What systemic factors influence the transition to entomophagy in the Netherlands?

A TIS-analysis of the entomophagy industry in the Netherlands

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Samenvatting:

Tegen 2050 is een toename in de voedselproductie voor de wereldbevolking van ongeveer 60% vereist. Eetbare insecten zijn een voedzame en duurzame oplossing voor de groeiende wereldwijde vraag naar eiwitten. Dit betekent echter niet dat de implementatie van entomofagie eenvoudig is. Hoewel entomofagie in Nederland al sinds 2006 bestaat, verloopt de adoptie moeizaam. De onderzoeksvraag is dan ook: **"Welke systemische factoren beïnvloeden de transitie naar entomofagie in Nederland?"** Om de veranderende aard van de Nederlandse entomofagie-industrie te laten zien wordt een TIS-analyse uitgevoerd. Door te kijken naar de vervulling van zeven specifieke systeemfuncties, kunnen systemische factoren worden gedefinieerd om entomofagie te implementeren of te weigeren. Deze analyse laat problematische functionele patronen zien. Hoewel er enkele positieve gebeurtenissen zijn geweest die entomofagie in Nederland hebben gestimuleerd, heeft geen van de geanalyseerde systeemfuncties zich in de loop der jaren voortdurend en structureel opgebouwd. Het lijkt erop dat, hoewel er veel positieve verwachtingen zijn gewekt door zowel onderzoekers als ondernemers, men niet in staat is om een groep actoren te mobiliseren die entomofagie tot een alom verbreide innovatie maakt. De belangrijkste systeemfactoren die deze groei belemmeren, zijn een gebrek aan regelgeving, een gebrek aan overheidssteun en een gebrek aan investeringen in de industrie.

Summary:

An increase of the global population food production of about 60% is required by 2050. Edible insects are a nutritious and sustainable solution to the growing global protein demand. However, this does not imply that the implementation of entomophagy is easy. Although entomophagy exists since 2006 in the Netherlands, it is still not a widely adopted practice. The research question is therefore: **"What systemic factors influence the transition to entomophagy in the Netherlands?"** To show the changing nature of the Dutch entomophagy industry over time, a TIS-analysis is performed. By looking at the fulfilment of seven specific system functions, systemic factors to adopt or abandon entomophagy can be defined. The dynamic analysis of the functioning of the entomophagy innovation system shows problematic functional patterns. Although some positive events which stimulated entomophagy in the Netherlands have happened, not one of the system functions that were analysed showed a continuous build up over the years. It seems that although there has been a lot of positive expectations ventilated by researchers and start-ups alike, they are not able to mobilize a group of actors that are able to push entomophagy forward. The most important systemic factors which hamper this growth are a lack of regulations, a lack of governmental support, and a lack of investments into the industry.

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Section 1: introduction

"Eating insects will be the new normal" (Protifarm, 2020). This promising quote can be found on the website of Protifarm, a Dutch insect rearing company which aims to provide effective nutrition for a healthy lifestyle and planet. But will it be?

Since the global population is expected to grow to 9.1 billion people in 2050, an increase in global food production of about 60% is required (Veldkamp, 2019). However, the food resources which are used nowadays are limited. The protein supply for food is highly critical and therefore requires a transition in protein resources to be able to provide enough food for the global population (Willemsen, 2015). Edible insects are by some considered to be the "missing link" in circular and sustainable economy which can provide a nutritious and sustainable solution to the global protein demand (Veldkamp, 2019).

The concept that insects should be adopted as a novel human food source is not new. However entomophagy, the practice of eating insects by humans, has especially gained attention since the Food and Agriculture Organisation (FAO) has published an influential report on the subject in 2013. The report is called *Edible insects: future prospects for food and feed security* (Van Huis et al., 2013). The principal reasons for humans to adopt insects in their diet mentioned in this report were that eating insects is good for both nutritional and environmental values (Van Huis et al., 2013). This report has sparked an enormous interest in both the world of academic research, as well as the world of commercial interest (Engström, 2018). Numerous papers have been written on this topic, and numerous companies have started to appear since the potential of insects as human food is enormous (Smith and Pryor, 2014).

Examples of Dutch companies active in the entomophagy industry are Protix and Protifarm. These companies are adamant on delivering insects as human food. Protifarm has recently received a multimillion-euro investment by the Dutch government to keep developing and endorsing their products. The two main selling points of these companies are that the products are healthy and sustainable alternatives to the conventional livestock industry, thus conforming to the values mentioned in the FAO report published in 2013. Since there is a growing attention towards more healthy and sustainable alternatives to the resource-consuming livestock industry from both scientific and societal perspective, the rearing of insects for human consumption could be of both high scientific and societal relevance (DeFoliart, 1989).

So, research into the success of entomophagy is of scientific relevance because it is a novel protein source of which there is relatively little knowledge still (DeFoliart, 1989), and

entomophagy is of societal relevance because it is a novel protein source which can help provide in the growing global food requirement (Veldkamp, 2019).

However, even though the scientific and societal potential of entomophagy is clear, this does not imply that the implementation of entomophagy is easy. The Dutch entomophagy industry already started forming in 2006 (Van Huis et al., 2014). Since then this industry has not developed in such a way that entomophagy is a widely adopted practice in the Netherlands (House, 2017). Therefore, in this thesis the history of the development and application of entomophagy in the Netherlands is analysed to learn lessons from the difficulties and successes that have characterized this development since its nativity in 2006. Most past research on entomophagy has focused only on the benefits of edible insects, but this research tries to learn lessons from the difficulties and successes of the diffusion of the innovation by analysing the whole system of the entomophagy industry in the Netherlands. The main research question for this thesis is therefore:

What systemic factors influence the transition to entomophagy in the Netherlands?

The reason why it is especially vital to research the diffusion of entomophagy in the Netherlands is because the Netherlands is a key player in the area of entomophagy in the world (Willemsen, 2015). Also, the Netherlands identifies itself as an advocate in the development and implementation of novel protein sources, which include insects (Willemsen, 2015). Furthermore, the amount of financial and institutional support by the Dutch government signifies that the Netherlands are a frontrunner when it comes to developing novel protein sources such as entomophagy. The success (or failure) of the implementation of this innovation could be used as an example for other countries to learn from.

