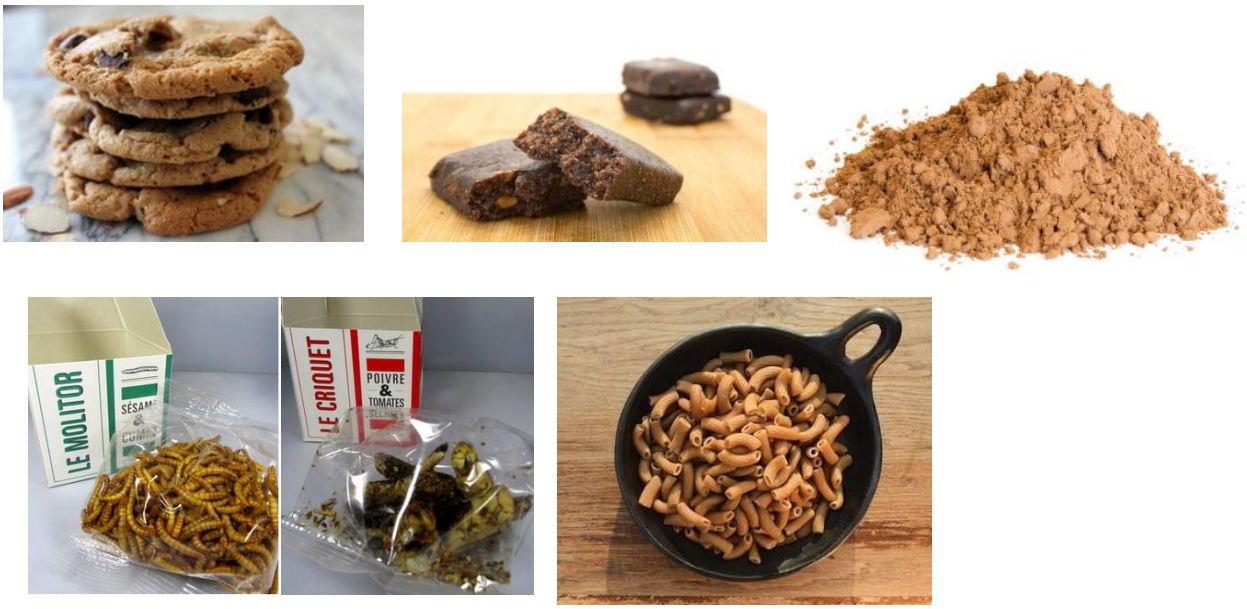


Figure 31 Products

Communication of the product and of the company

Companies and product are communicated differently. On the one hand, manufacturers of edible insects' products use marketing as a key feature to overcome the western taboo connected to insects as food. To sell the product it is vital for firms to communicate the right message to consumers, thus big importance is given to the content of the message. Communication is done mainly through corporate web pages, interviews and sharing of scientific opinions. The main topics used concern the benefits of eating insects (FAO), the way to eat insects, the safety of insects and the reason why people should eat an insect based product. Indeed, consumers need to know how, when, in which doses and with which ingredients is possible to combine the protein rich food, are showed and often illustrated by well-known chefs recipes. Social networks like Facebook, Twitter and Instagram are used even more that websites to communicate in an easy, direct and effective way to the public. References to informative articles or news about the company are used.

4.2.3. Urban farming of edible insects

On a small scale production, an interesting sector in development is the urban farming of insects, that is to say the production of insects to supply householder's protein requirements. This system has analogies with the urban horticulture and urban aquaculture. Companies and designers are developing this kind of technologies, for example Katharina Hunger designed a farm for black soldier flies (Image a), an Icelandic product designer came out with a fly farm (Image b) and Lepsis (Image c) is a grasshopper terrarium by Mansour Ourasanah. The third millennium farm developed the "cricket- reactor" cricket farm that can be used to transform waste as feed at household level (Image 34) and in Sweden a group of architects are projecting a city of insects to be built in Stockholm.

Figure 32 a. Farm 432; b. The Hive; c. The fly factory; d. Lepsis; e. Cricket-reacrot; f. mealworm farm; g. Insect city.

4.3. Group 3: Output (feed) oriented initiatives

4.3.1. General information

Insects are one of the possible alternatives among the ingredients that provide proteins required to animal feeds composition. Indeed as any other ingredient it is evaluated on the basis of its cost and quantity available. The feasibility of insects in animal diets varies a lot between different farmed animal groups but also within each species, since the requirements are different (fats, protein, digestibility, natural diet). Issues regarding the digestibility of the chitin contained in the exoskeleton of insects and amino acid composition are of interest to many scientists at this moment.

The main advantage of the introduction of insects in feed is the ability of some species to convert organic waste into high value proteins. This process is referred to as circular economy. The companies included in this group include seventeen (17) companies. The 17% of those companies is located in Spain, the 12% in France, the 12% in USA, the 11% in Canada while only one company per country are present in Brazil, Belgium, Germany, Malasya, Portugal, South Africa and The Netherlands. Other companies not in this group such as big players in the feed industry, are aiming to open to the business of edible insects as feed, however data are not available or kept confidential.

It is important to take into consideration in the scenario of insects as feed the regulation applied in each country. The legislative framework shows controversy and a lack of clarity. On the one hand, in Europe is not allowed to feed insects to farmed animals except for aquaculture and it is not allowed to feed insects with organic waste. On the other hand, the legislation is not present or unclear in other regions. The Food and Drugs Administration is the responsible for the legislation on food and food ingredients in the USA. However, at the current stage edible insects are not included specifically in any law.

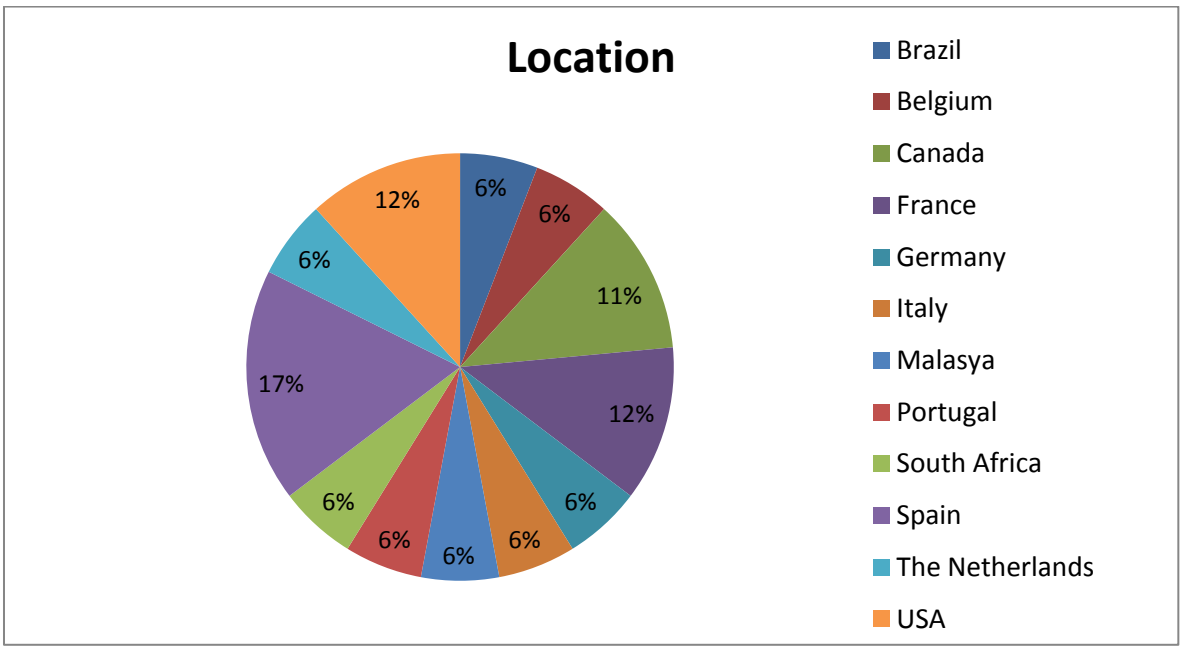


Figure 33 location, n=17

The insects species used for the processing of food are mainly flies and beetles. In particular, 74% of the companies use flies species including Black soldier fly larvae and house flies, while 26% of companies use Mealworms as raw material. Almost the entire group of feed manufacturers (94%) grow insects in their own facilities.
Moreover, the 71% of the companies use organic waste as substrate to feed insects, which is mostly composed by pre consumers waste. While for the 29% of companies data were not available or confidential about the substrate used.

