Insect feed for future

– Perceived pros and cons of insects as feed in Swedish conditions

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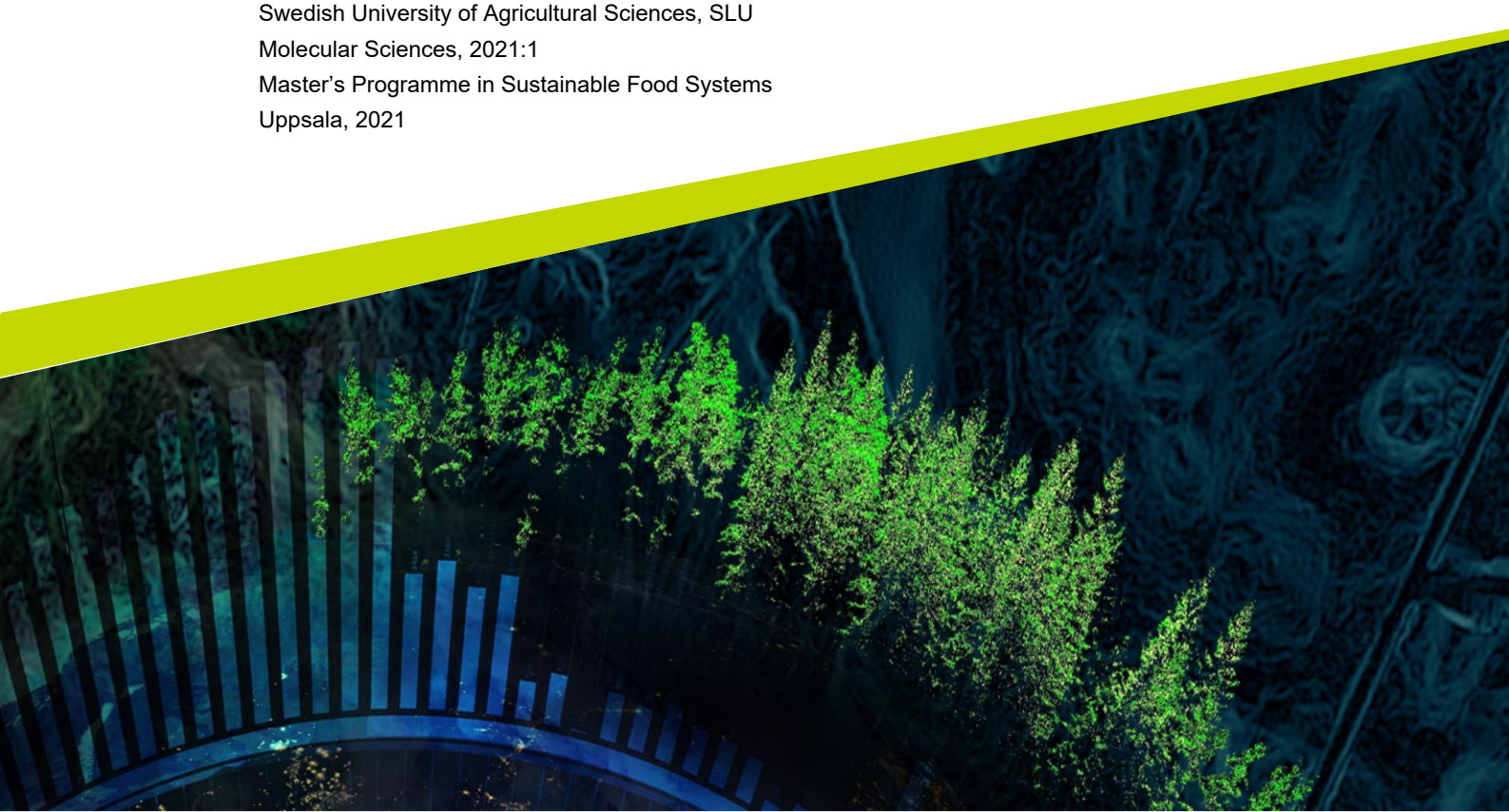

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Summary

A current challenge that Sweden is handling is the amount of food loss and food waste. One way to reuse food waste efficiently is to convert it to feed for insects. Studies have shown that insects such as black soldier flies (Hermetia illucens) and yellow mealworms (Tenebrio militor) are the most promising insects to be used as feed, since they can be provided food waste. Furthermore, these insects have a high protein and amino acid content, which can compete with conventional feed. However, one challenge is the legislation, which does not allow food waste to be given to production animals, including insects.