To define all the activities which have taken place concerning developing and implementing entomophagy in the Netherlands a Technological Innovation System analysis will be used. This analysis measures the activities throughout time. The timeframe chosen is 2006-2019, because the entomophagy industry started forming around 2006 (Van Huis et al., 2014) and 2019 is the most recent year of which information can be retrieved during the writing of this research. Through a TIS-analysis from the year 2006 up until 2019 it shall become clear what systemic factors positively or negatively influence the entomophagy industry in the Netherlands. With ‘systemic factors’, all the factors which influence the Technological Innovation System of the

entomophagy innovation are meant. These determining factors can be traced by identifying all those activities that take place in innovation systems that influence the development, diffusion and use of an innovation (Edquist, 2001). Bottlenecks shall be defined and recommendations shall be given to tackle these bottlenecks.

This paper is structured as follows. In section 2 the theory of the Technological Innovation System analysis approach is explained. In section 3 the methodology used in this thesis will be described. In section 4 the event description of the entomophagy industry in the Netherlands and an analysis of these events is given in section 5. Lastly, based on these results a conclusion will be formed in section 6. Annex 1 contains the actors currently involved in producing insects for human consumption in the Netherlands. The bibliography contains an overview of the sources used for this research.

Section 2: Theory

A Technological Innovation System can be defined as a "dynamic network of different agents interacting witch each other in a specific economic or industrial area in a particular institutional infrastructure and involved in the generation, diffusion and usage of technology" (Carlsson et al., 1991). Since entomophagy is a relatively new innovation in the Netherlands, it is important to define and analyse its Technological Innovation System so that the diffusion of the innovation can be described and explained. This can contribute knowledge about the barriers or incentives of the implementation of entomophagy to the already existing body of literature on entomophagy.

The underlying theory of this paper focuses on the bottlenecks that firms encounter when they want to develop new products for a new market. For the entomophagy industry to succeed in the Netherlands it is important that its Technological Innovation System develops successfully and takes over (part of) the Dutch food network. To be able to do so, it is important to define the determining factors that explain successful growth. According to Edquist (2001), these determining factors can be defined by identifying all the activities that take place in an innovation system that influence the development, diffusion and use of an innovation. These activities are the so called "functions of innovation systems" (Jacobsson and Johnson, 2000). These system functions are related to the interactions between the components of an innovation system; the actors (firms and other organisations), networks, institutions and infrastructure. Annex 1 contains an overview of the actors active in the production of insects for human consumption.

To understand how the entomophagy industry develops, diffuses and is implemented in the Netherlands, the functional pattern of its Technological Innovation System will be described and analysed through time. It can be expected that the more and the better the functions are served, the better the Technological Innovation System functions, which allows for a better development, diffusion and implementation of entomophagy in the Netherlands (Edquist, 2001).

The first step in the TIS analysis approach consists of defining the innovation system structure; the actors, institutions, interactions, and infrastructure (Hekkert et al., 2007). This analysis gives an indication of what the entomophagy industry currently looks like in the Netherlands. See Annex 1 for the actors active in the Dutch entomophagy industry.

The second step shall be the focus of this paper and consists of analysing seven system functions. Hekkert et al. (2007) defined seven system functions to structure empirical work on an innovation. These functions will be used to structure the empirical work on the entomophagy industry in the Netherlands. The functions are as follows:

Function 1: Entrepreneurial activities.

Existence of entrepreneurs is vital for an innovation system to function. The role of the entrepreneur is to develop a business network and take advantage of business opportunities. Entrepreneurs can either be new entrants that take advantage of said opportunities or incumbent companies who diversify their business model to take advantage of these opportunities. Since the entomophagy industry in the Netherlands is relatively new, entrepreneurs play an important role in shaping the business network.

This function can be analysed by mapping the number of new entrants related to entomophagy activities, the number of diversification activities by incumbents, and the number of experiments with new technology.

Function 2: knowledge development (learning)

Knowledge development is a very important function of an innovation system. In this thesis, it shows how well the entomophagy industry is able to learn from research.

This function will be mapped by counting the number of R&D projects per year.

Function 3: knowledge diffusion through networks

A network makes out the structure of the innovation system. Its essential characteristic is the exchange of information. (Hekkert et al., 2007)

This function can be analysed by mapping the number of workshops and conferences related to entomophagy in the Netherlands.

Function 4: guidance of the search

Because resources are always limited, it is important that specific foci are chosen for further development of the technology. Guidance of the search refers to those activities that can positively affect the visibility and clarity of specific wants amongst technology users. This can be fulfilled by the industry, the government and/or the market (Hekkert et al., 2007)

This function can be analysed by mapping targets set by governments or industries regarding the use of entomophagy and by mapping the number of articles in professional

journals that raise expectations about entomophagy. By counting the number of articles that are positive or negative regarding the new technology development related to entomophagy, the state of debate can be assessed. A strong discussion about the potential shortcomings would likely have negative effect on further developments while a strong emphasis on the positive aspects is likely to have a positive effect on the entomophagy development.

Function 5: market formation

For market formation to happen, entomophagy has to be able to compete with already embedded technologies in the food industry. Therefore, it is important that entomophagy is able to compete with these technologies.

This function is analysed by mapping the number of niche market initiatives, specific tax regimes for new technologies, environmental standards.

Function 6: resource mobilisation

Both financial as well as human resources are necessary for an innovation system to function (Hekkert et al., 2007)

This function is analysed by counting statements of actors regarding their views on if there is sufficient resource availability for the entomophagy industry in the Netherlands to develop.

Function 7: support from advocacy coalitions

To unlock its full potential, the entomophagy industry has to become part of the food industry. Advocacy coalitions can help to achieve this.

This function is analysed by mapping and counting the number of statements made by groups who have some kind of interest in the entomophagy industry.

A final note is that these system functions might influence each other since they are not per se independent from each other. Certain functions can positively or negatively influence each other. If one function is positively fulfilled it might strengthen one or more of the other functions, thus fortifying the probability of a successful diffusion of entomophagy. The opposite might also happen, where a function could be insufficiently fulfilled. This might consequently lead to a negative cycle where other functions might suffer from. This increases the chance of a slow or insufficient diffusion of entomophagy. On the basis of the data acquired in this research conclusions can be drawn about each function fulfilment.

Section 3: Methodology

To define the main systemic factors which explain the diffusion of Dutch entomophagy a TIS-analysis shall be performed. This shall provide a structured overview of the activities that have taken place to form the entomophagy industry in the Netherlands nowadays.

The first step in the TIS-analysis shall be done by performing a literature research to define the actors, institutions, interactions, and infrastructure. These shall be added to Annex 1.

The second step shall be done by performing a historical event analysis. Most of the time a qualitative analysis is used when empirical work concerning system functions is performed. The downside of this method is that it is not possible to construct detailed patterns of function activities since qualitative analysis through for example interviews generally lead to information on a limited number of key-events (Negro et al., 2006). In this research as much quantitative indicators as possible are used to be able to map functional patterns over time.

