BARRIERS TO THE IMPLEMENTATION OF CIRCULAR FOOD WASTE IN FARMING: EVIDENCE FROM THE INSECT INDUSTRY

Master's Thesis

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Abstract

The industrial farming of insects provides a novel solution and potential response to accumulating amounts of food waste and other organic low value streams, which cause various problems on a global scale. Despite considerable benefits of insects compared to other sources of animal protein, the industry is still in its infancy. Therefore, this study seeks to identify key barriers impeding implementation of low value streams. To achieve this aim, the theoretical structure is constructed based on a literature review of historical developments in waste valorization and the fit of insect farming into a Circular Bio-Economy. This framework is explored with data from semi-structured interviews with stakeholders either focused on knowledge provision or involved in operational practices. Findings demonstrate that barriers created from policy, knowledge and finance are expected to be overcome in the midterm while proactive approaches to reorganize food waste for insect farming are required as well as a reconsideration of business models in place. Hence recommendations and a conceptual model for the increased adoption of food waste and low value streams are provided to encourage practitioners in increased use of wasted capacities and to spark further discussions in sustainable entrepreneurship literature.

Keywords: Insect farming, Circular Economy, Waste Valorization, Barriers to food waste use, Sustainable Entrepreneurship

INTRODUCTION

The agricultural sector has seen exponential growth since the 1930s. This was largely enabled by technological innovations such as plant genetics and artificial fertilizers, achieving ever increasing efficiencies. Despite considerable advances in terms of feeding growing populations, these developments came at a cost and are now increasingly contributing to the transgression of various planetary boundaries (Ellen MacArthur Foundation, 2019; Steffen et al., 2015) To that end, food production is responsible for more than a quarter of all greenhouse (GHG) emissions, drives deforestation and loss of biodiversity, is the main contributor to fresh-water pollution and a key factor in ocean eutrophication (Poore & Nemecek, 2018). Half of the habitable landscapes, which means more than all forests combined, are already covered by agricultural area (Ritchie & Roser, 2020). While on one side exceptionally biodiverse areas are wiped out to be replaced by monoculture feed crops, thereby causing rising pressure on land use and disruption of natural cycles (Steinfeld et al., 2006), the other is characterized by crops being fed in disproportionally high amounts to livestock, which features very low feed conversion ratios. This means that several times the plant protein input is required compared to the outtake of animal proteins (Huis, 2013). To that end livestock raising accounts for 77% of crop use while only producing 18% of the calories (Ritchie & Roser, 2020). These practices seem incomprehensible in the face of more than two billion people still suffering from nutritional deficiencies (Cadinu, Barra, Torre, Delogu, & Madau, 2020).

However, the inefficiencies of the food system do not end there. Over a third, with assumptions ranging to a half of all food produced, gets lost or wasted (Lundqvist, de Fraiture, & Molden, 2008). The planetary volume of food waste was estimated at 1.6 Gigatons (Gt) in 2012, which accounts for more than 1% of all material throughput and equals a negative economic value of 750 billion USD, moreover, contributing negatively in several ways (Circle Economy, 2021). Methane emissions, which are produced when food rots, have a much higher warming potential than carbon dioxide and constitute 8% of all GHG emissions, which means if food waste was its own country it would place three after the US and China (Adhikari, Barrington, & Martinez, 2006; Gustavsson, 2011; PR et al., 2019). Next to environmental damage, negative social impacts have been shown to be directly linked to food waste and are often related to food security issues (Kummu et al., 2012). The expected population rise and the entailed increasing demand for food will only cause additional stress on ecosystems and the climate (Lenton et al., 2008).

In sum, the whole system is based on huge external efforts and artificial inputs achieving very inefficient results and entailing massive amounts of carbon emissions and resource depletion. Therefore, a rapid implementation of new solutions that turn away from the previously described approaches are urgently needed.

A more circular, relocated, and regenerative food system could guide the transition (De Boer & Van Ittersum, 2018). As part of such, insects could play a vital role. Particularly the use of food waste in rearing insects represents a quite new and promising approach (Cadinu et al., 2020). While insects imply several advantages over commonly raised alternatives of animal protein, in the context of this study possibly the most important feature is the ability to transform all kinds of biological side-streams, including food waste, into valuable nutrient-rich proteins. Due to their dietary and nutritional flexibility, the use of low-value food sources, such as by-products, food waste and other biological residual streams can be ideal for large-scale farming of edible insects (Cadinu et al., 2020; Cortes Ortiz et al., 2016; Huis, 2013; Ragossnig & Ragossnig, 2021). Particularly Black Soldier Flies (BSFL), the most widespread species chosen for breeding insects, are the best-known species in utilizing waste streams inedible for other creatures (van Huis & Oonincx, 2017). Furthermore, insects possess a high feed to protein conversion ratio. The BSFL for instance requires less than double the feed compared to its weight. Livestock animals in contrast, demand on average about six times (Huis, 2013). Next to that, insects function as natural protein sources, comprise short-reproduction cycles, high growth rates, and entail a small environmental footprint. Studies show that GHG as well as water and space requirements are much lower, than those of livestock (Varelas, 2019). On top of that, three end-products, namely insect meal, oil and frass, can be derived. The first two, insect protein and insect oil, can be used for human consumption, in agriculture, aquaculture, poultry farming or as feed for pets. As such, they have the potential to replace environmentally harmful proteins such as soy or fishmeal. Their residues, generally framed as frass, can be used as high-quality organic fertilizer. Hence, all derived products find further application in the food system and thus allow for closing the loop (Ragossnig & Ragossnig, 2021). Consequently, insects can be understood as the missing link for a food system oriented towards circularity (Madau, Arru, Furesi, & Pulina, 2020).

In spite of these considerable capabilities, the question remains as to why the insect industry is still in its infancy, particularly in regard to the usage of food waste (Cadinu et al., 2020). While literature proposes barriers to the adoption of low-value feed streams in insect farming such as strong fluctuations in availability, differences in composition and the lack of legal certainty, as well as organizational obstacles to access low value streams, those barriers are not well understood, nor are potential strategic solutions (Borrello, Lombardi, Pascucci, & Cembalo, 2016; Cadinu et al., 2020; PhI, Walraven, Bézagu, Lefranc, & Ray, 2020; Ragossnig & Ragossnig, 2021). Due to this lack of understanding the potential benefits outlined above could not be fully exploited. It follows that there are great opportunities to study the issue.

The following research question serves as a guideline for the entire study.

How do barriers impede increased implementation of organic food waste and thus prevent increased circularity and sustainability rates in insect farming?

This focus appears vital in providing guidance to entrepreneurs that aim to reduce impacts of food waste accumulation and who strive to become more circular. Moreover, decisionmakers might be led in directing increased support towards the sector to proactively respond to emerging trends. Lastly, research is informed, particularly with the help of a conceptual model (see Figure 4) about potential strategies for reconsidering the organizational and structural set-up of insect farming, with the goal to finally approach and harness the immense potential that insects possess.