This study aimed to identify factors that affect the development of using insects as feed in poultry and pig production in Sweden. A flexible research design was used in this study, where both qualitative and quantitative data were used. An exploratory case study as a method with an abductive approach was furthermore the method choice of this study. The data gathering consisted essentially of semi-structured interviews and, secondarily, a survey. The survey was carried to collect hints of attitudes and opinions about insects as feed among potential consumers.

The results showed that most of the respondents from the interviews were optimistic about transforming insects into a feed. It can possibly reduce the environmental impact connected to soy and fishmeal. The insects, black soldier fly and yellow mealworm were considered to take waste managers' role. Still, caution should be taken as to which substrate to use as feed for the insects. There were also split opinions between researchers about whether the black soldier fly or yellow mealworm is the best option for being transformed into a feed. There are concerns about using black soldier fly because it is not a domestic species. Furthermore, yellow mealworms might not be viewed as waste managers depending on how food waste is defined. Other concerns are that it will be challenging to identify and eliminate virus outbreaks from a circular system. Therefore, an essential characteristic of insects is that they function as a species barrier. The results made it clear that feed is rarely discussed in politics. Interest is required from politicians for this to end up on the political agenda. Furthermore, a large-scale production with an automated system is needed to lower the cost.

The conclusions from this study are that stakeholders are optimistic about insects as feed. Environmental and social benefits, such as reduced food waste and insects' being a species barrier. Previous studies and our study show that it is mainly preferred to provide insects as feed for fish and poultry as they are part of their natural diet. Since population growth and increased prosperity are on the horizon, and poultry is prospected to be highly demanded, it can be beneficial to invest in poultry production to release pressure on future generations.

Sammanfattning

En aktuell utmaning i Sverige är den stora mängden matavfall. Ett sätt att återanvända matavfall är att göra det till foder för insekter och studier har visat att svarta soldatflugor och mjölmask är de mest lovande insekterna för detta. De kan födas upp på matavfall och har som foder en hög halt av protein- och aminosyror, som kan konkurrera med konventionellt foder. En utmaning är dock det lagmässiga, som för närvarande inte tillåter att matavfall ges till produktionsdjur, där även insekter ingår.

Syftet med studien var att identifiera faktorer som påverkar en övergång till användning av insekter som foder i fjäderfä och grisproduktion i Sverige. En flexibel forskningsdesign användes i denna studie som innebär att både kvalitativa och kvantitativa data användes. Datainsamlingen bestod främst av semistrukturerade intervjuer, med intressenter som representerar organisationer som kan påverka utvecklingen av nya lagar rörande foder. Därtill genomfördes även en enkätundersökning för att få indikationer om attityder och åsikter om insekter som foder av potentiella konsumenter.

Majoriteten av intressenterna var positiva till att använda insekter som foder eftersom det potentiellt kan minska miljöpåverkan jämfört med soja och fiskmjöl. Insekterna svart soldatfluga och mjölmask ansågs vara lämpliga för att omvända matavfall till högvärdigt protein, men att försiktighet bör beaktas till vilket substrat de föds upp på, då man vill förhindra spridning av zoonotiska smittor. Det rådde även delade meningar hos forskarna om vilken av svart soldatfluga och mjölmask som är det bästa alternativet för ändamålet. Det finns oro för att använda svart soldatfluga, eftersom det inte är en inhemsk art, och vissa forskare anser att de kan bli invasiva. Mjölmask kan i vissa avseenden inte anses vara en avfallshanterare, eftersom vissa forskare anser att de kan äta substrat som skulle kunna ätas av människor, men detta beror dock på hur matavfall definieras. Annan oro som upptäckts i denna studie är risker för virusutbrott, som kommer vara svåra att identifiera och eliminera i ett cirkulärt system. Därför är en viktig egenskap hos insekter att de fungerar som en artbarriär. Empirin synliggjorde även att foder är något som sällan talas om inom politiken och att intresse krävs hos politiker för att frågan ska hamna på den politiska agendan. En ekonomisk analys pekar på att det skulle krävas en storskalig produktion med ett automatiserat system för att kostnaden ska reduceras och industrin bli lönsam.