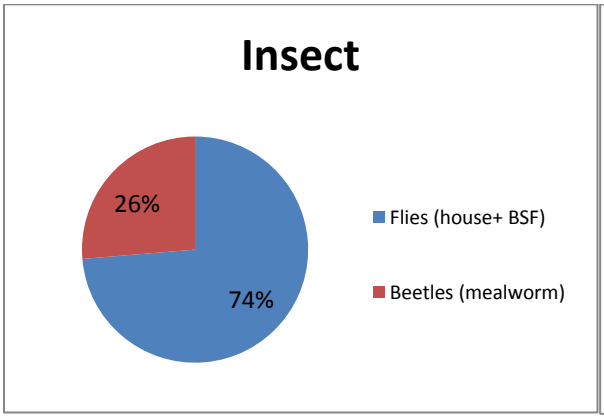


Figure 34 Substrate used, n=17

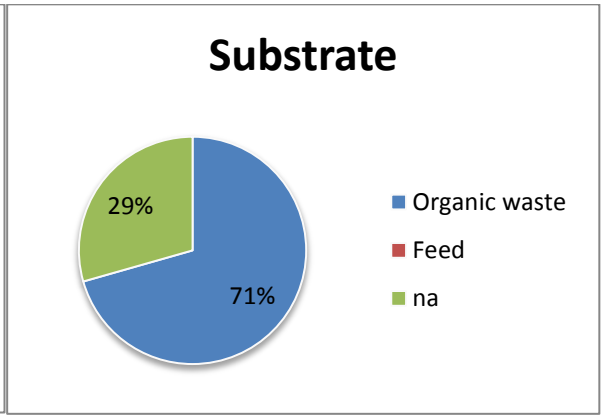


Figure 35 Insect used, n=17

The final products commercialized or researched by companies producing insects feed are 42% feed meals, 35% ingredients such as proteins, lipids or chitin, 19% fertilizers. Not for all the companies was possible to have such information.

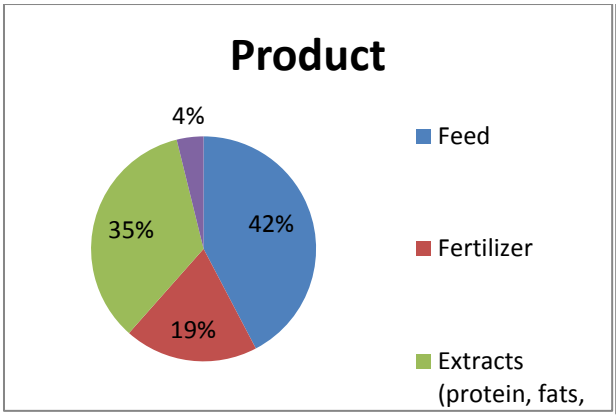


Figure 36 product used, n=17

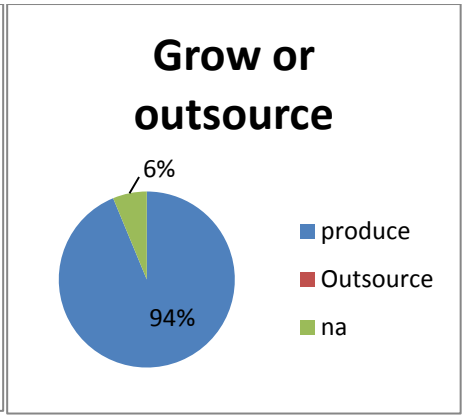


Figure 37 Sourcing, n=17

4.3.2. Innovation practices

Purpose and target

Companies that manufacture insects as feed have a mission that for the 23% of the cases relates to the need of new proteins sources, for the 23% relates to circular economy. Indeed, the edible insects' industry as feed is a common example to explain circular economy by transforming waste generated by humans into food. The 18% of the companies state in the mission statement their commitment to research and their willingness to contribute to the development of the sector. The 12% of the companies' focus on the production of insects feed to improve food security, the

12% aim to contribute to the sustainability of the food system and the 6% is focused on the nutritional values and advantages of insects compared to other feed ingredients.

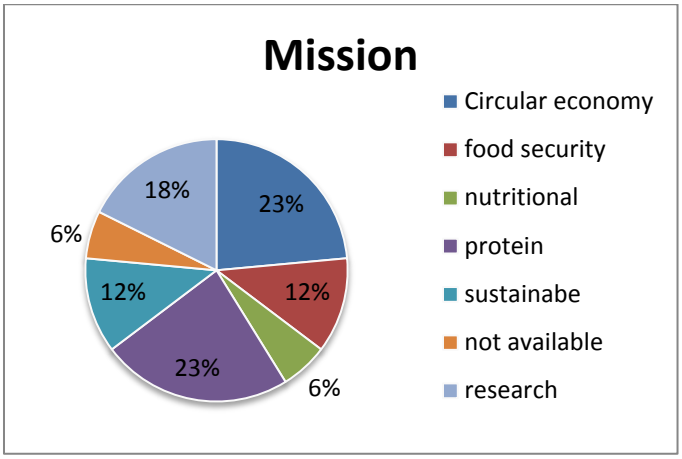


Figure 38 Mission, n=17

The target for companies that produce feed ingredients is mainly composed by other businesses such as feed developer while for feed and fertilizers the target are farmers that will
feed the livestock and fertilize the field. None of these products is sold to consumers, which will be able to eat meat products that come from livestock fed with insects.
From the study of the cases it emerged that insects bases feed are destined or formulated for different animals according to companies and regulations. For instance 23% of the companies' target livestock, 23% of the companies' target the aquaculture sector, the 18% target the pet industry, the 12% all animal nutrition. Moreover, the 18% of producers besides from targeting animal feed diversify the business by producing also green chemistry products.

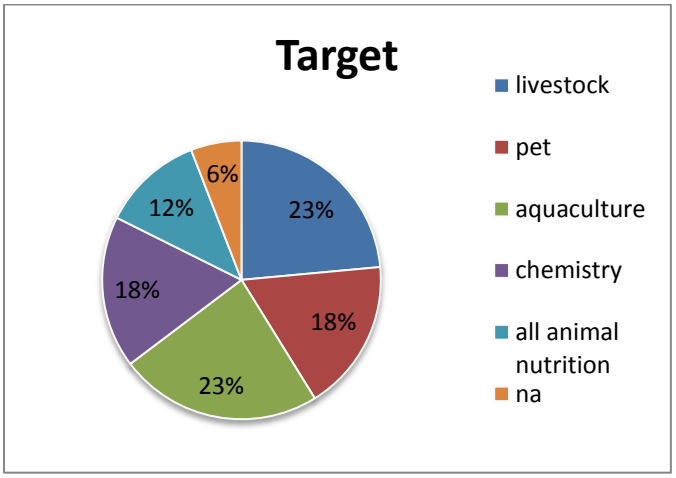


Figure 39 Target, n=17

Lifecycle innovation

The cases studied for the sector of insects manufactures for feed are quite recently formed, as for the case of insect based food. The oldest company was established in 2009 while the youngest in 2013. Several other companies were born in the years in the between.
The majority of the companies have already defined the idea behind the business, and developed the technology and are in the scaling up the business. A turning point is expected soon depending

on legislation Indeed, the allowance of insects as ingredient for feed formulation would open a new scenario, opening new dynamics in the feed market as alternative to soy, rapeseed and fish meal. Innovation has been triggered by scientific research on the use of insects as feed and the competitiveness with other kinds of feed.

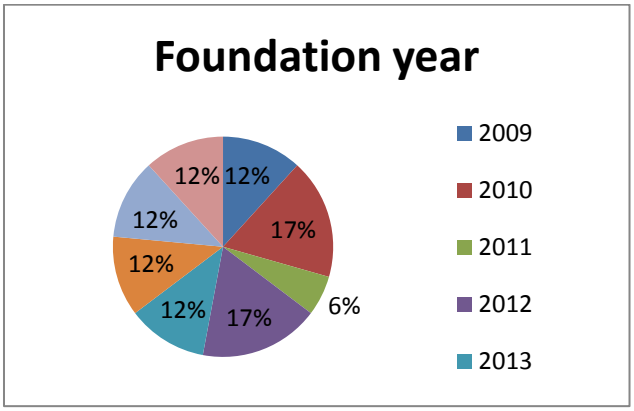


Figure 40 Foundation year, n=17

This industry did not experience the sudden increase in the number of companies that tend to be limited compared to the manufacturers of insects as food. A reason to this could be the limitations caused by the still strict legislation regarding insects as food and the secrecy of the industry.

Open or close innovation

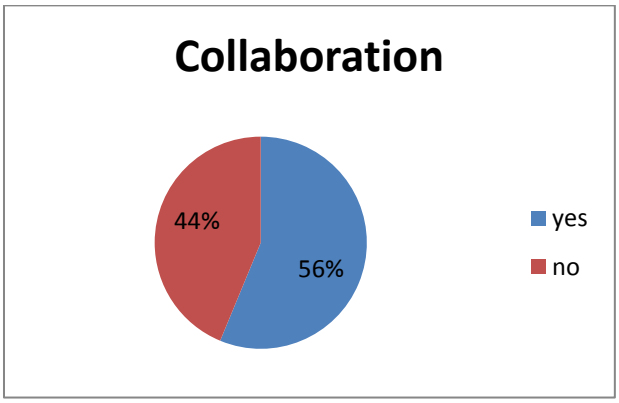


Figure 41 Collaboration, n=17

The 56% of the companies of this group established collaboration with other players in the edible insects industry. It is important for such companies to exploit external information concerning the technical, commercial aspects of the business. The flow of information is directed to research institutes like Wageningen University, associations, competitors and NGOs to fight for the common goal of enhancing the potential of the industry. The collaboration among companies is showed also by the reciprocal support on social media. However, the industry is still in a phase where only the strongest can survive and for this reason information on the rearing systems and on scientific advancement tend to be private and confidential.