To respond to the guiding research question, the study is structured as follows: It begins by framing the key concept of waste valorization in the context of food waste, its evolution, and what critiques exist. Following that, the concept of the Circular Economy (CE) is expressed with a focus on the bioeconomy, and the fit of insect farming. Lastly, barriers to the use of food waste are analyzed. In the empirical part an explorative approach using qualitative data is used to answer to the research question.

THEORY

Food waste and waste valorisation

Waste streams occur in middle- and high-income countries mainly in the final stages of the supply chain, although significant food waste and losses have also been found in the early stages (Gustavsson, Cederberg, & Sonesson, 2011). The streams of food waste and loss were measured at 1.6 Gt or 1600 Million tons, with the edible part accounting for 1.3 Gt (Imbert, 2017). The terms of food losses and food waste are often used interchangeably which links to the fact that there is still no standard definition of food waste (Bräutigam, Jörissen, & Priefer, 2014). Nevertheless, some studies have tried to differentiate them based on the stages of food supply chains (Kennard, 2019). Food losses can be defined as discarded food, produced for human consumption, at the production, post-harvest and processing stages of a food supply chain. When it is thrown away by the final users at retail and consumption levels, it can be termed as food waste (Gustavsson et al., 2011). This study will focus on food waste, according to the aforementioned definition. Households contribute to more than half of the total food waste generated (Imbert, 2017). Consequently, the largest potential for valorizing waste lies in the consumer sector.

For a long time, strategies within waste management have focused on treating food waste through incineration, composting and anaerobic digestion and related strategies (Arancon, Lin, Chan, Kwan, & Luque, 2013). Hence, no valuable and reusable products were generated from such decomposition processes. Furthermore, due to the generation of toxic methane gas, which is characterized by bad smell as well as high energy consumption, they cannot be seen as satisfactory for treating organic waste (Arancon et al., 2013). Lin et al. (2014) confirmed that alternatives need to be developed to maximize the value derived from such an important resource.

As an alternative to the classical approach, the concept of waste valorization arose. “It is the process of converting waste materials into more useful products including chemicals, materials, and fuels” (Arancon et al., 2013; Lin et al., 2014).

Despite the fact that some research has focused on using waste as an energy source, other measures of valorizing waste streams, before creating energy, should be promoted, following the hierarchy developed by the European Parliament in the 1970s (Arancon et al., 2013; EEC, 1975).

From the top to the bottom, the hierarchy (see Figure 1) proposes to follow the order of prevention, reuse, recycling, recovery (to which energy creating processes belong), and disposal (Salemdeeb, zu Ermgassen, Kim, Balmford, & Al-Tabbaa, 2017).

Figure 1 European waste hierarchy adapted from European Commission (2020)

Although providing an order, the hierarchy received indirect critique as it sets the priorities for the valorization of waste streams in a rather general way. The meaning of the hierarchy is thus sometimes interpreted differently to achieve certain objectives (Teigiserova, Hamelin, & Thomsen, 2020). This is largely due to the use of non-specific terms. The authors conclude that feeding animals with waste may fall into the category of reuse as well as recycling. Whereas Imbert (2017) accounts animal feeding to recycling only. This culminates in an unclear category assignment. Nevertheless, the agreement exists that reuse and recycling activities need to be preferred over energy recovery practices.

To make a clear distinction between the two notions and in light of the focus of this study, which is on the higher valorization of food waste, the emphasis will be on recycling, as illustrated by Imbert (2017). Recycling activities include repurposing waste as animal and insect feed, anaerobic digestion, composting as well as creating bioenergy and natural fertilizers (Ojha, Bußler, & Schlüter, 2020; Salemdeeb et al., 2017). Although composting can be valuable from an environmental point of view under certain conditions, it is not very beneficial from an economic standpoint (Lin et al. 2013). Further waste valorization practices, which come after reuse and recycle, include recovery and disposal but fall out of the scope of this study. Recovery involves the production of bio-based materials, anaerobic digestion and incineration with energy recovery (Imbert, 2017). Disposal practices determine the end-of-life streams of remaining materials and include non-valorization.

Circular (Bio-)Economy

In line with the evolution of waste valorisation principles, there is a growing consensus among researchers about the need for a new production system on a global scale that turns away from *today's take, make*, waste approach (Bocken, de Pauw, Bakker, & van der Grinten, 2016). The linear model and its production and consumption patterns can be visualized compellingly in the material throughput rate occurring in one year. This notion refers to materials that are extracted, manufactured, sold, used and discarded, thus material that does not return into the cycle. In 2020 this figure accounted for 91,4% of all materials entering societies (Circle Economy, 2021).

In response to these dimensions, which exceed the earth's capacities, a contrasting system oriented on natural cycles, framed as the *Circular Economy,* evolved (Steffen et al., 2015). It challenges the appropriateness of the linear model that has characterized economic activity since the industrial revolution by adopting strategies of a closed-loop system (Maina, Kachrimanidou, & Koutinas, 2017).

Examinations by the Ellen MacArthur Foundation (2013) led to the development of three widely accepted principles that narrow down the idea of a system coordinated by circularity. First, the design of materials and products, as well as their distribution, needs to be realized in a way that continuous use can be ensured. Second, regeneration of natural ecosystems must be encouraged, and lastly, the elimination of pollution and waste needs to be fostered. Further Jonker, Stegeman & Faber (2017) in their search for business models for a CE, provided three features that add to the former definition, and cover repeatedly occurring themes CE business models are characterized by. These features include (1) *the closing of raw material chains,* (2) *a transition from ownership to the provision of services, and* (3) *a more intensive utilization of the functionality of products*.

In light of the Circular Bioeconomy, the Cradle-to-Cradle principle is particularly noteworthy. It is based on the principle that one material becomes food for another and that material flows need to be differentiated into two cycles (McDonough & Braungart, 2002). One that circulates technical materials in high quality and without entering the biosphere. The other targets biological nutrients, which are organized to ensure their return to the biosphere, to restore it and contribute to building natural capital.

The case for the insect industry

According to that, moving to a circular food system means using practices and technologies that aim to minimize resources, promote the use of renewable ones and prevent the leakage of natural resources. Reuse and recycling of unavoidable losses and waste should be promoted so that the greatest possible value is preserved and returned to the food system (Jurgilevich et al., 2016).

The commercial rearing of insects can been identified as a promising approach to reintroduce nutrient losses back into the food chain(Ojha et al., 2020). The advantages (see Introduction) compared to alternatives in creating valuable proteins seem vast.

The fact that insects can be valorised entirely, creates a decisive link towards the transition to a CE. Hence, insect farming represents a promising solution to reduce and reuse food waste, which is occurring in increasing quantities while potentially replacing environmentally harmful proteins (Fowles & Nansen, 2020). Figure 2 provides an overview of a potential set up of the insect chain, taking advantage of non-used low value streams.

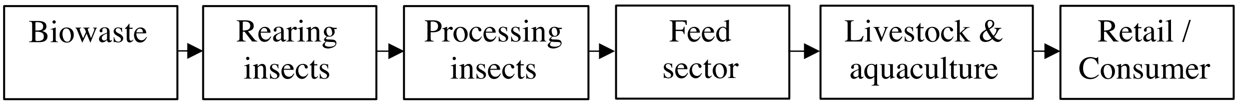

Figure 2 Food waste to insect chain adapted from Veldkamp et al. (2012)

Contrary to what some literature states about the widespread use of food waste, a closer analysis shows that several barriers impede increased use rates. Rather, the most progressive inputs in environmental terms, are by-products from industrial food processing that have been used primarily to date (Borrello et al., 2016; PhI et al., 2020; Ragossnig & Ragossnig, 2021).