Slutsatserna från denna studie är att intressenter är främst positiva till insekter som foder. Det finns miljömässiga och sociala fördelar, såsom minskat matavfall och att insekter kan fungera som en smittbarriär. Tidigare studier och vår studie visar på att det främst är eftertraktat att ge insekter som foder till fisk och fjäderfä eftersom det är deras naturliga föda. Eftersom befolkningstillväxten och ökat välstånd förväntas i framtiden samt att fjäderfä förväntas bli efterfrågat till en större grad, kan det vara fördelaktigt att investera i fjäderfäproduktionen för att minska trycket på de kommande generationerna.

Abbreviations

BSE	-	Bovine Spongiform Encephalopathy (mad cow disease)
BSF	-	Black Soldier Fly
CE	-	Circular Economy
CJD	-	Creutzfeldt-Jakob Disease
EU	-	European Union
GHG	-	Greenhouse gases
SDG	-	Sustainable Development Goals
TSE	-	Transmissible Spongiform Encephalopathies

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1. Introduction

Chapter one describes significant sustainability challenges for food systems and production. Focus is placed on food waste and alternative ways to use insects in animal feed. Based on the problem background, the aim and research questions follow. The chapter concludes with a presentation of the structure of the study's project report.

Natural resources need to stay within the planetary boundaries to ensure a healthy future on this planet for current and future populations (Rockström *et al.*, 2015, 137). There are nine planetary boundaries: climate change, freshwater consumption, land-use changes, stratospheric ozone depletion, biodiversity loss, nitrogen and phosphorus pollution, chemical pollution, ocean acidification, and lastly, air pollution or aerosol loading (Rockström *et al.*, 2015, 67). Maintaining and operating within the planetary boundaries will maintain economic growth and prosperity for humans (Rockström, 2015, 59). Nevertheless, humans have caused negative impacts on natural resources, which have led to undesired effects on social welfare and economies worldwide (Rockström, 2015, 62). The agricultural sector is affecting several of the boundaries, contributing to unsustainable earth (Campbell *et al.*, 2017). There are two boundaries already transgressed: the loss of biodiversity and nitrogen and phosphorus pollution. Furthermore, three boundaries are at increased risk of being exceeded: land-system change, freshwater use, and climate change (*ibid.*).

Agriculture production is one of the significant causes of greenhouse gas (**GHG**) emissions and a considerable threat to biodiversity (Rockström *et al.*, 2015, 135; van Huis & Oonincx, 2017). Rockström *et al.* (2015, 135) has stated that the world's population can be fed from the current agricultural land used if the resources are used efficiently. It is predicted to be around nine to ten billion people on the planet until 2050, which will lead to an increased demand for food. There has been a strong correlation between increased prosperity and increased demand for animal products, and the prediction is that the increased demand can be one cause of trespassing the earth's threshold (FAO, 2009, 4; Rockström *et al.*, 2015, 184; van Huis & Oonincx, 2017). Innovation within the agricultural sector is needed to feed the world's population in the future (*ibid.*).

In 2015, all United Nations members signed the United Nations 17 Sustainable Development Goals (**SDGs**) for a more sustainable future (UN, *n.d.*). According to the Brundtland Report, sustainable development is: "*... development that meets the needs of the present without compromising the ability of future generations to meet*

their own needs" (Brundtland, 1987, 41). The 17 SDG are guidelines to meet the world population's needs today while not compromising future populations' needs (UN, n.d.). Thus, the 17 SDG want to attain security and establish peace worldwide, and the goals are interlinked with each other (UN, *n.d.*). However, actions and collaborations will be needed from both industrialized and developing countries to achieve these goals (*ibid.*). The 12th SDG stands for more sustainable and responsible consumption and production throughout the supply chain (FAO, 2020a). The economy thrives on increased consumption and production globally; meanwhile, the consequence is that natural resources are unsustainably used. This leads to, *e.g.*, biodiversity loss, climate change, and scarcity in essential resources like freshwater (*ibid.*). A sub-goal within the 12th SDG is 12.3, which addresses food waste.