Entomotech, in terms of animal nutrition, collaborates with Universities like Universidad de Almeria (Spain), INRA (France) and had some collaboration with Wageningen UR. Moreover, the company has established much collaboration with other companies producing insects. Moreover, Entomotech collaborates with several industries for specific product/process development (Entomotech, 2016).

On the contrary according to Cheryl Preyer, the founder of Enviroflight Glen Courtright, worked largely on his own (Enviroflight, 2016).

Product/ process

The production of a new feed gives reason to a new product to be introduced in the feed industry. In that sense, insects' meals can be studied in relations to fishmeal, rapeseed meal and soybean meal on product innovation basis, such as level of nutrients and environmental aspects.
However inside the edible industry sector, innovations are focused on obtaining high technological and efficient processing systems. In fact, technology is needed to dry, grind insects and to extract nutritional ingredients in the most sustainable way. The processes behind insects' meals vary according to the insect used.
"Today much of the work is done manually. At larger scale, I expect that automation will be key to achieve and maintain very large scale production. We may be able to deliver a variety of nutritional offering depending on what the larvae eat, over time we may be able to craft the nutrition that we want the BSFL to deliver" says Cheryl Preyer regarding the type of innovation needed for Enviroflight (Enviroflight, 2016).

Figure 42 products

4.4. Group 4: Facilitators

4.4.1. General information

This group in meant to include companies, blogs, association dedicated to the diffusion of entomophagy in the Western societies. Those are called facilitators since their mission is not the production of a good made with insect but is the commercialization of products made by others, the diffusion of the correct information and support to the industry. Some of them have innovated by developing profit activities, while other companies do it for the sake of research or to help developing societies. NGO are engaged in many projects aimed to give poor a new source of accessible food.

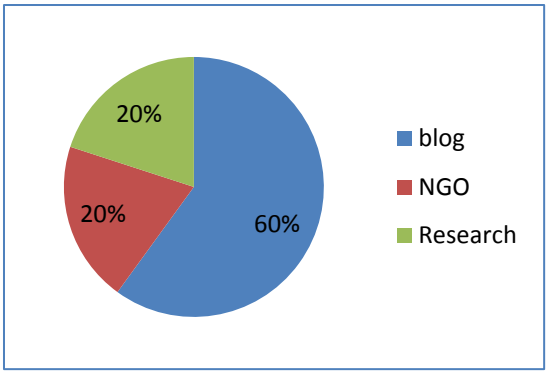


Figure 43 Facilitators

The development of the industry created problems on many levels from the side of consumers, producers and governance. For this reason producers associations, blogs, restaurants, specialized shops started to rise.

4.4.2. Association and NGO

Rearers and producers both of food and feed had to face several bottlenecks to develop their business. The most important questions to be solved were the legislation and the necessity for scientific information. To overcome those problems, producers had to be represented by a bigger entity being in this case producer associations. Examples are listed below concerning Europe.

PROteINSECT is currently the most important European initiative that embraces the challenge of researching a new source of protein to feed the increasing world population. Twelve delegates from seven different countries are aiming, under the coordination of the United Kingdom Food and Environment Research Agency (FERA), to reduce existing legal barriers to the introduction of insects as feed component. At the same time, they are investigating the efficacy and safety of using insect protein as a protein source for animal feed. The ongoing research is focused on two insect species: the black soldier fly and the housefly. (Proteinsect.eu, 2015)

Other European projects and organizations are showing interest in this topic as well.

BIOCONVAL is a project developed by the Technical University of Denmark in collaboration with the Dansk Teknologisk Institut, the Knowledge Center for Agriculture and the Aarhus University to develop and demonstrate a system to produce feed supplements consisting of live insect larvae with an ideal amino acid composition.

IPIFF is a European organization representing the interests of the insect breeders for feed and food. The objective is to find standards and best practices that can be applied to the insect rearing industry. Moreover, they encourage open collaboration and research among companies within the same industry. Among the members of this organization which are located all around the globe, are companies such as AgriProtein, Hermetia, Protix, Koppert, Ynsect and Entologics.

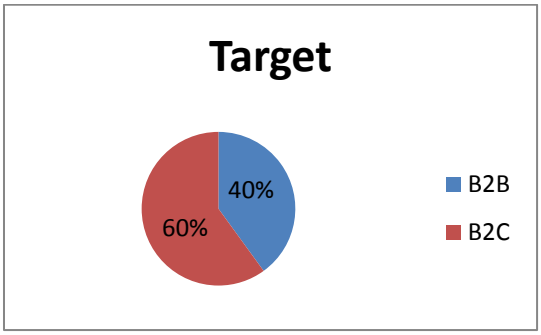
VENIK is the Dutch association of Insects producers. The objective of the association is to push favorable legislation at national and European level.

4.4.3. Throughput

Facilitators in the edible insect industry are those companies that work as wholesalers: they buy insects products from producers and sell it to other businesses or to consumers. In the sample 10 websites are analyzed. Three companies are actually also producing a little quota of insects' based

products. The majority of the companies sell its products directly to consumers, while the 40% of the sample targets other retailers, restaurants or catering activities.

Figure 42 Target

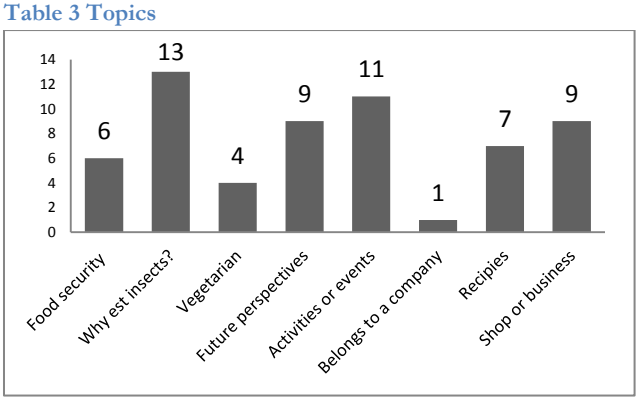


4.4.4. Blogs

As soon as people started to be more concerned about the impact of insect as food and feed system the information sharing became essential. Many platforms have the objective of research and educate people. The content of the websites is related to edible insects in many ways. The most discussed topic is the importance of eating insects; people need to know why it is important to substitute partially traditional livestock proteins with insects' proteins. The worry about future (increase in population and food security), Four webpages address the consideration of insects as food for vegetarians.

These teams of passionate people besides working on line are engaged in organizing offline activities. Activities can be a source of profit but also just free talks with the only aim of convincing people of the importance of edible insects. Payment activities include conferences, tastings, show cooking, etc.

Table 3 Topics



4.4.5. Innovation practices

Innovation in the group of facilitators is a service innovation. In fact what are those companies providing to the community are new services concerning education, information, restaurants, catering and research. More people can freely benefit from those innovations, but it is also an innovation for profit oriented businesses. The innovation in most of the times consists in information that is collected internally, through an internal research department. The positive

spillovers reflect both the industry and consumers by facilitating the contact between the two. However, companies are interested in internalizing this function buy creating communication platforms where they can meet consumers.

4.4.6. Restaurants

In the development of the edible insects industry for food, restaurants play an important role introducing insects in the dishes. The acceptance of consumers of insects as food has to come from many sides, it is important that the effort made by companies to be supported with other initiatives closer to what is already accepted by consumers. Moreover, restaurants are a field where it is possible to study consumers' tastes. Sushi, an Asiatic food, is an example of how a food has been gradually introduced in Western cultures and adapted to the host culture.

On the one hand, chefs are interested in the discovery of new foods together with development of science. The Nordic Food Lab is an organization no profit based in Denmark engaged in discovering the potential of foods from the Northern regions by researching new ways of cooking and ne cultures from all around the world. Among their projects the team is developing projects with edible insects.

On the other hand, edible insects are presented as a typical element imported from foreign cuisines such as the Mexican, more familiar with entomophagy. In this way insects are seen as an exotic food.

Table 4 Restaurants

Restaurant	City/ Country	Dish
Don Bugito	San Francisco	Traditional mexican food.
La Oaxaqueña	USA	Jumbo Grasshoppers tacos
Mezcal	USA	Sautéed grasshoppers, with garlic, lime & salt, served with a side of guacamole and tortilla chips.
Spektakel	The Netherlands	
Sticky Rice	USA	
Toloache	USA, New York	Grasshoppers taco
Tu Y Yo	USA	Grasshoppers taco
Typhoon Restaurant	USA	Stir-fried silkworm pupae
Vij's Restaurant	Canada	
NOMA	Denmark	
Alex Atala	Brazil Sao Paulo	
Laithwaite's Wine (insect and wine matching guide)	London	
Archipelago	London	Pan fried chermoula crickets, quinoa, spinach and dried fruit
Grub Kitchen	Wales	
Wahaca	London	
Atlantico	Toronto	
Charlie burgers	Almere (NL)	
Traiteur catering	Brussels	

4.5. Examples

In the following section representative case studies have been described in more details. The companies presented below are examples chosen to strengthen the analysis of each group. The selection of the cases has been done purposively by choosing a case study that reflects the characteristics of each group. The following cases have been chosen from the available data base.