Barriers

Regulatory and food safety. At the current state, insects can only be produced with substrates eligible as feed materials for farmed animals. Hence it is prohibited to use materials such as manure or catering waste (Regulation EC No. 1069/2009) containing animal by-products or processed animal protein (except fishmeal) (Ojha et al., 2020). Despite this lack of legal protection, a growing body of evidence shows that food waste from retail and food service operations can be effectively and safely utilized in commercial production systems with the right processing and safety measures (Torok, Luyckx, & Lapidge, 2021). In Japan, the pig industry has successfully introduced food waste recycling without experiencing any negative effects (Torok et al., 2021). The introduction was significantly promoted by national politics. Such strategies to mitigate food safety and biosecurity could also be reviewed elsewhere, hence as legislation is revised, changes are likely to be made to allow for more informed oversight. Overall, insects used as food and feed are considered safe (Belluco et al., 2013).

Composition of streams. As a consequence of the heterogenous nature of food waste it might be difficult for utilizing such streams to turn them into value-added products They can be characterized by showing biological instability, potential pathogenic nature, high-water contents, and more (Russ & Meyer-Pittroff, 2004). Also Lundy & Parella (2015) perceive the composition of household food waste for its later utilization as very critical, due its heterogeneous nature. The consistent provision of relevant material flows would therefore be complicated. Furthermore, the composition of the feed streams determines the growth phase as well as the nutritional value of the derived insect products (van Broekhoven, Oonincx, van Huis, & van Loon, 2015). Some researchers proposed fermentation as a potential way to make waste more usable. It could enhance the stream as it stabilizes the waste and increases food safety. Pre-digestion can also improve utilization for insect larvae, as well as bioavailability of nutrients in previously heterogeneous streams (Law & Wein, 2018).

Organization. In wider CE research with evidence from agri-food supply-chains Rizos et al. (Rizos, Bryhn, Alessi, & Righetti, 2021) identify barriers for implementing circular economy business models next to outlined ones, in economic factors, supply chains, technology, consumer preferences and internal company organization. In support of that Borrello et al. (2016) outline obstacles in the context of adopting insects in circular supply-chains to valorize food left-overs. Further, reverse logistics, geographical dispersion between stakeholders, system boundaries and technical barriers are accounted for. A particular focus of their study is on linear management systems, today's supply chains are trapped in. Means of transport regularly return empty after delivering goods (Borrello et al., 2016). This is neither economically nor environmentally beneficial. Against the backdrop of such system deficiencies, there is a need for circular supply chains in which reverse loops are created.

Although the loss of organic matter in these processes can be unpredictable, they must nevertheless be planned to limit material losses. This requires the establishment of take-back systems which are easily accessible and guarantee the maintenance of the quality of materials. Incentives are also needed for customers to return materials through such a system that is not energy, cost or time consuming. Within the EU, there are no significant barriers to import and export, whereas tariffs have to be considered during trade with third countries. Thus, the geographical dispersion of companies can be a potential barrier to the implementation of a circular model. Potentially negative impacts of transport on costs as well as negative externalities like emissions also have to be acknowledged. Generally, barriers to technological diffusion suitable for creating aforementioned closed loops are still present as technologies are not well known nor widespread (Borrello et al., 2016). Table 1 gives an overview of barriers found in literature.

Distinction	Barriers
Theoretical knowledge	• Policy • Food safety • Composition
Operational knowledge	• Organization

Table 1 Overview barriers found in literature

METHODS

Research design & method

In line with the aim outlined in the introductory part, the study focusses on the barriers for the adoption of low-value food waste streams in the insect rearing industry. As stated, barriers in the insect industry are manifold but not well understood, nor are strategic solutions. Edmondson and McManus (2007) highlight, that in areas where theory is still emerging, a qualitative approach is the suitable research method. Thus, this approach, which will be carried out through semi-structured interviews and a subsequent analysis of findings, will be taken as a research method, as it allows to investigate how food waste streams can potentially find increased adoption (see research question) (Bell, Bryman, & Harley, 2019). Therefore, it appears well suited for this research.

While such an approach may entail limitations, as it has been criticized for not being able to provide generalizations, this approach does not aim to generalize but to contribute with a particular perspective considering food waste usage, which adds theoretical contributions (Bell et al., 2019).

Data collection

Stakeholders and researchers involved in insect farming, sustainable agriculture, entomology research and CE consultancy were handpicked for this interview type, as it was aimed to gather a diverse expert perspective. While such an approach might increase the risk of selection bias, it was still deemed as a proper form of participant selection, against the backdrop of the nascent field under investigation (Atsma & de Vegt, 2011). Hence, several experts with different backgrounds were contacted via mail. This should lead to a diverse peer group and variance in responses. The participants were primarily chosen following recommendations of the founder of an insect start-up who functions as the co-advisor for this research. To meet expectations, criteria were established to pre-elect participants based on their qualification. At an operational level at least a managing position was required, whereas research participants had to be involved in a PhD program as a minimum. To that end a total of ten interview partners, except for one based in the Netherlands, agreed to participate. Hennink and Kaiser (Hennink & Kaiser, 2022) identified that qualitative studies can reach saturation with relatively small sample sizes of around 9-17 participants, especially for studies that have relatively homogeneous study populations and narrowly defined objectives. Therefore, this number is deemed appropriate, also considering the time constraints of this study.

The participants were provided with a consent form (see Appendix B) and asked for their agreement by signing the document so that ethical issues are properly communicated, and potential consequences avoided (Connelly, 2014).

A question catalogue was developed to guide the interviews and to make respondents reactions comparable (see Appendix A). The questions were formed through reviews of the literature taking into consideration the research question. Generally, they were designed to be neutral and non-leading. The structure follows a funnel approach, with open-ended questions that introduce the topic to then approach key questions about perceived barriers and strategies to food waste use. In addition, as Leech (2002) suggests, both planned and informal prompts were included to ensure that the interview resembles a normal conversation and that answers do not become ambiguous. The interviews were held and recorded online via google.meet, and conducted in English due to common understanding. Previous studies provide evidence that the data derived from online interview is similar to those conducted face-to-face (Kirchherr & Charles, 2018). Three interviews were partly held together with another student as introductory questions were overlapping. One interview was held with two respondents at the same time.

Table 2 provides an overview of the participants interviewed during the research. Information about background, sector, and time is provided.

Ethical considerations

To prevent this research to violate any ethical conduct, the study abides to the code of conduct from the University of Groningen, which can be found on the following website (https://www.rug.nl/about-ug/policy-and-strategy/research-ethics/?lang=en).