The approach used in this research shall consist of retrieving as many historical events related to entomophagy in the Netherlands as possible based on professional journals, newspapers and websites. The database used to retrieve this information is LexisNexis. Since the first steps to develop the entomophagy industry in the Netherlands were taken in 2006, the timeframe which encompasses this research shall be 2006-2019.

Next, the events retrieved are then stored in a database, labelled and allocated to one or more of the seven system functions. This results in a coherent sequence of events that describe how the entomophagy industry in the Netherlands has developed thus far.

The system functions are measured by counting instances of event types over time. However, a distinction should be made between positive and negative contributions to the system function. Some events have a positive contribution to the development of the system function, whereas other events have a negative impact. For example, when a project related to entomophagy starts it positively influences Function 1. When a project related to entomophagy stops, it negatively influences Function 1.

The fulfilment of the system functions are then presented in graphs where the positive line represents the total amount of positive activities per year, and the negative line the total amount of negative activities per year. See table 1 for the indicators. In this way, the development of the system functions can be clearly visualised. A structured overview of the entomophagy industry dynamics can then be seen.

Table 1: indicators for measuring system functions (Table adapted and customized for this thesis from Negro, 2006).

function	indicator	Sign/value
Function 1: entrepreneurial activities	• Project started • Project stopped	+1 -1
Function 2: knowledge development	• R&D projects, Investment in R&D, communities of practice • Expressed lack of R&D projects, investment in R&D, communities of practice	+1 -1
Function 3: knowledge diffusion	• Workshops, conferences, festivals, lectures	+1
Function 4: guidance of the search	• Positive expectations on entomophagy Regulations by government • Negative expectations on entomophagy Expressed deficit of regulations	+1 -1
Function 5: market formation	• Specific favourable tax regimes and environmental standards • Expressed lack of favourable tax regimes or favourable environmental standards	+1 -1
Function 6: resources mobilisation	• Subsidies and/or investments for entomophagy • Expressed lack of subsidies, investments for entomophagy	+1 -1
Function 7: advocacy coalition	• Support by government, industry • Expressed lack of support by government, industry	+1 -1

Lastly, the produced graphs will be analysed and bottlenecks will be defined in section 4.

Reliability and validity

Reliability: this research is mostly reliable because it is replicable. When the keyterms "entomofagie" ("entomophagy"), "insecten voor menselijke consumptie" ("insects for human consumption") and "insecten eten" ("eating insects") are searched in LexisNexis with a time scope between 1 January 2006 to 31 December 2019 and with a geographical scope of the Netherlands, the same results are yielded every time. However, there is a possible bias in this research because the event allocation is only performed by one person. Another coder might allocate some events to different functions. But, the use of as many quantitative indicators as possible for coding limits this bias.

Validity: since the use of the historical event analysis as part of the TIS-analysis is a widely used method to measure function fulfilment over time, it can be expected that the results measured give a clear indication of function fulfilment. Therefore this method seems to be valid.

Limitations of the study

A possible bottleneck for this research method is that every event has the same weight, namely a +1 or -1. It can be argued that not every event has the same importance. For example, in function 4: guidance of the search, a positive expectation on the future of entomophagy of a restaurant owner who sells insect-based foods is weighted the same as the positive expectation on the future of entomophagy by a professor who teaches at a university. The difference is that the restaurant owner probably has not done as much extensive research on the subject of entomophagy as the university professor. Therefore, it can be argued that that the opinion of the restaurant owner weighs less than the opinion of the university professor. Another example can be found in for example function 1: entrepreneurial activities. An entrepreneurial activity such as the launch of an insect-based burger by a new start-up might be of less importance to the function than if an incumbent (e.g. Unilever) decides to mass-produce insects for human consumption. However, because each event is weighted the same, some functions might be misrepresented.

A recommendation for future research to solve this is by attaching a value to some events which is not a hard +1 or -1. So for example for F1: Entrepreneurial activities, predetermine a value for companies based on for example their annual turnover. So, for example 0.95 for an incumbent such as Unilever and 0.1 for a successful restaurant owner. In that case when Unilever decides to start an entrepreneurial activity a value of +0.95 is attached to this (instead of +1) whereas the restaurant owner only receives +0.1 instead of (+1). This shows a more nuanced overview of the function fulfilment and it might help to tailor advice.

Section 4: Results

In this section, I will analyse the functional pattern of the Dutch entomophagy industry.

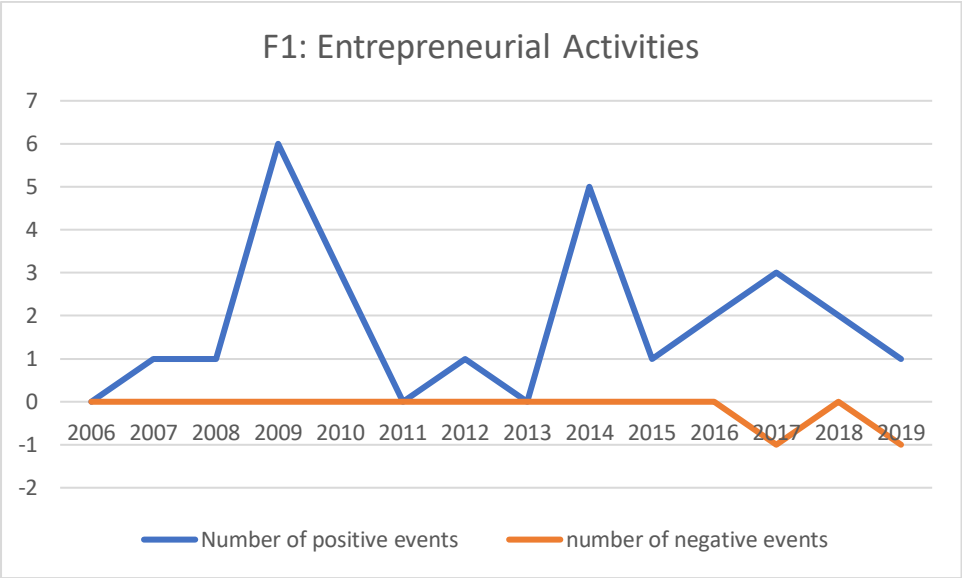

Figure 1: F1: Entrepreneurial activities

The first function, entrepreneurial activities has two noticeable peaks. One major peak in 2009 can be explained by the formation of VENIK in 2009, which is a branch organization that brings insect breeders together to market insects for consumption, for both feed and food. Since the formation of this organization, some insect breeders who used to breed for applications of insects in for example feed for animals, also started breeding for human consumption. However, after 2009 the number of entrepreneurial activities steeply declines, until it rises again in 2014. This is probably because of the release of the landmark FAO report in 2013 which sparked enormous commercial and academic interest (Engström, 2018). It is possible that due to the positive expectations on entomophagy described in that article many entrepreneurs thought that it was the right time to start a project related to entomophagy. However, from 2017 onwards some projects have been stopped.