4.5.1. Kreca

Kreca is a Dutch company focused on the development of knowledge on breeding system and rearing insects. The main objective of the company is to provide big amount of insects to different markets. The company has the mission to *"Bring well-being to the world by being the main source for delivering the best quality and tasty insect-derived protein products at a competitive cost price using sustainable production methodologies*" (Kreca, 2016). This concept is used by many companies to stress the importance of introducing edible insects in the food supply chain. A relevant element in the mission statement is the word "protein", often used as key word to attract the reader.

From the website it is not clear what the targeted market is. The products developed by the company suggest that customers range from pet owners to the feed and food industry and direct consumers. It is possible to buy on the website accessories for pets. However, great importance is given to the human and livestock consumption of certain species of insects.

Kreca was established back in 1978 in the Netherlands and now the facilities allow the breeding and rearing of more than twelve species of insects. The majority of the insects (95%) are reared for pet food while the company decided to differentiate the offer by rearing a 5% of the insects destined human food, since they are authorized by the Dutch governments (Allabooutfood.com). Kreca was established in 1978, making the company an established business with experience in the sector. It is a family owned business with a history. Nine people work at Kreca on daily basis (Kreca, 2016).

Kreca collaborates with many actors. The company is partners of the University of Wageningen (laboratory of entomology), the TNO Innovation for life centre, the insect breeder association VENIK, and Insectcentre.

The collaboration with Venik (Verenigde Nederlandse Insectenkwekers) is important for the company. In fact, being part of the biggest Dutch association of insects breeders gives more power to all the members. As insects' industry association it can influence policymakers to adopt legislation favourable to use insects as food and feed and insure higher quality standards.

The collaboration with the Dutch company TNO is aimed to create project on Flying food in Kenya and Uganda in order to tech the local population how to rear insects for their own consumption. The project aims to stress the potential of insects to sustain developing societies.

The insects are fed on insects' food that is made of corn meal or groat meal and and carrots, for the humidity. Organic waste streams, are not used as a substrate as the contents vary too much and the quality cannot be ensured.

The farm grew during the years by rearing new insects' species but also by finding new and more advanced rearing processes. The innovation in Kreca is on the establishment of "quality standards for insects: the quality and food and feed safety and to improve technical upscaling of insect farms and new product development". Besides, a constant research is performed to expand the knowledge basis.

Kreca does not make use of any social network and the communication is limited to the website. It is structured in the following sections: research, partners, online shops and contact.
In the section "video" of the website, there are videos stressing the importance of entomophagy including the nutritional, environmental and secondary benefits and videos that introduce the company and its activities. In the home page of the company there are two reportages recorded by Insect Centre and A Jazeera reporter and a link to an article about Kreca in "all about feed", which is a website that analyse the feed industry. Both, the videos and the reference have the same content. The speaker, Marieke Calis, shows and explains the process of growing insects from the substrate used to the cages to the final result of adult mealworms.

4.5.2. Exo

Exo is a company based in New York City that started its operations in 2013. In the USA the authority controlling food ingredients is the FDA. At this point in time there no regulation about edible insects. Exo produces protein bars containing 6% of insect flour, particularly crickets. The crickets are supplied by insect suppliers that for privacy issue were not mentioned by Exo, as well as the diet of those.
Exo protein was founded by Gabi Lewins, from Glasgow with a degree in Philosophy and Economics, and Greg Sewitz, from Los Angeles that studied Cognitive Neuroscience and English, both graduated from Brown University. Starting from the need for a nutritional and tasty food, the idea of using crickets came from a conference on the benefits of edible insects at MIT University. The two young entrepreneurs performed their first experiments at home and used the clients of a Crossfit gym as first testers. At this point they decided to take the idea to the nest level. The startup was created with the name Exo with the mission of "pursuing to introduce insects as an alternative protein source." They engaged soon in fund raising activities, first, by participating to AccelFoods an incubator for startups and then by launching crowdfunding campaigns. The most important investors that contributed to the success are incubators such as the Collaborative Fund and Start Garden and Tim Ferriss as business angel.
In July of 2013 Kickstarter campaign helped them to raise $55,000.00. The company was finally launched in 2014 with an initial production of 50.000 bars and the objective to grow by scaling the production, hire new people and expand the range of products.
The two needs for Exo were to find breeder who could manufacture for human consumption separately than feed and someone who could manufacture the bars.
Differently from many other companies that manufacture edible insects, the web page of Exo barely refers to the necessity or the importance to eat insects to feed the growing population. On the contrary they focus more on the nutritional values of insects. There is no mission or vision stated. The only sentence that refers to a purpose is "10g of protein per bar, offering a sustainable and complete alternative protein source" (Exo, 2016).
Exo is targeting all new consumers, but from the slogan used "crikets are the new kale" and pictures of mountains the ideal consumers are represented by sportive people and healthy consumers. The company has become popular in the Crossfit and Paleo world. Another element to understand the target is the community composition. In fact, the supporters, sponsors range from chefs to nutritionists or athletes and sport people. Also few celebrities are present in the list of community of Exo, like the guitarist of Pearl Jam. Exo sells the bars through their website and other retailer shops.

Exo fits in the group of companies considered as start-up even though among the ones that sell insect-based protein bars, is in a more advanced stage. In fact many startups are still in the idea generation phase, while Exo is already inserted in the market and in national retail and internationally via the internet.

Exo protein collaborates with "cricket farmers and our feed is a bit of a trade secret. You might have more luck communicating with the farms directly" (Exo, 2016).

A revolutionary idea for Exo was the collaboration with Kyle Connaughton, the former head of the Michelin-starred Fat Duck restaurant in the UK "We teamed up with a rock star chef who used to head up research and development at The Fat Duck Restaurant, considered one of the best and most progressive restaurants in the world." (Exo, 2016) The chef is working on the taste of the bars, looking for new nutritious combinations of ingredients.

Moreover, the collaboration with important investors, like Tim Ferris, was important to the development of the company.

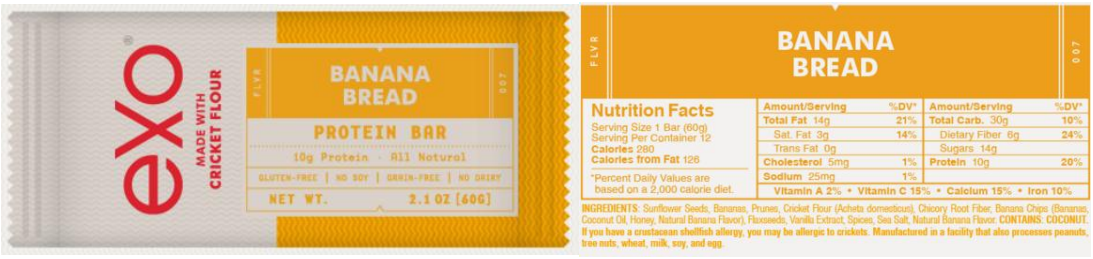


Figure 44 Exo protein bar. (Exo, 2016)

The bar is the first product the company introduced in the portfolio. It has been designed together with the chef that collaborates with the company. The innovation presented by Exo protein is considered radical if we take as reference the market of bars. Consumers in Western countries are not used eat insect derivative products. Contrarily, if we take the point of view of the company itself the innovation is

The cricket bar of Exo is a product innovation. The company entered the already existing popular market of healthy bars with a new product. "At any given store, there are 50 to 100 protein bars on the shelf, and they all look the same; it's a very saturated market and very hard to stand out," Lewis acknowledges. "We want to connect directly to consumers."

Each bar contains around 40 crickets, 270-300 calories, 10g protein, 14-20g fat, 13-18g sugar, and 5-7g fibre. The ingredients of the bar consist of sunflower seeds, bananas, prunes, **cricket flour**, chicory root fiber, banana chips, flaxseeds, vanilla extract, spices, sea salt, and natural banana flavour. The bar contains "No gluten, grain, soy, dairy or refined sugars.

The bar is available in four different flavors: cacao nut, peanut butter and jelly, apple cinnamon and blueberry vanilla New flavors include mango curry, barbecue, Mediterranean flavors. The retail price is $3 each. The price is explained by the cost of production of insects flour (small scale), the other ingredients which are considered premium like raw cocoa, coconut flour, almond butter, dried fruits and honey. Also the bars have a bigger portion than the average and the count on the high nutritional content and low level of processed ingredients.

And it is indicated on the webpage that is to be consumed as "a meal-replacement, healthful snack or pre/post-exercise" (Exo, 2016).

Exo founders consider the possibility of producing new foods with cricket flour, such as pizza dough, bakery foods and shakes. (Exo, 2016)

Exo has a big use of communication means. They are establishing a connection with the customers through the website, the presence of conferences and the use of social media and food blogs. Facebook, Twitter and YouTube are the most popular. Additionally the communication of the product is clear; indeed the presence of insects in the bar is communicated on the package.

Figure 45 Exo page on Facebook

Figure 46 Exo page on Instagram

The Facebook page is used as communication tool much more than the website. The company uses this platform to spread the voice on the benefits of eating insects' proteins, and to promote the company and related articles.

The communication frequently used on the social networks includes paleo diet, recipes, references to media articles, advertisement of the company, customers reviews, benefits of eating insects and video or pictures on entomophagy or on the company.