Inter -viee	Position	Organization	Sector	Background	Date, Time, Duration
I1	Senior Communication Professional	Accelerator transition to regenerative agriculture	Agriculture	Specialists on networks	April 28th, 2:00pm, 41min
I2	Researcher	Insect farming startup	Agriculture	Life Cycle Assessment	April 29th, 2:30pm, 25min
I3	PhD	University	Business Economics	Profitability of Insect farms	May 2nd, 3:30pm, 48min
I4	Co-Founder	Insect farming Startup	Agriculture	Business Expert	May 3rd, 5:00pm, 31min
I5	Business Consultant	Circular Agriculture	Food Industry	Specialist on sustainable food transition	May 4th, 11:00am, 55min
I6, I7	PhD, Research Engineer Entomology	University, Insect farming Startup	Agriculture, Food industry	Live Cycle Assessment, Animal nutrition	May 9th, 09:00am, 50min
I8	Manager	Insect farming Startup	Food industry	Business strategy	May 11th, 3:pm, 30min
I9	Co-Founder	Insect farming Startup	Supply-Chain	Business development, Networks	May 13th, 10:00am, 50min
I10	Business Consultant	Accelerator transition to sustainable foods	Food Industry	Specialists on Insect networks & strategies	May 13th, 01:00pm, 29min

Table 2 Research participants

Data Analysis

Data analysis started by transcribing the recorded interviews. To subsequently analyze the data, coding was conducted in two cycles with the online tool Atlas.ti.

The first cycle of coding considered keeping an open mind while the primary focus was applying predefined categories based on the barriers to food waste use (see Table 1). For example, if one participant mentioned regulatory actions as a decisive barrier for increased food waste implementation, this was then framed as a code and directed to the category of policy.

However, to work more closely with data, in the next round of coding further emerging categories were also considered, hence an open coding scheme was adopted (Hsieh & Shannon, 2005; Locke, 2001). Figure 3 provides an overview of the process of how a code was developed in cycle 2 (category of substrates taken exemplarily). As a rule of thumb, for a code to be developed and taken forward, at least two respondents would have needed to mention it.

A third round of coding sought to control the data for a last time, to control if any notable patterns were overlooked. The resulting code categories are summarized in Table 3 and build the basic structure for the findings. To that end the finding section is divided into *regulatory, knowledge, financial* and *organization*. Furthermore, within future-oriented strategies to potentially overcome barriers, three main categories framed as *Using what's locally available*, *reconsidering the business focus* and *reorganizing the chain* are outlined.

Source	Categories
Derived from literature	• Policy • Food safety • Composition • Organization
Derived from data	• Current state of insect farming • Substrates • Insect products • Future expectations.

Table 3 Interview categories

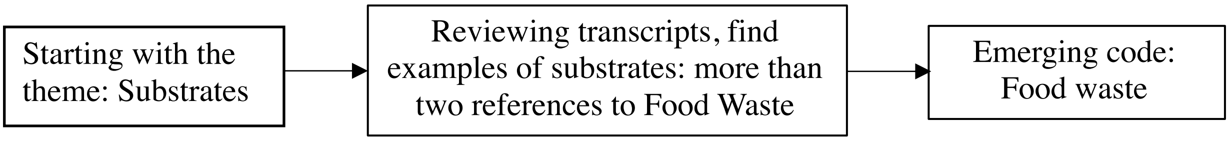

Figure 3 Coding Process for emerging codes from data

FINDINGS

Table 4 covers the main findings, as well as illustrative quotes mentioned by participants. More quotes can be found in the Appendix B, Table 2B. The following descriptions are oriented on the three overall categories: Substrates, Barriers and Strategies. Considering the limited space, these were found particularly informative considering the research question. These categories are split according to the chain of insect rearing to visualize the current state regarding substrate use, how insect products are determined by feed streams to then report barriers hindering the usage of food waste or alternative sustainable waste streams, which could be overcome with several strategies mentioned by participants.

It should be noted that the categories identified and presented are not ranked or ordered in terms of importance; if this were the case, it would be explicitly mentioned. This is due to the exploratory nature of the qualitative approach adopted, and the desire to solely outline key factors.

<table>
<tr><th>Category</th><th>Finding</th><th>Quotes</th></tr>
<tr><td>Substrates</td><td>Feed-food-fuel competition (Price, limited resources)
System in place for side streams (Organization)
Food waste, manure, sewage sludge not allowed in feed for insects</td><td rowspan="5">Substrates
There's a lot of competition for side streams, they are already used in an efficient way (I6)
Barriers
The legislation is what is really limiting sustainability, it is limiting circularity […] if it will be able to increase the pace to reach our level, then insect farming can become an important player in circularity and sustainability of the food production sector (I6).
There's lots of things to research about food safety (I5)
Investments should be in the billions, insects are just a basic part of life, and we've always neglected this. So, it's just a logic, it will become a massive industry (I9).
Strategies
Logistics within Europe should not be a problem (I3)
I see insect rearing as manure management (I2).
We would almost need a system set up (I3)
You need to organize collection (I4)</td></tr>
<tr><td>Insect products</td><td>Nutritional value to a certain extent dependent on nutritional value of feed source
Locally produced protein → decrease dependency on external partners
Frass as source of energy or fertilizer
Oil, protein, chitin applicable in different markets
USP of insect products due to a lack of knowledge not yet exactly known</td></tr>
<tr><td>Barriers</td><td>Regulatory (decisive factor)
Knowledge (in research, operations, food safety)
Financial (investment in growth)
Strategic (composition, availability, traceability, accessibility, waste separation)</td></tr>
<tr><td>Strategies</td><td>Account for local context (given rest streams, geographical setting of rearing facility)
Hierarchy of valorization - valorize as much and smart as possible
Differentiation of types of insect farming facilities (for food/feed or other purposes such as waste management)
Considering closed-loop applications</td></tr>
<tr><td>Expected Future developments</td><td>Law adaptations (Mid-term, 5 years, food waste allowance, Long-term, 10 years - manure & comparable waste streams allowance)
Research will advance in terms of food safety</td></tr>
</table>

Table 4 Overview core findings and quotes interviews

Substrates, Food waste and Insect Farming Outputs

Given the current setting around substrate use for insect farming, it was often mentioned that the use of agricultural side streams from crops such as potatoes, wheat and more, is widespread.

This efficient usage is outstanding in the European context, where the Netherlands are on the forefront in terms of a well-structured system, that offers accessibility to low-value, homogeneous and moist substrates (required for rearing BSFL). The set-up of such a system was enabled by a network of food processing companies and logistical suppliers (I5,I7,I8). Insect farming companies can thereby anticipate the provision of required feed streams in terms of quality and amounts. A notable finding in the context of substrates was that the quality of feed streams only influences the growth phase up to a certain extent (I6). Particularly in the first days the larvae seem to require higher qualities, whereas in the following stages lowest value streams, such as food waste and manure, might be used (I9).

The efficiency of the system simultaneously enhances competition among the demanding parties, which makes it difficult to draw higher margins out of the business model. In contrast, the adoption of less or hardly demanded streams like manure and food waste, which are prohibited by law, could improve economic viability (I6). The main sectors in competition with insect farmers are energy providers and the wider food production sector (I6,I8). Furthermore, the logic of added value to the food chain of farming insects can be called into question when insects are fed with side-streams that could also directly be fed to conventional farm animals. Effectively such actions only add an additional layer to the food chain (I4,I6). As long as it is not clear where the actual unique value of insects over other animals lies, e.g., in terms of micronutrients valuable for human or animal health, such approaches cannot be seen as tools of higher valorization (I5).