Conclusion: there is no structural growth of entrepreneurial activities; the growth realised in 2009 and 2014 is not followed by many other entrants.

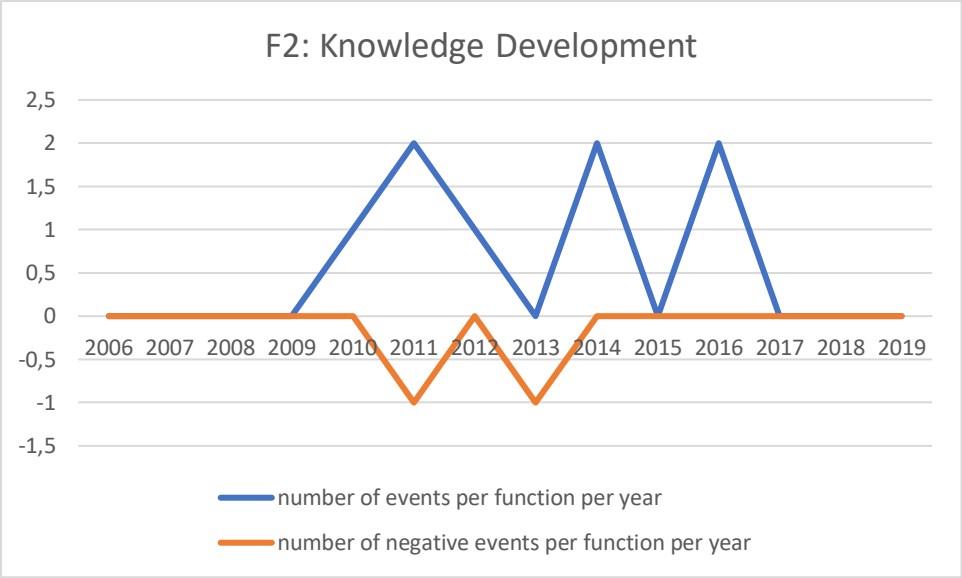

Figure 2: F2: Knowledge Development

The function of knowledge development was practically absent until 2010. The most noticeable peaks can be found in 2011, 2014 and 2016. The most noticeable valleys can be found in 2011 and 2013. The first peak can be explained by the collaboration of Wageningen University with the FAO. Research was performed on the best species selection for human consumption. Also, research was performed at Wageningen University on the safety of insects for human health. The second peak can be explained by the start of Insectpoint, which is a community of practice which investigates the acceptation of entomophagy in society. The third peak is explained by the formation of another community of practice, the Insect Protein Innovation Platform (IPIP). However, there are also expressed lack of R&D projects mentioned in 2011 and 2013. It was stated that not enough research is happening on both the production methods of insects as well as the safety aspects.

Conclusion: there is no structural growth of knowledge development. The three initiatives mentioned above are a sign of positive interest of actors in the market, however it is not clear if results are shared between the three. It is stated on multiple occasions that too little research is happening.

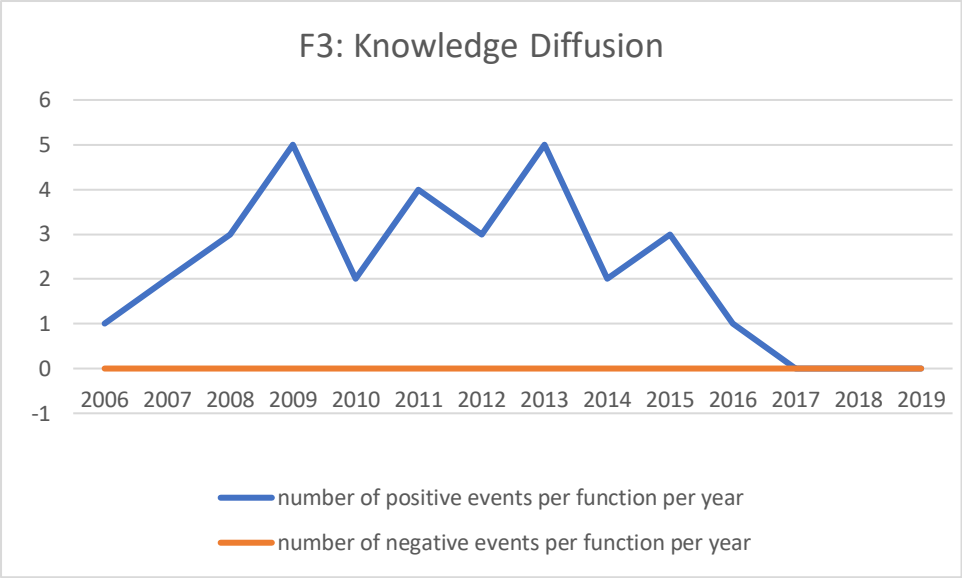

Figure 3: F3: Knowledge Diffusion

From the outset onwards, knowledge diffusion rapidly increased. Knowledge diffusion started in 2006 with a festival in Wageningen called City of Insects. Insects for human consumption were available there. From this moment onwards small conferences or lectures were given, mostly by researchers of Wageningen University. There was a peak in 2009, when Marcel Dicke gave a talk at TED Amsterdam on the benefits of entomophagy. Another peak can be seen in 2013, which can probably be attributed to the appearance of the landmark FAO report released in that year. This report titled "Edible insects: future prospects for food and feed security" sparked both commercial as well as academic interest (Engström, 2018). However, after 2013 the knowledge diffusion starts to weaken and eventually flattens out in 2017. Since then no noticeable events have happened in the spreading of knowledge concerning entomophagy.

Conclusion: there is no structural growth of knowledge diffusion. Entomologists at Wageningen University started with knowledge diffusion but it gradually declined and flattens out.