Exo protein bars are presented as a good food for people following the Paleo diet. The articles on Facebook show the possibility to include insects in this particular diet. Recipes are a minor part of the advertisement in the webpage. Since the bars don't need extra cooking, recipes are not important to sell. There is a lot of advertisement on the advancements of the company, their successes and presence on important newspapers and social events.

In addiction pictures of bars are shown. Communication about the importance of eating insects is low. In the section of the website "why crickets?" there are environmental, nutritional aspects of insects compared to livestock, plus the rate of consumption all over the world. However this section seems to be not relevant to the business, indeed there are not many articles.

4.5.3. Enviroflight

Enviroflight was established in Yellow Springs, Ohio in 2009 and focuses on the development of an insect-based feed. Glen Courtright founded the company with the objective of providing a new source of protein in the food supply.

Courtright worked as military force, first joining the Air Force and then the Navy Reserve but beside that, he designed electronics systems for oil and gas companies, defense, automotive and telecommunications. His background gave him the urge to find a solution for the increasing scarcity of natural important resources. After researching many alternatives he developed the idea of rearing insects to feed the planet.

The objective of Enviroflight is to produce insect meal for aquaculture feeds and as fertilizer. The target of the company at this moment are zoo and the pet industry, however team is working to expand the market.

The company is located the small town of Yellow Springs in a 20,000-square-foot facility that was previously a seed storage. Courtright looked for workforce in the city university in order to hire high educated people from the region and to keep a strong connection to the place. Today the

company is established but waiting for a legislative change.
Enviroflight rears black soldier fly that feed on and bio convert a substrate made of dried distiller grains with soluble from ethanol plants and spent brewer grains. "We hold some of our insects for brood stock, and periodically introduce additional native Black Soldier Flies from outside our community" (Enviroflight, 2016). The resulting frass becomes a feed ingredient for aquaculture fish rich in protein and low in fats. into a meal that is 40% protein and 46% fat. The oils can be extracted, which boosts the protein content to above 70%. "Today our products feed animals not in the food chain (zoo animals, insectivore pets). With regulatory approval and expanded production capability, we expect our Black Soldier Fly Larvae to feed aquaculture and other livestock in the future" (Enviroflight, 2016). The final product could be used also for pigs and cattle nutrition (FAO). "We follow Association of American Feed Control Officials (AAFCO) guidelines just as expected in the U.S. for feeding any other livestock. This is why we feed only pre-consumer food waste/by-products" (Enviroflight, 2016)
Black soldier flies are native from America and can adapt to different temperatures. The larvae are very efficient in converting organic waste into protein, lipids and fertilizer. However, the main difficulty is to scale up the production of the black soldier fly with low technology costs (Inc.com, 2014). "Today at our Pilot Plant, we process up to 6 tons of incoming material on a daily basis (pre-consumer food waste). Our output production varies depending on the feed stock and how well the BSFL bio convert it". (Enviroflight, 2016)
The founder of Enviroflight worked largely on his own but now is working with others on applied research - both to support the regulatory approval process and to gather data to support use of Black Soldier Fly Larvae in feed (Enviroflight, 2016). According to Courtright there are a few major players in this field with their own technological solutions to scale and with so much intellectual property being developed; there is not a lot of sharing. At some point, many of the researchers tackling this may be able to help each other improve their technological solutions (Enviroflight, 2016).
Enviroflight means of communication are the website, and social network. However, since the final customers are other businesses the level of communication meant as publication of articles, pictures and videos is low. Facebook is used to communicate the advancements made by the company.

4.5.4. Little Herds

Little Herds is a non-profit organization that works in Austin to facilitate the introduction of edible insects in the food system. The mission is to educate people of the community on the nutritional, environmental and social advantages of eating edible insects.
The organization was established in 2013 and according to Robert Nathan Allen "it was kind of a catch-all organization; supporting startups with resources and information; working with regulatory agencies to clarify rules and regulations; and educating the public and children about insects as a food source, especially safety and sourcing advice" (Edible bug farm, 2016). Today, Little Herds organize events for schools, chefs, individuals, farmers, museums, companies, markets and other organizations.
The idea came from the founder Robert Nathan by attending a conference in Austin about entomophagy and its beneficial aspects.
The services offered by Little Herds are a service innovation.

The NGO collaborates with all the actors along the value chain of edible insects, including firms or people and governmental institutes are important partners. Indeed, local, state, and federal regulatory agencies work together to create the basis in order to set rules and standards to rear insects for human and animal consumption.
Little Heards is devoted to communication. It is essential for the organization to establish a link with the consumers and other public and private authorities. However since the industry is not regulated in the USA, The content of the messages communicated has the main objective of ensuring people of the safety, healthiness and transparency of the processes.
The organization uses the website but also social networks, especially, Facebook and Twitter. The Twitter profile is used to share and developments achieved by players in the edible insect industry.

5. Discussion

The potential of EI has been extensively studied in terms of nutritional and environmental impact. However, the translation of the knowledge into large scale marketable products by the private sector in relation to sustainability is still unexplored. This research project focuses on the exploration of innovation practices in the EI and leads to a reflection on the role played by companies with regards to sustainable diets. In this chapter, the concept of sustainable diets is used as background in order to make inferences on innovation practices and on the direction taken by the industry. The responsibility of companies to develop products that fit in the concept of sustainable diets is explored using the results of the case studies analysis.

The industry represents a niche in Western countries even though there has been an increase in the past years but it is still a small proportion of the food and feed market. Entomophagy, in Western countries, has been defined by Rogers (2003) as a "failed diffusion" because EI have never been completely accepted by consumers after many years of promotion (Rogers, 2003 from Shelomi, M. (2015).

The EI industry is composed by 22% of input producers namely rearers of EI, 59% of processors of EI as food while the remaining 19% are rearers and processors of EI as food or feed ingredients. The main markets are consumers, feed producers and wholesalers.

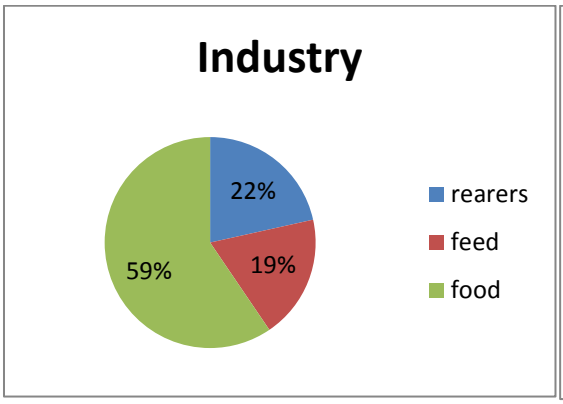


Figure 47 Share of the industry

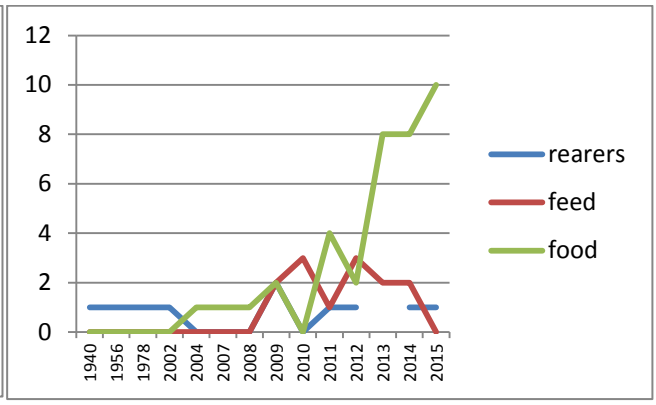


Figure 48 Development of the industry

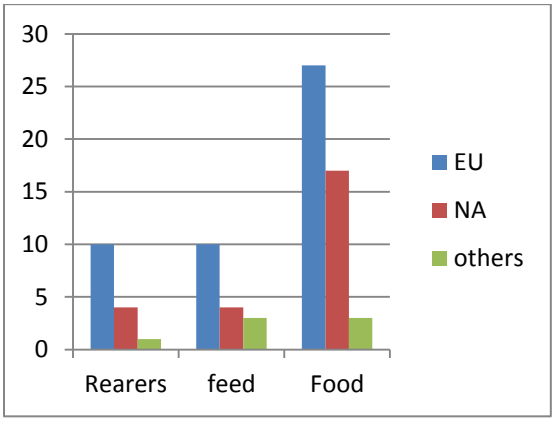


Figure 49 Location of companies divided by sector

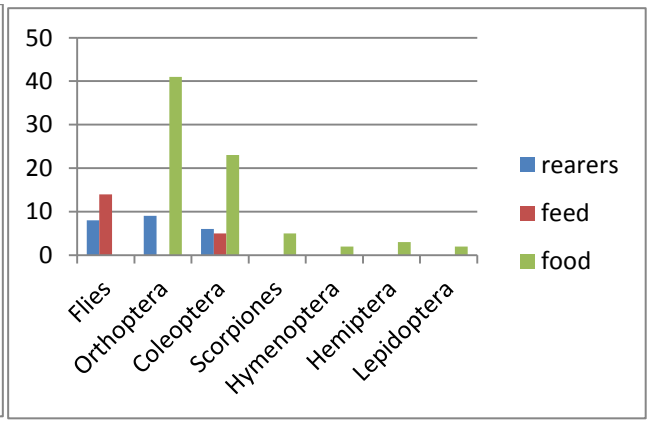


Figure 50 Insects used by companies divided by sector

The map below (Figure 52) shows graphically the location of these companies. It is interesting to notice that the picture reflects the opposite trend if compared to the map depicting countries where entomophagy is practiced. Two sides of the world are experiencing different dynamics related to insects. In the West of the world, where culture and perception of EI are limited, markets for insects as food and feed are Europe and North America. The 59% of the companies is located in Europe, the 32% in North America and 9% elsewhere. Moreover, the input used by the industry don't refelct the abundancy and variety of insects species that are consumed in tropical countries. Indeed only few secies are be used for large scale production of food and feed. Food processors tend to outsource insects while some feed processors internalized this function, making the import and export patterns interesting for further studies. A low variety and low linkage to seasonality of insects is associated to the mass rearing of insects in Western countries. Edible insects are extrapolated from a context where they have a low social value and commercialized in western countries through the industry in high value products in Western society (Shelomi, M., 2015).