Barriers Impeding Higher Circularity

Regulatory. This barrier was by far mentioned the most, including every interview participant. The field seems to be decisive and interconnected with and for all future activities. The barriers created by this field are manifold. One is that insects are categorized as conventional farm animals. This means they underlie equal restrictions and can only be fed on agricultural side streams or conventionally farmed crops (I5,I6,I7). In other words, economically and environmentally attractive streams such as slaughterhouse waste, manure, sewage sludge and food waste, which could all be valorized by insects, are not allowed for use. Furthermore, the general strictness of regulations is perceived to relate to food safety and linked to past experiences with diseases (I7). Nevertheless, countries such as Korea, Japan and China, show that the different approaches to the systemic usage of waste streams like food waste can work successfully in terms of strict food waste separation and further valorization through e.g., pigs (I2,I3). Generally, it is perceived as if legislation cannot keep up the pace with developments in the fast-accelerating insect industry (I6).

Knowledge. An additional decisive category that emerged covers the field of knowledge within the industry, which relates to both operational and scientific knowledge. The participants I2,I3,I4,I6,I7 all mentioned that fast advances are required to create a more solid baseline to increase pressure towards political change. Particularly in terms of food safety and quality more research must be done (I3). Contamination of waste streams in the past led to disease spreading which in turn led to tightened legislations. Therefore, usage of slaughterhouse waste for instance, which could be a valuable source of protein (I6,I7) and the impact of bacteria, heavy metal or micro-toxins and more all must be considered future wise. Interestingly, slaughterhouse waste is allowed for use among pigs and poultry, as long cannibalism is prevented (I7). More knowledge must also be provided in reference to insects as potential vectors of spreading diseases. In contrast to the point aforementioned, this does not refer to food safety issues in terms of the feed provided but in terms of living insects as spreaders of diseases (Malaria, etc.) (I2,I6,I7). I2 and I5 both mentioned the general lack of specific definitions which are needed to enable stakeholders to differentiate all kinds of food waste streams. Currently it seems hard to describe which exact qualities and types of streams could be demanded for rearing insects due to this non-existing determination.

Financial. I3 mentioned the chicken and egg problem of regulatory and finance. The current legislation framework sparks several uncertainties for potential investors. Therefore, investments are still low compared to other fields. Low investments then in turn prevent the industry from scaling up quickly, which furthermore entails that the price of farming insects remains high (I3).

Organization. Another arising pattern was about the composition of food waste which may always vary in quality, size, and material stream components (I2,I3). Centralized farms would need to be able to anticipate certain amounts and qualities to maintain the production capacities at the maximum level. I3 expressed the doubt that geographical distribution of supermarkets, households or restaurants would be a hurdle in the western context. I4, in contrast, perceives accessibility against the backdrop of logistical organization of waste streams as an issue (I4). All the different sources of food waste would add additional complexity to the chain which would affect the traceability of origins of streams. Maintaining transparency and traceability would be highly relevant to recognize potential problems before they occur (I4). Another interesting point was mentioned alongside varying availability of differing types of food waste streams throughout a year (I5). Also, a lack in trusting consumers to separate waste streams accordingly seems to be prevalent (I3,I4)

Strategies

Approaches and ways to overcome the barriers outlined were as manifold as the variety of problems the industry is facing. In addition, the perceptions of how strategies could look like, varied among the participants. Next to law openings which all interviewees accounted for, the following three main categories arose from the data.

Using what's locally available. A core point that arose was in regard to the context insect farmers operate in. When considering what's locally available, the choice of the geographical location of the rearing facility could be additionally determined or influenced (I6,I9). This in turn could lead to a reconsideration of centralized plants, which I4 perceives as the most promising approach and which are currently the preferred option for rearing insects on industrial scale (I4). I9 instead, sees the biggest opportunities in decentralized farming approaches, as non-movable plants might be less favorable in terms of their ability to react to changing environments. Closed-loop systems instead could be complementary and promising approaches against the backdrop of what's locally available (I8).

Additionally mentioned was a pivot from the typical western context, which clearly offers advantages in terms of infrastructure, logistics and waste management system in place. Instead the focus might be extended to the global south, or generally less developed regions where laws often are less strict and where a huge protein gap still impedes societal development (I5,I6,I7,I9,I10). An example that was mentioned by I5 and I10, was about toilets that could be rethought as sources for insect feed. Also, from a compositional angle where higher quality of streams is only required in the first days of rearing, and lower quality streams can be implemented after that, this perspective appears notable (I6, I9).

Reconsidering the business focus. In light of food safety concerns the final market insect products are produced for, could be reconsidered (I9). Deviating from food markets as a potential recipient and instead a focus the pharmaceutical or the chemical sector could be targeted, where biodegradable products and oils are in high demand (I9). Additionally, a focus on the third, but still often neglected product, frass could come in place, where insect farmers might replace synthetic products and fertilizers with frass streams derived out of waste (I3).

Given laws open up, a focus on the BSFL, as waste managers, could become a single focus of insect companies. In addition, waste collection could become part of the business model as margins might be increased when additional players (waste-management companies) are leapfrogged (I4,I5).

Reorganizing the chain. Reorganizing food waste collection by targeting restaurants, supermarkets, bakeries etc., where streams can be anticipated and are easier to gather and more clearly defined, the system could be set up in a new way (I3,I4,I5,I7,I8). From there upon additional players might be needed to process and pre-treat streams to make them food safe and graspable for insects (I3,I5,I8). Quality control might become a decisive point within the chain to prevent problems before they can occur (I3,I4). Additional players could also focus on storing streams when available, to hand them out when demand is high (I5). Generally, most participants agree that although every further player adds additional complexity to the chain they will be needed to guarantee food-safety and to meet requirements for farming insects out of waste streams (I3,I5,I7).

DISCUSSION

As outlined in the introduction, the globalized food system is vulnerable to disruption, broken in several ways and a significant contributor to the transgression of various planetary boundaries such as climate change and biodiversity loss (Steffen et al., 2015).

Insects which call this planet a home for millions of years and which by far represent the most diverse species in existence, outline very promising characteristics to contribute to a turn away from destructive patterns of business as usual, towards a less harmful, socially fair and prospectively regenerative food system (Cadinu et al., 2020). To allow the insect farming industry to expand their market shares and to add circularity and sustainability through using low value feed streams, several barriers must be overcome.

Barriers

Barriers are overwhelmingly connected to the regulatory system in place. Consistent with Ojha et al. (2020), insects are categorized in the same level as conventional livestock, which in turn means low-value streams such as slaughterhouse waste, sewage sludge, manure or food waste are prohibited for use.