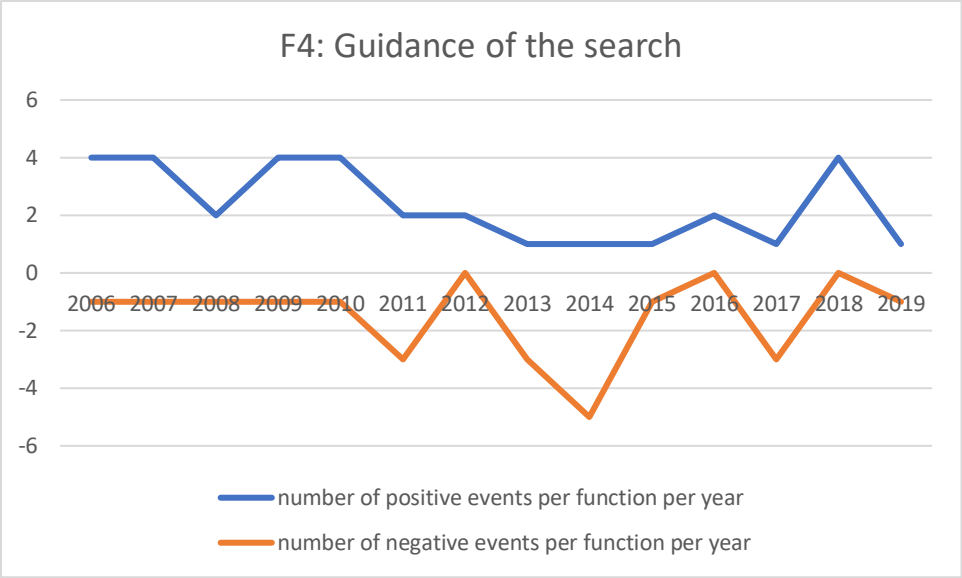

Figure 4: F4: Guidance of the search

Function 4, guidance of the search has no extreme peaks or valleys. Especially in the period of 2006-2010, the system function is fulfilled by positive expectations on entomophagy. These expectations were mostly formulated by researchers of Wageningen University as well as insect breeders of the VENIK organization. From 2010 onwards, the positive events of this function decline slightly until it rises again sharply in 2018. This is probably due to the implementation of the new EU regulation (EC No 2015/2283), see also function 5. This regulation supports the breeding of insects for human consumption and could therefore be accountable for the renewed positive expectations in 2018.

However, this function has also been characterized by negative events. The only years in which there were no negative expectations or an expressed deficit of regulations on entomophagy were the years 2012, 2017 and 2018. All the other years have at least one negative event. There is a steep valley in the period 2013-2014. In these years, most of the negative events were expressed lack of regulations. Insect breeders as well as researchers of Wageningen University expressed their concern about the lack of regulations which hindered their insect production for human consumption.

Conclusion: there is no structural growth in the guidance of the search. Although there were a lot of positive expectations formed by especially researchers at Wageningen University and breeders of the VENIK organization, there has been a vast amount of expressed lack of regulations which hampers growth.

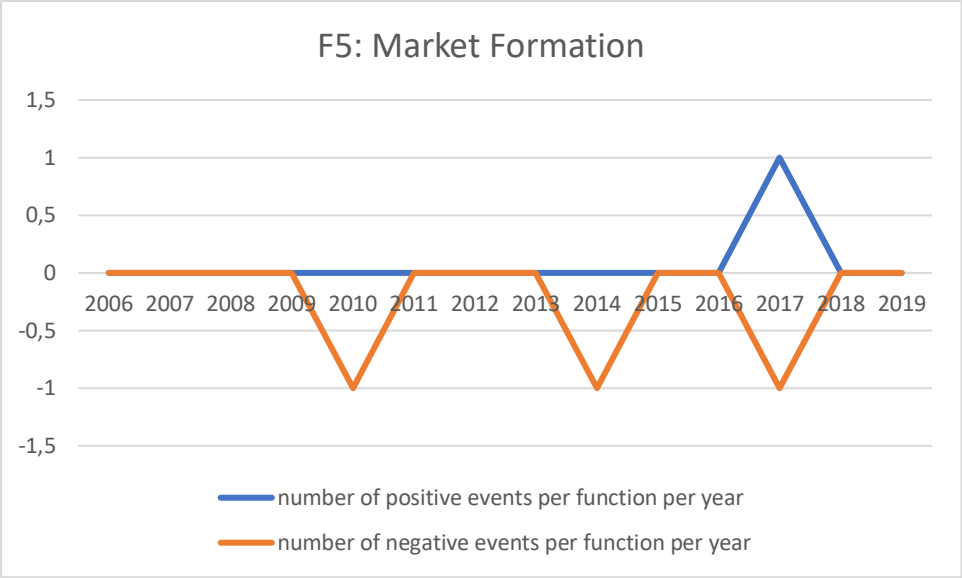

Figure 5: F5: Market Formation

The function of market formation has been severely underrepresented in the entomophagy industry. The creation of markets has not been stimulated by market stimulation policy or tax exemptions up until 2017. In fact, there were several mentions in 2010, 2014 and 2017 that the market was lacking favourable tax regimes or favourable environmental standards. The only event which fulfils this function is the implementation of EU regulation (EC No 2015/2283). One of the aspects of this regulation encompasses that sustainable food initiatives should be encouraged. The regulation was mentioned in an article in 2017, but became into effect on January 1st in 2018. This encompasses that insect breeders are now required to submit applications to have specific insect species for human consumption for sale. This regulation relatively formalized the context of insect production for human consumption, however little has happened ever since.

It is also striking to see that there are no market formation initiatives which take consumer acceptance into account. For a successful implementation of the entomophagy innovation, consumer acceptance is crucial. Companies and governments alike would benefit from this knowledge. However, consumer acceptance was not mentioned in LexisNexis. Therefore, we can assume that little governmental or industrial market research into consumer acceptance has happened. This can hamper the growth of the market formation fulfilment. There have been academic articles which research consumer acceptance on a qualitative basis by performing interviews (e.g. House, 2016; Tan, 2017). However, as we can see from the lack of this function fulfilment, this knowledge has not been widely investigated by the industry or government.

Conclusion: no structural growth in market formation. Very little has happened. Only one event fulfils this function, while there are three negative events. Therefore, this function has been severely underrepresented.