"*By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"* (FAO, 2020b).

Globally, more than one-third of the food is being wasted or lost, while there are still more than 690 million people that live in hunger and are malnourished (FAO, 2011, 4). According to the FAO (2020c), people need to be guided into diet and consumption behavior changes to reach a safer and more nutritious diet that has a much lower environmental impact on meeting the future population's needs. According to Dicke (2018), the sustainable development goal 12.3 is closely linked to a circular economy system. Two components are included in this goal; food waste and food loss as can be seen in Figure 1.

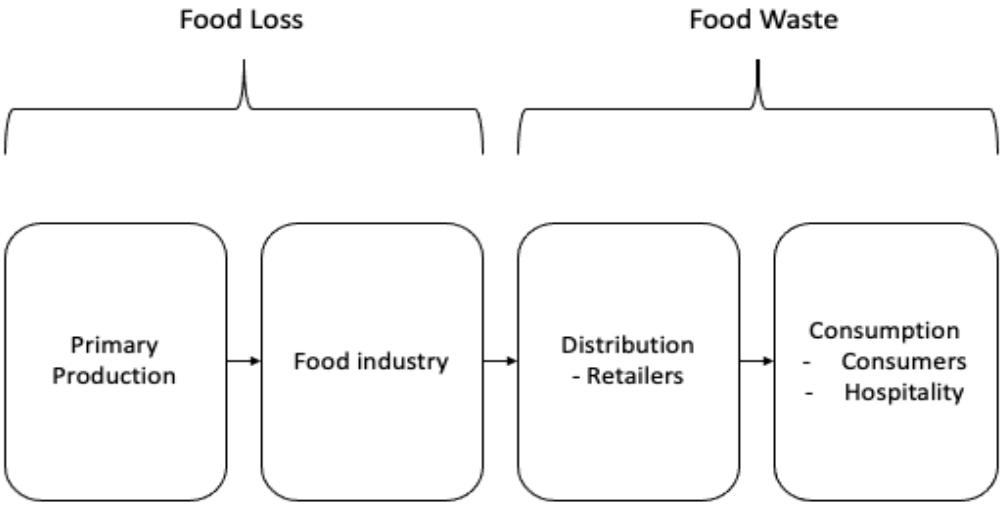

Figure 1. Stages where food waste and food loss occur, inspired by Ojha et al. (2020, 601), with modifications

Figure 1 presents the difference between these two concepts is that food waste occurs at the consumption and retail level due to overstocking, food not being valued enough, and thereby thrown away at the final destination (FAO, 2009; Ojha *et al.*, 2020). On the other hand, food loss occurs from stages before consumer and retail stages, *e.g.*, primary production and distribution, due to lack of storage, early harvest, *etcetera* (FAO, 2020b). It is critical to address both food loss and food waste during all stages since it can ensure food security, increase income, and reduce hunger and malnourishment, particularly in developing countries (FAO, 2011, 1). Furthermore, food losses and food wastes impact the environment, food quality, and the economy worldwide (*ibid*.).

1.1 Problem background

A system with sustainable food supply and demand is associated with several challenges (van Huis, 2015). Besides food loss and food waste, a few challenges are related to resource management, *e.g.*, feeding a growing population without depleting resources; climate change; eutrophication; and identified wealth distribution. These challenges are far from resolved (*ibid.*). One current challenge that Sweden tackles is food waste (The Swedish Environmental Protection Agency, 2020a). One way to reuse the resources efficiently is to use food waste and food loss that humans cannot eat as feed (The Swedish Board of Agriculture, 2020, 6;17-18). Resource efficiency means that industries use current limited resources in a sustainable way to minimize the industry's environmental impact (*ibid.*).

From a resource perspective, it is essential to reduce food waste throughout the supply chain and take advantage of the resources in an efficient way that comes up in the food supply chain (Swedish Board of Agriculture, 2020, 1). The preferred levels to reach are shown in Figure 2 (*ibid.*).