As noted, the occurrence of previous disease outbreaks contributed to an increasingly stringent food safety legislation. It seems reasonable to infer that, if insect breeding expands its market share, e.g. by partly replacing livestock, the risk of possible new disease outbreaks could be reduced. In support of that, the study of Joosten et al. (2020) found that particularly BSFL appears resistant against diseases, as no outbreak caused by pathogens has been reported to the day. This overlaps with the findings which state that knowledge to date implies that insects in the form of feed cannot be carriers of diseases. Although generally more research is needed. Surprisingly, laws in existence permit for instance the usage of pig slaughterhouse waste in poultry feed as well as the other way round. To that end a reconsideration of composition of feed streams appears overdue. Additionally, measures from operational practices, such as introducing pigs in recycling, are already known on how to treat low-value streams to potentially become food safe (Torok et al., 2021). However, research must continue to look into the various topics of food safety, which appears, when knowledge can significantly advance, to be one of the core levers for increased usage of food waste streams.

Next to that the unique value that insect products might offer needs further research, to enable the development of baselines for new market applications. In that sense, insects could not only benefit the food chain but potentially provide materials for the chemical, pharmaceutical or more sectors. In that line food safety issues could be less of a concern.

Overall, it can be stated that there is a common expectation that policy changes will be made in favor of the insect breeding industry in the mid-term, which would also entail reduced uncertainties for investors and allow for higher financial flows. Most of the aforementioned barriers should thereby be overcome. As Bijvoet (2022) states, this could then also enhance ecological, social and economic outcomes of business models in insect farming.

In their study in search for CE business models Jonker, Stegeman, & Faber (2017) outline three elements repeatedly occurring in CE literature, that a CE business should comprise. They concern the *closing of raw material chains, transition from ownership to service orientation and a more intensive utilization of products*. Building on these features, the following strategies are aimed to guide practice and research to potentially overcome barriers in the context of insect farming and are summarized in a conceptual model in Figure 4.

Strategies

Focus on the lowest value streams. Insects are increasingly perceived as the potentially missing link for a circular food system (Ragossnig & Ragossnig, 2021). As long as predominantly agricultural side streams are used, the theoretically promising characteristics of insects are undermined and thereby cannot exploit their full potential. In the current setting insects do not provide the addressed link, but solely contribute further to the growing food-feed-fuel competition. Considering the European food waste hierarchy all actions should be aligned to valorize low value streams in existence as efficient as possible, which aligns with *a more intensive utilization of products* (Jonker et al., 2017). In context of food waste use in insect rearing this can be referred to higher utilization of non-used streams. In turn this would mean to deviate the focus from agricultural commodities towards the lowest value streams available. These may cover human fecies, manure, slaughterhouse waste, sewage sludge and homogenous, pre-treated food waste streams, which cannot be valorized by any other animal (Huis, 2013).

Consequently, these streams need to become accessible in an advantageous form.

Reorganizing the food waste chain. By using renewable bio-based materials that formerly would have ended up as waste, a business contributes to *closing the raw material chain* (Jonker et al., 2017). In terms of logistical organization given frameworks above all target linear logistics, meaning the transport of goods one way, without considering lost capacities on the way back. As Borrello et al. (2016) highlight, logistics needs to be complemented by reverse cycles. Barriers to the diffusion of technologies to establish reverse logistics are still prevalent. Technologies such as blockchain which could potentially facilitate and automate processes and help measure CE performance in reverse logistics are not well understood and need further research (Kouhizadeh, Zhu, Alkhuzaim, & Sarkis, 2022).

In contrast, for reverse cycles to be established, there is common understanding that central and effortless accessible collection points are needed, to logistically increase effectivenes. Thus, additional actors will be needed, or at least actors in existence that diversify their portfolios with complementary business strategies with such a target. Such would include collection, potentially storage and pre-treatment of material streams so they can become available in a homogenous and food safe form. At an initial stage, retailers, restaurants, catering firms and fast-food chains could be targeted as potential sources of low value proteins as the anticipation in terms of composition, availability and quality of streams might be clearer. At later stages and when more specific definitions of the different food waste streams are endowed, and technologies of waste management firms advanced enough or the separation of different waste streams at the consumer can be relied on, collection at the consumer could turn into the focus. There the biggest potential of in terms of volumes lie.

Using what's locally available by reconsidering the business model. Streams tend to vary depending on the given local environment, thereby a focus on accessible streams could be helpful in achieving valorization in the most efficient way possible. Contrary to current developments, business models that target decentralized ways of farming insects, could be better positioned to react to ever changing requirements. Additionally, as stated, traceability and transparency are of high relevance and might be facilitated through such an approach. Decentralized models could further facilitate the enactment of closed loop supply chains. Such are understood as "the configuration and coordination [...] to close, narrow, slow, and intensify resource loops [...] to minimize resource input and waste and emission leakage out of the system [and to] improve the operative effectiveness and efficiency and generate competitive advantages" (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). This focus would decrease dependencies on external inputs known to centralized applications like energy demands and resources, and organizational efforts connected to transport ways, which in the current form create additional emissions (Borrello et al., 2016). Furthermore, in a CE there is a *transition from ownership to service orientation*. By maintaining ownership over the product and solely asking for service fees from the costumer, businesses are incentivized to build long lasting products (Jonker et al., 2017). This could be realized for instance through small-scale modular containers handed out as part of a subscription model, where service and potentially human labor are provided to valorize streams in a closed loop system.

Such approaches could also be considered by turning away from a western perspective towards formerly neglected geographical regions such as the global south. This might be due to preferrable climatic conditions better suited for farming insects. Also the lack of protein supply referring to more than one billion people being undernourished, while simultaneously the acceptability to eating insects being significantly higher, frame various potentials for market applications for small scale insect farms in developing contexts (Dickie, Miyamoto, & Tilly Collins, 2019). Beyond that, regulation might be a less decisive barrier, thus the use of lowest value streams prohibited for use in e.g. Europe, can be taken forward. Consequently, the use of locally available low-value streams and the subsequent provision of high-quality insect products could create jobs and contribute to filling the immense protein gap impeding sustainable development (FAO, 2021). Additionally, even smaller scale insect rearing modules, made for the single user or family, which target small scale sources of food waste, could potentially provide additional approaches on counteracting food waste accumulation.