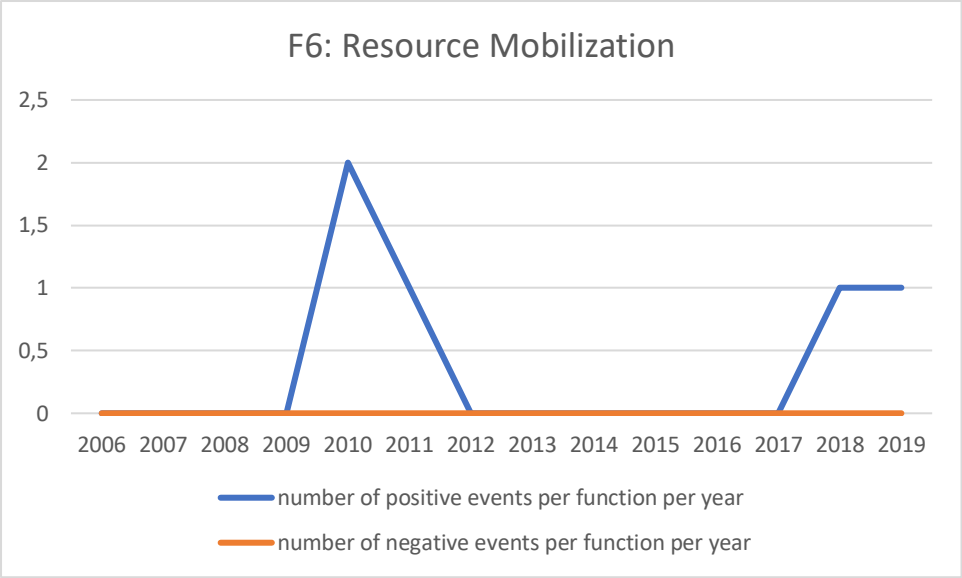

Figure 6: F6: Resource Mobilization

Function 6, resource mobilization has also been underrepresented. In 2010 Wageningen University received an investment of 1 million euro by the government to finance research on insects for human consumption. Another company also received a private investment in that time. In 2011, Insectlab, a community of practice, has received an investment of 70.000 euro to finance research.

In 2018 and 2019 Protix, an insect breeding company, has received investments by OostNL (East Netherlands Development Agency) commissioned by the ministry of Economic Affairs. Protix has not enclosed how much exactly the company received but it is a “multimillion euro investment”.

Conclusion: there is no structural growth in resource mobilization. Significant funds are available, but apparently not on a structural basis per year which is why no continual improvements can be seen.

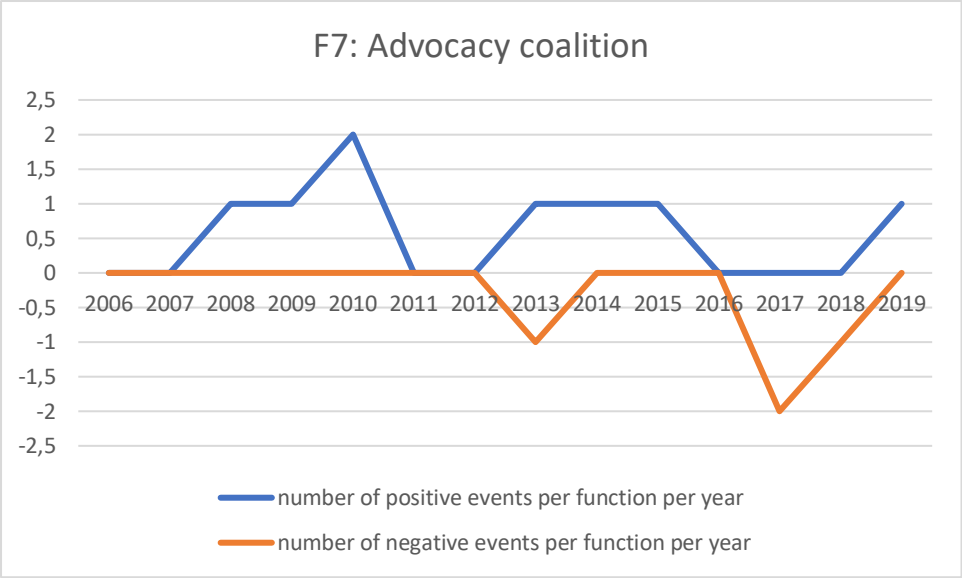

Figure 7: F7: Advocacy coalition

Function 7, advocacy coalition, rises from 2007 up until 2010. The minister of Agriculture, Nature and Food Quality expresses verbal support of research on entomophagy in several articles. Her lobbying has eventually led to an investment of 1 million euro in the entomophagy industry. In 2013 and 20014 several politicians have expressed their support for eating insects, and in 2015 the Dutch cabinet has stated that the Dutch people should eat more insects. The political debate remained silent until 2019 when the Dutch government commissions OostNL to invest in the entomophagy industry in the Netherlands (see also F6: Resource Mobilization).

However, quite some negative events have occurred as well. In 2013, Arnold van Huis expresses the lack of support of the industry. He says that big companies such as Unilever should support the entomophagy industry. Another entomologist at Wageningen University, Marcel Dicke expresses the lack of support by the government in 2017. He says that the Dutch government promised to provide more attention towards entomophagy in 2015, but that the political debate remained silent ever since. Also, in 2017 the NVWA (Dutch food safety authority) has advised people to eat a maximum of 45 grams of insects per day because eating insects could have negative side effects. In 2018 Arnold van Huis expresses the lack of support from the government once again. He says that there are too few regulations and that the government does nothing to support the Dutch entomophagy industry.

Conclusion: At first there was some positive political lobbying, but not on a structural basis. In the later years, parties interested in entomophagy expressed a lack of industrial support but especially a lack of governmental support.

Section 5: Discussion

Some peaks and valleys can be explained by the interaction effect which some of the functions have with each other. The fact that system functions interact and influence each other can be considered a necessity; the function fulfilment can lead to positive cycles of processes that strengthen each other and lead to building up a sort of momentum to be able to integrate in the incumbent food system (Jacobsson and Bergek, 2004). However, the same process can also happen if some functions are left unfulfilled or are not fulfilled enough. Two positive feedbackloops can be defined. One in 2009-2010, and one in 2013. However, these are not strong enough to gain a position in the incumbent food system which becomes clear from the fact that no continuous improvements or lasting trends can be noted. For a successful transition into entomophagy, the innovation needs to gain a position in the current food market.

A peak where a positive interaction effect can be seen is in 2009-2010. There has been an interaction between the entrepreneurial activities, knowledge diffusion and resource mobilisation function.

The first commercial interest started around 2007. Three insect producers decided to start working together to commercialise insects for human consumption. In 2009 they formed VENIK (Verenigde Nederlandse Insectenkwekers, in English called Dutch Insect Breeders association) (van Huis et al., 2014). Arnold van Huis, entomologist at Wageningen University, was involved in VENIK meetings and gave a TED Amsterdam talk in 2009 on the subject.