Figure 51 Geographical location of companies divided by sector

The rearing of EI is an industry composed mainly by actors that where already producing insects as pet food. The opening of a new market created the possibility for them to rear insects for human and livestock consumption. For this shift and for the future of the sector the innovation needed regard the process. The final products are alive, frozen and grounded insects. The consumption of those products with a very limited processing is what is happening in the East of the world but results not acceptable by consumers in Western countries.

The food manufacturers sector is going through the introduction phase of the industry characterized by many entrants, low barriers to entry, high uncertainty and high efforts needed to differentiate the offer thus to acquire a market share. The majority of the companies are small or startups that generated an innovative idea around the marketing of EI and are now launching it on the market. In this sector the figure of the entrepreneur is very important together with

funders and chefs. Collaboration with public and other private corporations is very much needed to strengthen the message and to obtain consumers' attention.

Food manufacturers do more product innovation rather than process oriented innovation. They consist in the formulation of products aiming to match the palatability of Western consumers, by at the same time making use of a certain amount of insects (between 10-30%). Products range from bars, pasta, flours, additives and candies. Thus, insects are added as an extra to a product that in most of the cases is already accepted by consumers losing its original function that is associated to them in tropical cultures. In Western countries the less visible and identifiable are the insects the better for consumers (Shelomi, M., 2015).

The message associated to the products is likely to attract consumers to try EI moved by couriousity or novelty feelings, whereas underestimating that the benefits derive from a normalized entomophagy practice. The objective is not to let people try insects one, but to push them to a regurlar consumption, to actually implement them as meat substitute (Shelomi, M., (2015). Even though there is a wider acceptance of weird foods in Western societies (the history of sushi being an example of a food going from a niche to regime in short time), it is doubtable that EI products will be accepted as determination of self-realization, experience and self-expression in food choices. According to the study by Tan et al. (2015) there are different perceptions and expectations on the evaluation of edible insects in different cultural contexts. Indeed, the appreciation of a food depends on the cultural background of the person that includes experiences and preferences even of species and preparation. For instance, Western consumers might try insects but it is unlikely that they will introduce them as staple food in their diets (Tan et al., 2015).

The fundamental rational behid the introduction of insects as food should be the reduction of other unsustainable foods more than the addition of a new food. Indeed many companies are looking at entomophagy practices in developing countries where people eat insects because they have no other choice, while promoting them in the Western world as delicacy products (Shelomi, M., 2015). There is a bigger need to wisely use the available protein. This is shown by the mission statements of the companies that often promote their product as a delicacy. EI based foods are targeted by the industry to niches such as sportive people, paleo diet and gluten free diets and curious consumers.

In Western countries, in order to be considered edible, insects have to be processed into elaborated products and enter the food chain distributed through retailers resulting in high price products. Recently, supermarkets have started commercialization but only a very little proportion, the majority is sold trugh specialty shops and online selling.

Retailers, online sellers and specialized shops are facilitators that, together with blogs, NGOs and association, are encharged of spreading the message and connecting consumers to entomophagy practices in order to foster a development of the industry. However, the distance between what is told and what people experience is high and it might be a motivation for a first try but not necessarly for enduring consumption. Given the novelty of the industry innovations are expected from the consumer side. Those are the ones that given a raw material can find the most appropriate way of consumption according to the context.

Innovation is approached differently by feed manufacturers. The sector is composed by small newborn companies and bigger and more established ones. In addition, already established companies saw the potential of EI based food for an increasing demand.

Feed manufacturers consider process innovation key for the development of the sector. Automation of the machines and the processes will allow having a feed that is in terms of costs comparable to soybeans, rapeseed and fishmeal. In fact, insects as feed are cheaper if compared to other feed ingredients. Companies are competing on the quantity and the price and have fewer concerns on the acceptance of consumers. The impact for the final consumers in this case would be much lower since the difference between meat fed conventionall and the meat fed with insects is not big. Ramos-Elorduy (1998) suggested that the meat from livestock fed insects tastes better (Ramos-Elorduy, 1998).

The feed industry is working closely without an explicit collaboration with others because the change in legislation could determine the dynamics of leadership. Companies of the sector are in a different stage of readiness compared to food manufacturers. Huge progresses are in fact being made on the application of the feed and on new technology however only few products are already available and commercialized. The products are insects' based ingredients such as lipids, proteins and fat that can be included in livestock feed. Some companies produce already the feed while others sell to further transformation.

The mass rearing of insects can be a solution but it is related to the overall sustainability of the food system. The mass rearing of insects for the direct consumption would be a sustainable option for the lower water usage, lower land and high conversion rate. However, the sustainability of the production of edible insects as food and feed is limited to the acceptation and the decrease in consumption on meat will increase as it is announced the problem will come back. Another market for insects' fats is in the chemical industry.

Input, manufacturers and consumers have different impact on sustainable diets. From the point of view of the business, the production and commercialization of a product has to be simultaneously beneficial for the environment (biodiversity and climate), the nutrition (well-being health Food nutrient needs, food security), the economy (accessibility) and sociocultural (cultural heritage skills, eco-friendly seasonal, local , equity and fair trade) to foster sustainable diets. This concept results in a mix between innovation and tradition while helping increasing resource efficiencies. In the EI industry, input producers and processors want to stimulate the consumption of EI products as food or indirectly as livestock feed as sustainable innovation in the food system supported by other private or public entities. The drivers to the development of sustainable new insects based food are attributable to the supply nutritional input, the production of an alternative source of protein also in under-developed countries, the reduction of air pollution and the energy consumption, the development of new food culture and the reduction of waste streams.

In order to reach more sustainable diets in Western countries efforts should be done by every actor involved with respect to all the areas related to sustainable diets. In a context where there is higher consumers demand for sustainability and the scientific world investigates sustainable alternatives, businesses are making profits from the development products associate to sustainable concepts. Considering the goal of achieving sustainable diets, there are many innovations and practices that can be implemented by consumers such as nonanimal diets, nose-to-tail feeding, or in vitro meat and among them entomophagy (Shelomi, M., 2015). The push for the consumption of EI should be linked to achieve higher consumers' sensibility on issues that can impact sustainable diet such as meat and dairy consumption. However, since not all the consumers will turn vegan or practice entomophagy it is necessary the responsible involvement of the food industry. The products must be projected to long term shift towards sustainable diets

in all its aspects and presented as such. For instance, tradition plays an important role in determining innovation quality in the food industry and should be respected and enhanced together with dietary diversity, food balance and seasonality. Moreover every innovation should achieve an affordable price. The diffusion of a partial or misleading message would risk a dilution of the sustainability message thus undermining the credibility of the industry where transparence ensures higher credibility.

Conclusions and recommendations

This study was set out to explore innovation practices in relations to the EI industry. At the same time the research aimed to give insights on the role that innovations in the case of EI can play to foster sustainable diets in Western countries. The general theoretical literature explores the two most important topics concerning this thesis, namely the EI industry and innovation theory. Scarce literature was available on the innovation practices in the EI industry especially in Western countries.

The major empirical findings concern the general research question on innovation practices and are analyzed by groups. Reares innovate in the way the process the insects. Innovation efforts are put in the technical aspects and are incremental innovations. The group is composed by mature companies in growing phase of the industry. The collaboration among players of the industry is low, companies tend to innovate autonomously. There is room for innovation in the achievement of automatized processes.

Food manufacturers of edible insects innovate by developing new products. The innovation generates from combined ideas of food entrepreneurs and chefs. The majority of companies are in the initial phase of the industry and it is still not clear whether their innovation can foster a radical change in society or incremental improvements. The level of collaboration is high. High uncertainty derives from consumers' acceptance.

Feed manufacturers of edible insects are dedicated to product innovation, consisting in the formulation of feed optimal for different animal targeted. The companies in this group are in the growth phase of the industry however the adverse legislation constitutes an obstacle to their development and to knowledge sharing. The introduction of such innovations fosters radical changes in the food and indirectly in the food system.

The group of facilitators includes companies born to smoother the commercial exchange. Blogs, online shops, NGOs, innovate in the field of edible insects by providing a service. Those businesses are small. The degree of the innovation is likely to be incremental.