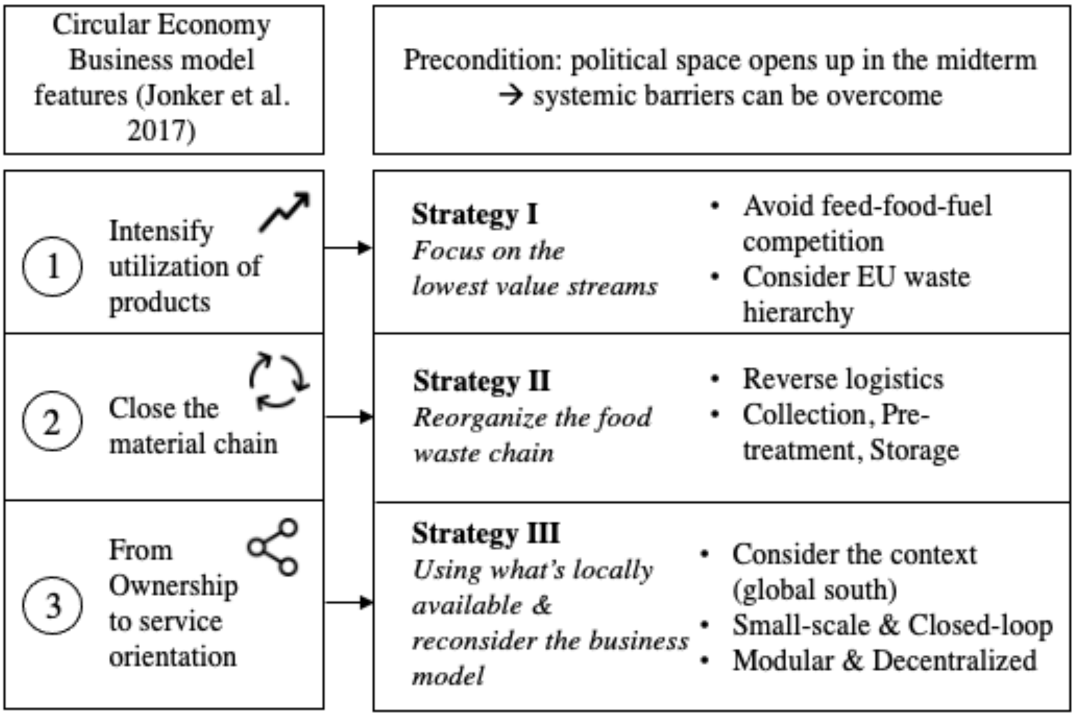

Figure 4 Strategies for reorganizing food waste adoption in insect rearing

Other strategies, where further investigation could be promising, cover insects as efficient bio-processors, where the business focus could be directed towards waste management or fertilizer production only, while reconsidering new market applications for insect products. Particularly the pharmaceutical and chemical sector seem to be potential recipients where food safety concerns are of less relevance.

CONCLUSIONS, RECOMMENDATIONS AND FUTURE RESEARCH

This study has sought to identify barriers inhibiting the adoption of food waste and lowest value streams in insect farming. By undertaking interviews with operational stakeholders as well knowledge provisioning researchers, key barriers such as *regulatory,* *knowledge, finance* and *organizational* were identified and go beyond these accounted for in theory.

By discussing potential strategies that were framed as *Focus on lowest value streams, Reorganizing the food waste chain* and *Using what's locally available by reconsidering the business model*, this research has provided a first assessment covering barriers to food waste adoption in insect farming more broadly. The study also goes beyond one potential type of food waste and additionally provides potential strategies. It thereby takes an entrepreneurial and transdisciplinary perspective, which is needed within the scientific community (Lang et al., 2012). This is important, due to the need for the insect sector to become circular, while considering a focus on lowest feed streams available to not further amplify the growing food-feed-fuel competition.

While key barriers as *regulatory, knowledge and finance* are assumed to be overcome in the mid-term, *organizational* barriers instead, need a proactive approach, prospectively by firms with a business model oriented on CE principles. In light of future progression, these points may be particularly relevant in different contexts than the western one, where a lack of protein supply inhibits human development. However more research will be required for this to be confirmed.

Further results of this study identified that barriers accounted for in other literature are still persistent (Cadinu et al., 2020; PhI et al., 2020; Ragossnig & Ragossnig, 2021). This means more resources need to be guided in that direction. Only awaiting external forces such as policies to rapidly adapt to the problems ahead will unlikely be sufficient to enable circular food waste adoption in insect farming.

This research has also contributed by adding to existing literature through the provision of a conceptual framework (Figure 4). This may aid future research efforts in the area, in which the model can be tested, extended and applied, depending on the given research focus.

LIMITATIONS

First, all of the interview participants, except for one, had a Dutch background. Thus, this view could be perceived as narrow and could be complemented by an even more diverse group of interviewees. Particularly, statements about business model application in the global south, by entrepreneurs originated from such a region, could have enriched this paper. Further research might take this into account. However, as this study took place in the Netherlands, which is one the forefront of insect rearing, the choice of people was reasonable. Also, initially it was intended to conduct interviews with waste managers. As none were approachable in the given time, in-depth statements towards waste management were therefore restricted. That perspective as well as a political one, could be taken forward by future research.

Second, although a main intention of the study was to spark ideas for practitioners, in terms of rethought approaches, and to stimulate further discussions in future research, it fails to give detailed guidance. The strategies proposed are described as a general re-set of food waste reorganization, but a more exhaustive view would probably benefit interest groups the most. To that end, following studies could uncase i.e., one of the proposed strategies, by identifying a step-by-step instruction.

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APPENDICES

APPENDIX A: Research Design

Figure 1A. **Consent form for participation of research thesis on insect rearing**

Please tick the appropriate boxes	**Yes**	**No**	
Description and aim of the study This research aims at investigating the strategic barriers that prevent higher usage of household and catering food waste in insect rearing. To do this, theoretical findings are laid out and at the next step enriched by results derived from interview data. Therefore, the goal of this interview is to gain information about circular economy, the role of insect farming and barriers that prevent increased circularity rates.			
● I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	◻	◻	
● I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions or withdraw from the study until **the date of interview**, without having to give a reason.	◻	◻	

● I understand that taking part in the study involves that the interview will be audio recorded, transcribed and analysed by a student of the RUG (namely: Julius Fischer), only he and the supervisors have access to the data provided during the interviews. The recordings will be transcribed. The use of the recordings will be limited to academic purposes, and they will be destroyed after the submission of the project.	☐	☐	
● I give my permission to be quoted verbatium in the final report	☐	☐	
● *I request my name and/or company to be anonymized in the transcript and the final report*	☐	☐	
● I understand that personal information collected about me that can identify me, such as e.g. my name, e-mail adresses or other personal information, will not be shared beyond the study team. ● The interviewee will receive the complete report near the beginning of June.			
I have read and understood the explanations given to me. By signing this form, I agree to the terms listed above.			
Signatures **The participant**			
________________________ ________________________ _________ Name of participant Signature Date			

The researcher

_____________________ _________________________ _________________________

Signature Date

Contacts

Student:
Julius Fischer:
j.f.f.fischer@student.rug.nl

Figure 2A. Questions catalogue for interviews – Barriers for food waste usage

Organizational

- Consent form and agreement to it, permit to record the interview
- Explain the field and aim of the research (core findings) > *Study focus on barriers for household and catering food waste use (household & consumer), and the application in the field of factory raised insects*

Content

Introduction

1. Can you tell me
   a. who you are and provide short background information about your vocational pathway,
   b. as well as your current position and your responsibilities within the field?

Circularity and Insect rearing

2. What is your perception about the current state of insect farming in the circular economy? Is it already part of the circular economy?
   a. *Explain circular economy (design out waste and pollution; keep products and materials in use; regenerate natural systems; cradle to cradle)*
   b. *Explain insect rearing (input, output, no side products, replacement of harmful agricultural products)*

3. Can you take me on a quick tour of the input section and the output processes of insect farming? I'm particularly interested into the products that insects are being fed on?

Waste valorization *(the process of converting waste materials into more useful products including chemicals, materials, and fuels)*

4. How would you describe the current state european state of food waste management? What strategies are mostly followed?