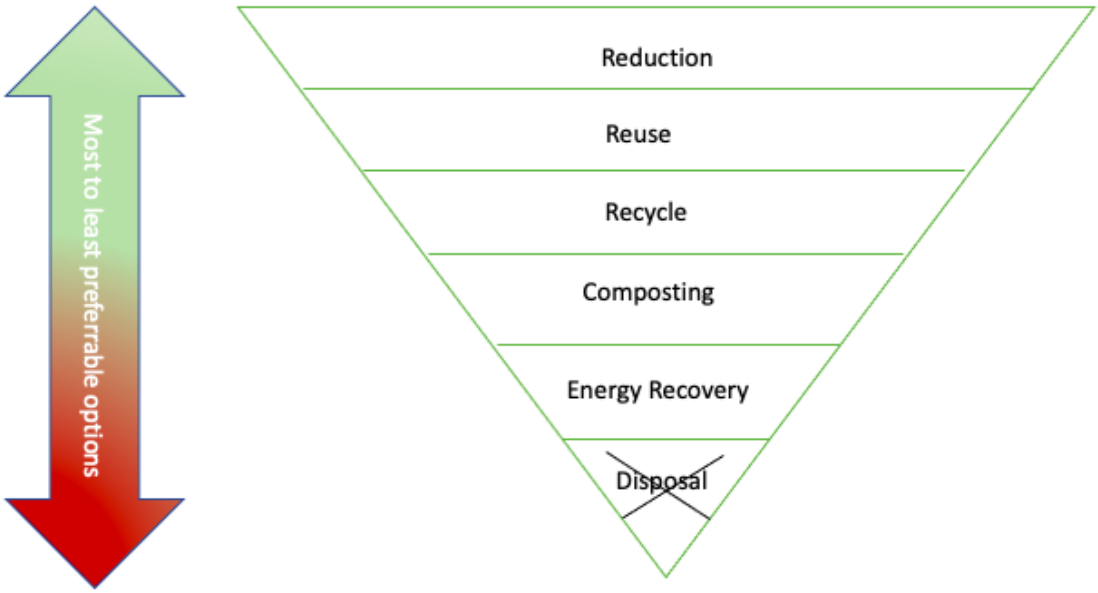

Figure 2. Waste hierarchy based on The Swedish Board of Agriculture (2020, 6), modified to this study and Swedish condition.

The waste hierarchy above consists of five levels and has the most to least preferred actions. The aim is to reach the reduction stage, which is at the top of the waste hierarchy. If this is not possible, one should strive to reach the highest stage possible in the hierarchy (The Swedish Board of Agriculture, 2020, 6). The chosen action should be defensible, both environmentally and in terms of resources (*ibid.*) According to the Swedish Environmental Protection Agency (2020b), the disposal of organic wastes is prohibited in Sweden, and therefore it is not included in the waste hierarchy above. According to the waste hierarchy, it is crucial to prevent food waste at all stages in the food supply chain to reach the top. A behavior change is required to reach the top level of the waste hierarchy (Ojha *et al.*, 2020). The Swedish Board of Agriculture (2020, 7) states that the waste hierarchy can be used as a foundation for a strategy to reduce food waste and as guidance for communication about these efforts. However, it is essential to remember that the waste hierarchy cannot be applied in every industry or suitable for every occasion (*ibid.*).

Awareness among policymakers, producers, and consumers is required to meet the increasing demand for food and feed for future populations. In return, awareness needs to be applied to actions and policies to ensure adequate food and feed for the existing and future world population (FAO, 2009, 4). New legislation and transparency from the government have an essential role in supporting innovations

for crops provided to the increased demand while still being nutritious (Rockström *et al.*, 2015, 137). Sweden is bound to follow EU-regulations. Thus, the legislation and context can appear different between different member states.