In July 2009 the Dutch government formulated a plan to become internationally known as a leader in sustainable food production (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2009). Due to the formation of VENIK and the TED Amsterdam talk, the Dutch government announced a funding of 1million euros for research and knowledge exchange in the area of entomophagy in 2010, particularly in the nutritional and safety aspects of insects as food. This project was led by Arnold van Huis and called “sustainable production of insect proteins for human consumption”, otherwise known as (SUPRO2) (Oonincx and de Boer, 2012).

So, the governmental, academic and commercial sides of the Dutch edible insect industry developed alongside each other and interacted with each other in the time period of 2009-2010. The formation of VENIK in 2009 in combination with the TED Amsterdam talk in 2009 has led to a governmental investment of 1million euros in 2010 into research and knowledge exchange concerning entomophagy.

This interaction can be clearly seen in the graphs F1: entrepreneurial activities (formation of VENIK), F3: knowledge diffusion (influential TED Amsterdam talk) F6: resource mobilization (government subsidy), F7: advocacy coalition (Government lobbying to gain the government subsidy). It is most likely that these events strengthened each other and this interaction could create a momentum to gain a position in the Dutch food market.

Another positive interaction can be seen 2013. Not only Wageningen University played a role in shaping the early stages of the entomophagy industry, the FAO (Food and Agriculture Organization) played a role as well. Exchange of knowledge paved the way for one of the most crucial events in the development of this industry so far. The publication of a report published in 2013 by the FAO titled "Edible insects: future prospects for food and feed security" used global knowledge around entomophagy and argued for an implementation of this innovation in Europe. This report argued that eating insects has both environmental as well as nutritional values (van Huis et al., 2013) and sparked commercial and academic interest (Engström, 2018). This interaction can be seen especially in F1: Entrepreneurial activities, F2: Knowledge Development and F3: Knowledge Diffusion.

It is most likely that the introduction of this report has a strengthening interaction effect between those functions because it sparked a peak in those three functions. Due to the introduction of the report, Wageningen University played an important role in developing knowledge by performing new research and subsequently spreading it by organizing conferences. This caught the attention of entrepreneurs who thought it was the right time to start a project in the entomophagy industry.

Another interesting development can be seen at the end of 2019. Insect-breeding company Protix has received millions of euros to develop insects for human production. However, the question remains if this will lead to a positive feedback loop strong enough to have a lasting effect, or that it will turn out to be the same weak feedback loop as in 2009-2010 and 2013.

However, these positive feedback loops do not outweigh the negative barriers. As the graphs show, there is no continuous improvement or long-lasting trend in the graphs. In short, the Dutch entomophagy industry is characterized by too much talk and too little action.

The most noticeable barrier in this industry is the lack of regulations which could formalize the entomophagy industry in the Netherlands. New EU food regulations were announced

concerning novel foods in 2015 (EC No 2015/2283). The regulation came into effect on January 1st in 2018. This encompasses that insect breeders are now required to submit applications to have specific insect species for human consumption for sale. Before this regulation, the Dutch food safety authority (NVWA) had agreed with VENIK in 2011 that they allowed a so called 'regulatory tolerance' which allowed insect production in the Netherlands if the breeders could incorporate general EU legislation regarding the production and supply of food (House, 2018).

However, the regulatory tolerance and the introduction of the new novel food regulation in 2018 have not necessarily significantly improved the diffusion of entomophagy in the Netherlands. A general lack of evidence concerning the safety of the introduced insect species remains. For example, there are indications that some insect species might induce allergic reactions in humans similar to house mites (Hustinx-Broekman, 2017). In 2013, Arnold van Huis complains about the lack of support from big companies such as Unilever for the industry. It is probably because of this lack of regulations that big companies such as Unilever are hesitant to diversify or invest into the entomophagy industry since it could be too risky to mass-produce insects in an unauthorized manner.

Another barrier is the lack of support by the government. In 2017 Marcel Dicke expresses this lack of support by the government. Especially since the government promised to bring more attention towards entomophagy in 2015. However, not much has happened ever since. This lack of support is mentioned once again in 2018 by Arnold van Huis. (See F7: Advocacy Coalition for a more detailed description). This lack of lobbying and lack of support by the government can not only be seen in F7: Advocacy Coalition. It can also explain the relatively low number of investments made by the government in F6: Resources Mobilization,

Overall it can be stated that although some positive-feedback loops have occurred, they are not enough for the entomophagy industry to gain a position in the incumbent food-system in the Netherlands. The development of the Dutch entomophagy industry is mostly characterized by a vast amount of positive expectations in the academic, commercial and governmental world, but little action actually happens to facilitate this development. To support this industry more governmental support and more regulations and investments are needed to formalize the industry and to ensure continual growth of the seven system functions which lead to a more secured place in the Dutch food-system. New governmental policy could be especially vital for the functions F4: guidance of the search, F5: market formation, F6: resources mobilization and F7: advocacy coalition.

Hence, a relatively successful systemic factor is a vast amount of academic knowledge creation and diffusion, also a few enthusiastic entrepreneurs have stood up. However the systemic factors which now hamper a continual growth are a lack of governmental policy guidance and lobbying and a lack of investments in this industry.

Usefulness of the historical event analysis

Although the historical event analysis might slightly misrepresent some functions because a value in between +1 or -1 cannot be attached to an event, the functional analysis of emerging innovation systems has proven to be useful. It leads to additional insights compared to empirical analysis:

Firstly, the historical event analysis was helpful in structuring the vast amount of empirical material in a coherent, structured, and quantitative way. It helped categorizing different event types and to find out if these events have consequences for other events.

Secondly, The fact that the entomophagy industry has been analysed with the seven system functions allows to compare the case with other TIS-analyses of more successful innovation systems. In this way, further research can learn how the functional patterns of less successful food related innovations, such as entomophagy in the Netherlands, differ from successful food related innovations. This is useful information for future policy creation to stimulate entomophagy.

Also, the use of the historical event analysis yields both scientific as well as societal implications. The scientific implication of this research is that the structured overview of the events can help future scientific research to develop policies by looking at successful or unsuccessful systemic factors in more depth. The societal implication of this research is that although entomophagy has a clear potential, thus far it cannot be seen as a feasible novel protein source.

Furthermore, it is striking that consumer acceptance is not considered a hampering systemic factor when performing this historical event analysis via LexisNexis, although it could be a large factor contributing to the success or failure of the implementation of entomophagy in the Netherlands. For further research it would be interesting to somehow integrate consumer acceptance.

Section 6: Conclusion

"What systemic factors influence the transition to entomophagy in the Netherlands?"