The sub research question of this research project concerning the role of the EI industry in the achievement of sustainable diets in Western countries is discussed in general terms. The impact of each innovation on sustainable diets is defined by the simultaneous occurrence of economical, sociocultural, environmental and nutritional aspects. Edible insects are one of the alternatives driven by sustainability. The increase in production and thus consumption of edible insects doesn't necessarily foster sustainable diets per se. Innovation from manufacturers' perspective has to work in combination with traditions and cultural, local food systems, and affordable prices. More in-depth research is needed to explore the complex framework of sustainable diet applied to innovation in the EI industry. There is an urge to understand the degree in which products are a radical innovation in Western countries.

The limitation of this research is the availability of data because of the initial phase that the industry is experimenting. Moreover, patterns of innovation should be monitored and supported by quantitative analysis.

Acknowledgments

I would like to thank my supervisors for the inspirational lectures and for the support throughout the period of this thesis research in which I could exercise my ability to be an independent thinker.
I would like to tank Stefano Pascucci for the effort and time invested in the development of a difficult project. The continuous definition of concepts and ideas has been a process that led me to a personal and professional growth.
I would like to thank Jessica Duncan for showing me the way to match the many discrepancies between the managerial and sociological approaches and for her key feedbacks and comments.

I want to thank all the companies that replied to my emails, providing me with important data.

I would like to thank who is always with me, la mia mamma, il mio papà e Miguel.

"Strano destino viviamo in un mondo pieno di contraddizioni! Sarà stato sempre così, lo riconosco, ma per me è sempre una novità. Non vedi attorno a te alcun atto ideale. La gente, e mi riferisco ai più, non vede in genere al di là dell'immediato guadagno. Ma è uno sprone che non mi soddisfa! È troppo misero e basato su una interpretazione nuova e stupida della vita. Ma le mie idee e quelle di alcuni amici miei, sono folli! Il mondo moderno vuol tutto livellare, vuol imporre a tutti gli uomini la stessa vita, vuol scoraggiare, con immense difficoltà, chi vuole agire diversamente seguendo i propri ideali. Ma si rinuncia ad essere se stessi quando alti ideali lo esigono [...]"

Appendix I- References for literature review

Feature	Relevant References
Radical/ incremental	(Ducheasneau from (Ettlie, Bridges et al. 1984)) (Shumpeter,1934 from (Chandy and Prabhu 2011)) (Garcia and Calantone 2002) (Ettlie, Bridges et al. 1984) (Chandy and Tellis 2000) (Chandy and Tellis 2000). (Earle 1997). (Crossan and Apaydin 2010) (Ettlie, 1983) (Chandy and Tellys, 1998)(Garcia and Calantone 2002) (Capitanio, Coppola et al. 2010)(Earle 1997)(Pascucci and Magistris 2013) (Veldkamp 2012) (Manceron, Ben-Ari et al. 2014) (Belluco, Losasso et al. 2013) (Spiegel, Noordam et al. 2013) (Ramos-Elorduy 1998, Taheripour, Hurt et al. 2013) (van Huis, Van Itterbeeck et al. 2014). (Rumpold and Schlüter 2013) (de-Magistris, Pascucci et al. 2015)
Open/ Close	(Omta, Fortuin et al. 2014) (Enkel, Gassmann et al. 2009) (Enkel, Gassmann et al. 2009) (Baum, Calabrese et al. 2000)(Vanhaverbeke and Cloodt 2006, Sarkar and Costa 2008).
Product/ Process/ Organization	(Oke, Prajogo et al. 2013). (Danneels 2000) (Cheng, Chang et al. 2013) (Tohidi and Jabbari 2012). (Pullen, de Weerd-Nederhof et al. 2012) (Davenport, 1993) (Davenport 2013) (Capitanio, Coppola et al. 2010, de-Magistris, Pascucci et al. 2015) (Rumpold and Schlüter 2013).
Supply chain	(Roy, Sivakumar et al. 2004) (Soosay, Hyland et al. 2008)(Mudambi 2002) (Cohn, 2015). (Fern and Brown 1984) (Lambert and Cooper 2000, Grunert and Traill 2012, Manzini and Accorsi 2013, van Huis, Van Itterbeeck et al. 2014)
Life cycle	(Mueller 1972) (Klepper 1996) (Seyman, 2003)(van Huis, Van Itterbeeck et al. 2014)(Hoffman, 2014)

Appendix II Case studies of insects reares

	Company name	Location	Insect	Foundati	Substrate	Quantity	Product
1	BioflyTech	Spain	Flies: Hermetia illucens (HI) and Protophormia terraenovae (PT).	2012	Brewery wastes and PT feed on fish wastes.	Around 50 kg/mo	Flour, protein, faty acid.
2	Bitware Farms	USA	Cricket	2015	Many Feedstock		dry insects
3	Entomos	Switzerland	Worms, house fly, crickets, blatta	2009	na		dry insects
4	Fly farm System	USA	House fly	2011	na	?	live, dried, frozen, whole, liquefied, ground, pelletized, flaked and loaded.
5	Insagri	Spain	BSF	?	na	300-500kgs per m	dry insects
6	Insect Europe	The Netherlands	Crickets	?	na		dry insects
7	Kreca	The Netherlands	12+ spieces of insects	1978	corn meal or groat meal	Few tonnes/ week.	dried insects
8	MARBA APELDOORN BV	The Netherlands	Mealworms, giant mealworms	1940	na		dry insects
9	Meertens	The Netherlands	Locusts freeze dried	2002	insect feed (grass)		dry insects
10	New Generation nutrition	The Netherlands	na	?	na	up to 1000 kilos	na
11	Nutrinsecta	Brazil	BSF, crickets, beatles	2014	na		dry insects
12	Protix	The Netherlands	BSF,	2013			ingredients
13	Rainbow mealworms	USA	Worms/ crickets	1956	insect food		dry insects
14	Timberline	USA	Crickets, worms	?	insect food		dry insects
15	Van de Ven	The Netherlands	mealworms, buffalos, Morio worms, grasshoppers and crickets	?	na		blanched or deep-frozen

Appendix III Case studies food manufacturers

	Company	Foundation	Location	Product	Insect
1	**Aldento**	2015	Belgium	pasta	mealworms
2	**All things Bugs**	2011	USA	cricket flour	crickets
3	**Aspire**	2012	USA	cricket powder	crickets
4	**Bens bug**	2014	Belgium	hamburger	mealworms
5	**Besteinsecten**	na	Germany	dry, grilled	crickets, mealworm, buffalo
6	**Bitty food**	2015	USA	biscuits	crickets
7	**Bug foundation**	2014	Germany	hamburgers	buffalo worms
8	**Bug muscle**	not selling	USA	na	na
9	**Bugs Original**	2013	The Netherlands	dry insects	mealworms, crickets, locusts
10	**Bugsolutely**	2015	Thailand	pasta	crickets
11	**C Fu Foods**	na	USA	na	crickets and mealworms
12	**Chapul**	2013	USA	bars	crickets
13	**Coalo Valley**	2015	USA	dry + choco	crickets
14	**Crickerscrackers**	2014	USA	crakers	crickets
15	**Cricketflours**	2014	USA	cricket flour	crickets
16	**Critter bitters**	not selling	USA	cocktails	cricket
17	**Crobar**	2015	UK	bars	cricket
18	**Crowbar Protein**	2015	Iceland	bars	crickets
19	**Damhert Nutrition**	na	Belgium	nuggets, schnitzel, burger	buffalo worms
20	**Deli bugs**	2011	The Netherlands	dry insect, lollypop	buffalo worms meal worms crickets grasshoppers scorpion
21	**Dimini Cricket**	2014	France	dry or choco or creme	crickets
22	**Edible bug shop**	2007	Australia	dry/ roasted/ chili. Mission also	crickets, ants, mealworms, cockroach
23	**Ento**	not selling	UK		
24	**Entomofarms (Next Millennium Farm)**	2014	Canada	Cricket flour	crickets
25	**Essento**	2014	Switzerland	na	mealworms
26	**Exo**	2013	USA	bars	crickets
27	**Gryllies**	2015	USA	powder , souce	crickets
28	**Hopperatx**	2015	USA	granola	crickets
29	**Hotliks**	na	USA	candy	meelworms, crickets, schorpions
30	**Insecteo**	2015	France		mealworm, crickets
31	**Insectes commestibles**	2009	France	aperitives, snack, candies	scorpions, crickets, mealwor
32	**Jiminis**	2012	France	dry insects spices	crickets
33	**Kephri**	not selling	France	na	crickets
34	**Kinjao (entotech)**	2009	France	bars, pasta	cricket
35	**Little Food**	2013	Belgium	dry, transformed	crickets
36	**Micronutris**	2011	France	grilled, bars, pasta, popcorns, bis	mealworms, crickets
37	**Nochey**	2008	The Netherlands	Frozen sausages, burgers, croqu	na
38	**Ronzo**	2015	Poland	granola	crickets
39	**Sexy food**	2014	France	canned dry insects	giant waterbugs, grasshoppers, rhino beatle, meal worms, queen weaver ants, small crickets, black scorpions, yellow scorpion, sago worm, super worms, ants
40	**Six Foods**	2013	USA	Chips	crickets
41	**Smash Nutrition**	na	UK	additive protein	crickets
42	**SNACK-INSECTS**	2013	Germany	dry insects	crickets
43	**Tasty Bugs**	na	The Netherlands	dry, bitterballen	mealworms, grasshoppers, crickets
44	**Thailandunique**	2004	Thailand	product with sugar, vodka, chocolate..	crickets, mealworms, water bugs, grasshoppers, rhinobug, silkworm pupae, hearthworms, scield bugs, cicada, scorpions, bamboo worms
45	**The Green Kow Company**	2013	Belgium	souces, chocolate	mealworms
46	**Uka proteins**	2013	Canada	bars	crickets
47	**Ynsect**	2011	France	protein extract	beetle and fly