5. What do you think are the most promising strategies in achieving circularity within food waste management?
    a. *Focus away from incineration & composting, using waste as energy source (negative side effects) towards circular use and upcycling > valuable products derived from waste*

6. What role could insects play within such strategies and could you provide insights into the current state of the usage of food waste within the insect industry?
    a. *rephrasing questions 1 or 2*
    b. *Repurposing waste as animal feeding belongs to recycling*

7. What do you perceive as the central barriers for the usage of food waste?
    a. *Prompt > example for barrier*
    b. *Differentiate between general (e.g. regulatory & composition – overall)*

8. Apart from the mentioned general barriers, various strategic barriers for a reorganization of food waste after the consumer exist. What are the core ones and what could be potential levers to overcome these?
    a. *and strategic (e.g. reverse-logistics, graphical dispersion, accessibility of take-back systems, maintenance of material quality) barriers*

9. What do you expect to happen in regard to food waste treatment in a scenario where obstacles can be overcome?
    a. What is your vision of food waste valorization?
    b. And the role for insect rearing in the future?

Official end of recording, any questions to me ?

Legend: *italic* = prompts

APPENDIX B: Data Analysis

Figure 1B. Coding Scheme

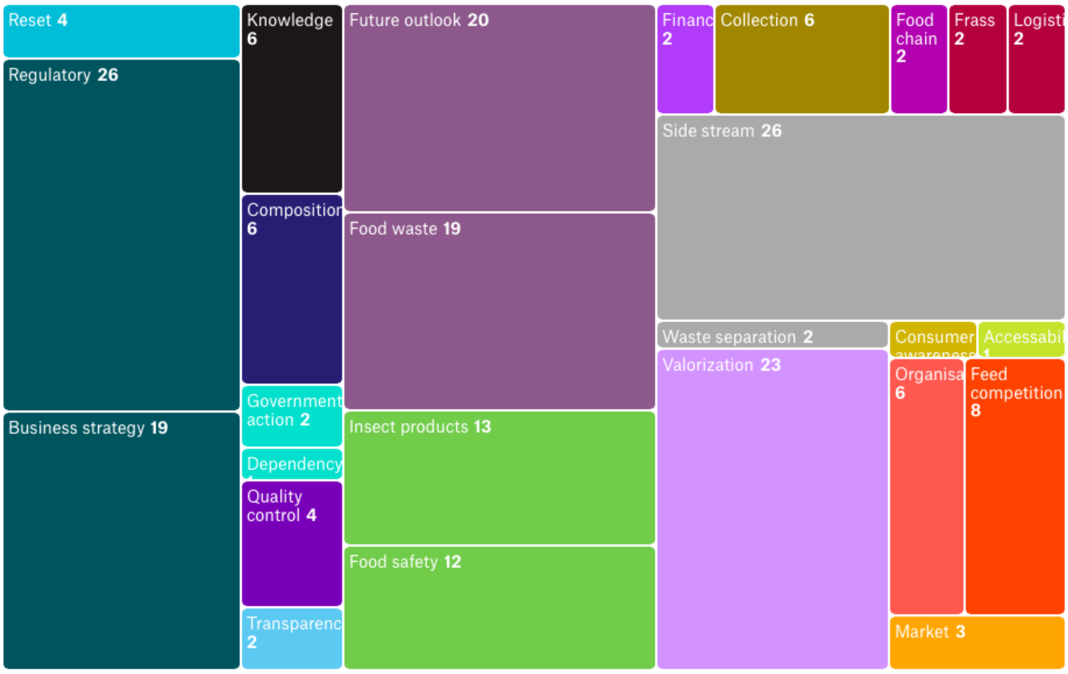

Table 2B. Quotes

Quotes
Substrates
• *A very crucial point is really this processing of food scraps. In the supermarket, there are products like apples, lettuce, bread, whatever. These are often large accumulations of leftovers. (I8)*
• *But in the in the end, you still think about the competition between each other. Because of the feed, food and fuel competition (I6)*
• *all insects are fed with feed grade material, that also can be fed to pig and sometimes poultry. But there is a bit of competition currently (I4)*
• *currently the streams which are super cheap, are the ones which are not allowed in feed, or have 95% moisture and only a very little bit of dry matter or are contaminated with all kinds of unwanted materials. Well, all kinds of reasons why they are not yet used and therefore also cannot or we don't want to use them also not in the insect feed (I6).*
• *One is the possibility that it contains meat in it and that is not allowed at this moment. So that is pure legislation, and pod. The contamination and that's one of the biggest problem. (I5)*
• *But I think generally in Europe, you do not allow to use food waste to feed for for animals. As I know, in China and Japan, especially in Japan, I think 70% of their food waste go to the pig. This also happens for pig in China before the African swine fever. But in in Netherlands, I think is not allowed to use food waste, as feed. Maybe if the legislation change you can use it in ways for insects, and that insect can go to food.*
Barriers

- *I think first we need to get the law to be more open. So, we can use more proper waste stream as feed for insects, so that there is no competition between insects and the animal about the feed (I7)*
- *I also think that market barriers, financial and, like, demands barriers for the product (I3)*
- *One is the possibility that it contains meat in it and that is not allowed at this moment. So that is pure legislation, and pod. The contamination and that's one of the biggest problem (I5)*
- *if you work with waste streams, pre consumer waste drinks from supermarkets, for example, the quality and the composition of the waste stream will be different every day. (I4)*
- *don't forget that on the operational side, so for black soldier fly, you need quite some investments (I3)*
- *I think the investments should be billions. So guess there's more focus on centralized, but it's still nothing. I So it's just logic,we'll reach the conclusion that is just a massive industry. (I8)*
- *there are some logistic barriers. How do we get the big pre consumer waste stream from the supermarkets from 10 Different supermarkets to our facility? How do we collect them? And it's, it seems like a small problem, but it is quite challenging. (I4)*

Strategies

- *But what you see also in Africa, , there they have public toilets, where under the toilet the waste streams cinsects can grown. And that is fed to the cattle they have. So that means that they have the grains they grow, they don't have to fed to the cattle, but that they can be fed to the people themselves. There are whole new streams I think we have to work on. The long term for manure, slurry, all the waste streams, we really need to research a lot how they can be used, because that is the future.I see insect rearing as manure management* (I5).
- *I think it all start with product design. So at the bottom of that you have product design (I5)*
- *Is Netheralnds the smartest place to start rearing insects? Well, from some aspects, maybe not, because a lot of streams are used already here. And side streams are in general, quite expensive (I7)*
- *But when you speak about the change you make, I think then the change is the largest at the end of the chain, because those products are usually harnessed to upgrade. So I think there is where the impacts comes like the highest impact. (I3)*
- *I think when it is allowed to process or to feed food waste to insects, then you need an organization who maintains the overview and who guarantees the safety of the whole food waste that is collected and measures for example, on heavy metal contamination I4)*
- *the feed streams, for the insects, I think we would almost need like a new set up system in which the food waste, for example, from households, So that we would get collection points actually, of food waste. Both from like, from companies, manage it own companies, from restaurants, and from households (I3)*

Table 2B Overview core findings and quotes interviews