The dynamic analysis of the functioning of the entomophagy innovation system shows problematic functional patterns. Not one of the system functions that were analysed showed a continuous build up over the years. Regularly entrepreneurial activities are undertaken by enthusiastic pioneers but this does not necessarily lead to positive feedback loops in the other functions which basically shows the different logics of the functions and actors. Two major positive feedback loops can be defined, namely in 2009-2010 and in 2013. Perhaps another beginning feedback loop can be defined at the end of 2019, although it is too early to state this with certainty. However, these feedback loops do not create enough critical mass to guide the entomophagy industry to a more secured position in the Dutch food market.

Moreover, the institutional environment in which the innovation system functions is unstable and not stimulating for entomophagy initiatives. Therefore, the entomophagy community is often not successful enough to lobby for improved institutional arrangements. Very few network and lobby activities are observed.

It seems that although there has been a lot of positive expectations ventilated by researchers and start-ups alike, that they are not able to mobilize a group of actors that are able to push this innovation forward in difficult times. On the other hand, It is understandable that this edible insect network is difficult to form when the institutional support is extremely fluctuating over the years. It seemed as though the Dutch government supported the industry in 2010, only to remain passive until late 2019. This creates much uncertainty amongst entrepreneurs and researchers and other actors involved in the industry. A misalignment between government actions and entrepreneurial needs can be noted.

Government policy should focus on the developing of the functions F4: guidance of the search, F5: market formation, F6: resources mobilization and F7: advocacy coalition. Supportive regulations could support the developments in these functions. Also more governmental and industrial investments in the industry could enhance the development of these functions. Only if these functions are sufficiently fulfilled, the Dutch entomophagy industry has a chance to succeed.

The overall conclusion is that so far the transition of entomophagy in the Netherlands has not (yet) been a success. In the beginning of the implementation of entomophagy the systemic factors which seemed to develop positively were a great amount of knowledge creation and new entrants into the entomophagy system. However these factors eventually were not great enough to propel the innovation into a success. The main systemic factors which hampered this growth were a lack of continuous support by the government, especially in its investments, lobbying and regulations into the industry. There have been interactions between the academic, commercial and governmental world but so far this has not led to fruitful developments. There are not enough success factors because all the functions are eventually underdeveloped. There has been a lot of talk but little action.

Annex 1

Actors in Dutch entomophagy industry:

The following section lists all the important actors potentially influencing the development of the insect-based products for human consumption. It includes the actors engaged in research and knowledge, production, education, the markets surrounding the technology in the value chain, the institutions that regulate policies, and the intermediates interfering between government, industry and developers. Adapted from Engström, 2018.

- Dutch companies selling edible insect products under their own brand(s)
  - De Krekerij (krekerij.nl)
  - Distribugs (www.distribugs.nl)
  - Kreca Food (www.krecafood.com)
  - Tiny Foods (www.tinyfoods.nl)
  - Tjirp Insect Food (www.tjirpfood.nl) Note: their website is now under construction and last known internet activity which I found was on their Instagram on 30th of March 2019.

- companies/chefs focused on delivering insects:
  - Bugzz (bugzz.nl) Catering, workshops, dinners.
  - Insect-o-shi (twitter.com/insectoshi) The company's main focus is to create sushi with edible insects. Note: there has not been any Twitter activity since 16 January 2017. It is unclear whether this project has failed or is still in the development stage.

- Online stores selling insects for human consumption:

The previous named companies above have their own shops selling their own products directly to consumers. Below is a company who sell a range of different insect products from different companies.

  - Delibugs (www.delibugs.nl)

- Wholesale of edible insects to restaurants and shops:
  - Distribugs (www.distribugs.nl)
  - Good Bug Food Store (www.goodbugfood.store)

- Companies which sell insects as animal feed:

Several companies do not directly feed humans, but do so indirectly by providing insects as feed for livestock. Their main selling point is that it is more efficient to rear insects locally than shipping for example soy all over the world. Especially if the insects are reared on leftovers from the food industry.

  - Illucens (illucens.com/)
  - Proento (www.proento.com) (Netherlands/Mexico)
  - Protix (www.protix.eu)

- Professional insect farmers

Companies that are rearing insects for human consumption.

  - Fair insects (fairinsects.nl) (A Protix company.)
  - Kreca (www.krecafood.com) (sister company of Protifarm) (protifarm.com)
  - Protifarm (protifarm.com) delivers insects in the form of powders or ground up "insect-meat" as a crude resource for other companies.

- Other farms, farm consulting, equipment:
  - Amusca (www.amusca.com)Amusca enables companies worldwide to produce insect larvae locally using their smart insect technology and services.
  - NGN New Generation Nutrition (ngn.co.nl) New Generation Nutrition provides sustainable insect applications to companies.
  - Wadudu Insecten Centrum (wadudu.eu) Wadudu Insect Center focusing on Advice, Research & Production of both mealworms and Black Soldier Flies.

- Insect farming as a means to provide protein for developing countries:
  - Insects for all (www.insectsforall.nl/en/)

- Research projects:
  - Wageningen University (www.wageningenur.nl) The university responsible for the FAO report: Edible insects – Future prospects for food and feed security
  - Maastricht University
  - Utrecht University

- Insect industry organisations:
  - Venik (venik.nl) (Netherlands) Organisation for the Dutch entomophagy industry.
  - InsectCentre (insectcentre.com) InsectCentre is a network organisation. Their goal is to connect all parties who have an interest in contributing to the introduction of insects as feed, food and pharma in order to speed up accomplishments which are greater than those a single participant could reach.
  - Ipiff (ipiff.org/) IPIFF is an EU non-profit organisation which represents the interests of the insect production sector towards EU policy makers, European stakeholders and citizens. Composed of 64 members, IPIFF promotes the use of insects for human consumption and insect-derived products as a top tier source of nutrients for animal feed.

- Other insect eating advocates or individuals:
  - Marcel Dicke, (twitter.com/DickeMarcel) Dicke's TED Talk on the topic "Why not eat insects" from 2010 is an important milestone in the entomophagy movement.
  - Oh my bug recipes (www.ohmybugrecipes.com)
  - Bugalicous (www.bugalicious.nl) (catering, lectures, festivals)

- Insect startups that disappeared:
  - Jumping Jack Snack (jumpingjacksnack.com)
  - SEQ Foods (www.seq-foods.eu)
  - Good Bug Food Shop (www.goodbugfood.shop)
  - Ento.farm (ento.farm)
  - In-oil Food (inoilfod.wixsite.com/inoil)

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