[3]

[3] Insecteo and Kinjao belong to the same company Entomotech, but different market

Appendix IV Case studies food manufacturers

	Company	Country	Insect used	Substrate	Product	Destination	Quantity	Foundation
1	Agriprotein	South Africa	Fly, worms	Organic waste	Feed, fertilizer, ingredients	livestock	7 tonnes of MagMeal™, 3 tonnes of MagOil™ and 20 tonnes of MagSoil™ per day	2010
2	Diptera srl	Italy	BSF	Pre-consumer vegetable waste	Meal, oil, compost	Pet food	400 kg/day (live weight, 2016 pilot plant)	2014
3	Enterra	Canada	BSF	Organic waste	Feed ingredients, fertilizer	Aquaculture		2013
4	Entofood	Malasya	BSF	Organic side st	Fertilizer, whole larvae, feed meal and ingredients	Aquaculture	?	na
5	Entologics	Brazil	BSF	Organic waste	Insect meal	Fish, poultry, pigs and	?	2010
6	Entomotech	Spain	Mealworm, BSF	wheat bran restaurant food wastes. fruit disposal from fruit shop and fruit shortening and packaging warehouse. food industry	Flour, ingredients (fats and proteins)	Pets and prawns	Around 100kg/day, just for experimentation	2012
7	Eviroflight	USA	BSF	6 tons of pre-consumer waste	feedstuff and ingredients	zoo animals, insectivore pets, aquaculture in future	?	2009
8	Hermetia	Germany	BSF	na	na	na	?	na
8	Meal Food Europe (more like a bree	Spain	mealworm	na	Alive larvae, powder chitin, fat	green chemistry		2013
9	Millibeter	Belgium	BSF	organic waste	Chitine, fat, protein.	Chemicals and cleaning	?	2012
10	NextAlim	France	BSF	Organic waste	Fertilizer, feed ingredients (protein, oils),	green chemistry		2014
11	Ofbug (production?)	Canada	(yellow mealworm), BSF larvae in a	pre-consumer, clean, traceable food waste.	whole, flaked or ground form	Poultry, hogs.	?	(pre- order, research)
12	Ovrsol	USA	BSF	Organic waste	Feed	Aquaculture		2010
13	Protix	NL	BSF	?	Ingredients	Chicken and pig diets…		2009
14	Pupa Planet	Spain	Flies	?	Feed	Aquaculture, Poultry & Pet food		2012
15	Sparos	Portugal	?	?	Feed meal	Aquaculture		na
16	Ynsect	France	Beetles and flies	Organic waste	Feed	All animal nutrition		2011

Appendix V Case studies facilitators

	Company name	Country	Production	Founding year
1	Edible bug farm	UK	Blog	?
2	Edible insect Network	UK	Blog	2015
3	Bug burger	Sweden	Blog	2014
4	Mangen des insectes	France	Blog	?
5	4 Ento	Switzerland	Blog	2014
6	Bug vivant	USA	Blog	2014
7	Food insect news letter	USA	Blog	?
8	Insects are food	USA	Blog	?
9	Little herds	USA	Blog	2013
10	Woven network	UK	NGO	?
11	Tiny Farms	USA	NGO	2012
12	Entomoproject	Dublin	Research	?
13	Bugs for life	Benin	NGO	?
14	Ital bugs	Italy	Research	2014
14	Protein Synergy	Switzerland	Market research	
15	Mighty	USA	Research	?

Appendix VI

	Company name	Country		
1	ACRS	France	Shop	buisness
2	Bizarre Food*	UK	Shop	buisness
3	Buggrub (Unique Food)	UK	Shop	consumers
4	Bush Grab	UK	Shop	consumers
5	Edible unique	UK	Shop	consumers
6	Europe entomophagie*	France	Shop	buisness
7	Gourmex (not selling online, yet)	Canada	Shop	consumers
9	Lazybone	UK	Shop	consumers
10	La boutique insolite	France	Shop	consumers

Appendix VII Evaluation of blog topics

Variable	**Presence or absence of the topic**
Food security (projects in Africa, Asia…)	Section of the blog where it is mentioned (increase in population, scarcity of proteins)
Why eat insects?	Presence includes environment, nutritional and social benefits
Vegetarianism	Absence/ presence
Future perspective of the industry	Presence includes: list of companies, consumers survey, interviews
Activities	Coordination of events by them or by others
Link to a company	Absence/ presence

Appendix VIII Rubric for the assessment of innovation practices

Rubric	
Startup	Startup is a company that started its operations less than five years before this study (until 2010), the ability to grow and to scale up quickly and without geographic constraints makes startups different from small businesses. Moreover a startup is characterized by low revenues (below 20$ million), less than 80 employees and from a strong power in the hands of the founders or starters.
	A company will thus be considered as a startup when one or more of these characteristics are found.
Product	A product innovation will improve the performance of an existing product; will satisfy new customers' needs such as a higher quality of the product and new technology product innovation will give the firm a competitive advantage, making it different from others. It can include a new ingredient or a new component.
Process	A process innovation is characterized by an improvement in a productive process, or even a new productive process. It helps in reducing the costs of the company and to provide a better quality to the final customers. The new process can be also used to create new products.
Collaboration	Collaboration is the presence of exchange of information and sharing of efforts by many actors, being them both public and private entities. The actors involved are mainly customers, suppliers, competitors, research institutes, governments.
	When one or more is found the company is assumed to be no collaboration. Only what is published online will be valued because we assume that a company if is in collaboration, is willing to publish the partnership.
Radical	"Radical innovation establishes a new dominant design, and hence a new set of core design concepts embodied in components that are linked together in a new architecture." Henderson and Clark (1990)
	" a change that builds on a firm's expertise in component technology within established product architecture." Christensen (1993)
	A radical innovation is based on the exploration of new technology; it is characterized by a high level of economic risk because of its uncertainty. It can be related to process, products or services with new performance characteristics. One important aspect of a radical innovation is that it creates a dramatic change in an industry, transforming it in a new one.
Incremental	An innovation that exploits existing technology is called incremental. It drives a low uncertainty and has a focus on improving costs or features using existing products, processes, services, marketing or business models.

Appendix IX Questionnaire to rearers

My name is Lorenza Pasca, I am a student of Wageningen University and an insect lover. I am currently writing my Msc thesis on the development of the industry of edible insects as feed and food. More specifically my objective is to understand the **innovative characteristics** adopted.
In order to do so I am collecting data from the web. However some important information is not always available and I would appreciate very much if you could provide me with those.

- Which insects do you use? Where do you source your insects? Do you consider making also other products? What do they feed on? What is the quantity produced?

- When did you start your activity? Do you collaborate with others, like research centers, breeders, consumers? Do you consider making also other products?

- What kind of innovation do you think is needed in the sector? What kind of communication do you think is needed to persuade skeptic consumers?

Thank you very much for your patience and time. This will help me so much to have stronger results and so to give a new input in literature studies.

I am totally available to answer any question or doubt about the research.

Best regards,

Lorenza Pasca

Appendix X Questionnaire to feed manufacturers

My name is Lorenza Pasca, I am a student of Wageningen University and an insect lover. I am currently writing my Msc thesis on the development of the industry of edible insects as feed and food. More specifically my objective is to understand the innovative characteristics adopted.
In order to do so I am collecting data from the web. However some important information is not always available and I would appreciate very much if you could provide me with those.
*Which insects do you use? Where do you source your insects? What do they feed on? What is the quantity produced? To which animals is your final product destined? Do you export your product abroad?

*When did you start your activity? Do you collaborate with others, like research centers, breeders, consumers?

*What kind of innovation do you think is needed in the sector?

Thank you very much for your patience and time. This will help me so much to have stronger results and so to give a new input in literature studies.

I am totally available to answer any question or doubt about the research.

Appendix XI Questionnaire to food manufacturers

My name is Lorenza Pasca, I am a student of Wageningen University and an insect lover. I am currently writing my Msc thesis on the development of the industry of edible insects as feed and food. More specifically my objective is to understand the innovative characteristics adopted.
In order to do so I am collecting data from the web. However some important information is not always available and I would appreciate very much if you could provide me with those.

*Which insects do you grow? What do they feed on? What is the quantity produced? What is your final product? To which industry is your final product destined (feed, food)? Do you export your product abroad?

*When did you start your activity? Do you collaborate with others, like research centers, breeders, consumers?

*What kind of innovation do you think is needed in the sector?

Thank you very much for your patience and time. This will help me so much to have stronger results and so to give a new input in literature studies.

I am totally available to answer any question or doubt about the research.

Best regards,

Lorenza Pasca

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