The EU regulation 1069/2009 Article 11 prohibits food waste from consumers and retailers to be given as feed because of health risks. The Public Health Agency and other authorities in Sweden are responsible for human health and zoonoses prevention (Public Health Agency of Sweden, 2020). Zoonoses are infectious diseases transmitted between animals and humans. Over 200 existing, changed, or new types of zoonoses can cause outbreaks in the world. Zoonoses stand for 60% of the global outbreaks and can be spread quickly between countries (Public Health Agency of Sweden, 2020; WHO, 2020a). Some of the more known types of zoonoses are Ebola and rabies (WHO, 2020a). There are indications that the current pandemic, COVID-19, is a novel disease derived from zoonoses (WHO, 2020b). Climate change is a significant driver for zoonotic diseases' development and proliferation (Public Health Agency of Sweden, 2020). Other causes that can enhance the risks of zoonotic outbreaks are animal transports, changes in animal production, and wildlife (*ibid.*).

Currently, the protein feed of monogastric animals in Sweden includes fishmeal and soy to a varying extent, which can be consumed by humans (FAO, 2011, 105; Muscat *et al.*, 2020; van Huis & Oonincx, 2017). To use soy in feed leads to deforestation; moreover, both soy and fishmeal leads to biodiversity loss and increases the emissions of CO_2. Without any changes, all the problems will worsen (van Zanten *et al.*, 2014). However, the benefits of soy and fishmeal are the high content of amino acids, such as methionine and lysine (Spörndly *et al.*, 2019). One measure to reduce environmental impact from the current feed is using low environmental impact feed in poultry, fish, or pigs (van Huis & Oonincx, 2017). Industries have started considering using insects as a food waste manager to reduce pressure on the environment (Stamer, 2015; van Huis & Oonincx, 2017). Insects as feed and food are more common in the developing world, especially in tropical countries (van Huis, 2015). Currently, there are more than 2000 edible insects around the world (*ibid.*). Different production methods can produce insects, *e.g.*, semi harvesting, and industrial production (*ibid.*). Insects need to be reared in large-scale production to promote insects in the market (*ibid.*). However, populations in industrialized countries are reluctant to have insects as food or feed, even if they are aware of the benefits (*ibid.*). The most common reason is that it is not culturally accepted and can relate to neophobia, which is the fear of trying novel food (*ibid.*).

Axfoundation has a project regarding the possibility to use insects as feed to locally grow salmons to develop a circular system. Insects have been fed with pre-consumer food waste to reduce food waste in Sweden (Pers.com., Hanssen, 2020).

The project had positive results; therefore, Axfoundation has expressed interest in similar poultry and pigs' initiatives.

1.2 Problem statement

Currently, some livestock in Sweden is fed with soy and fishmeal to a varying extent, which often is imported. Sweden strives to manage food loss and pre-consumer food waste, where 235 000 tons of food were lost and wasted from the agriculture, food industry, and retailers in 2018 (The Swedish Environmental Protection Agency, 2020c, 3). This is equivalent to 24 kg are wasted per person (*ibid.*), and one solution to reuse it efficiently is by nourishing insects with food waste (The Swedish Board of Agriculture, 2020, 6;17-18). Food wastes from consumer stage were not included in this study. Studies have stated that insects such as black soldier fly (**BSF**), *Hermetia illucens,* and yellow mealworm, *Tenebrio militor,* are the most promising types of insects to rear in a large-scale industry (Ojha *et al*., 2020). This is due to their qualities, such as a largemouth to masticating food, soft bodies to move through various substrates, be nourished on food waste, and turn it into high-quality products (*ibid.*).

Furthermore, their protein content can compete with conventional feed (van Zanten *et al.*, 2014; Moon & Lee, 2015). However, there has been insufficient research about the willingness and reactions to give insect feed to livestock from different stakeholders (Verbeke *et al.*, 2015). Lacking research can explain cultural barriers to insects in food systems (van Huis, 2015) in industrialized countries. As Sweden is an industrialized country, it is essential to investigate if various stakeholders are reluctant in Sweden. If there is no acceptance from various stakeholders, farmers might be reluctant to feed their livestock as it will not survive in the market (*ibid.*). New stakeholders within this new sector will be needed, and also system changes are required to manage and decrease the risks that come with this type of industry (van Huis & Oonincx, 2017).

1.3 Aim and research questions

This study aims to identify factors that influence the development of extended use of insects in animal feed. Animal production of interest in Sweden is poultry and pig because they are omnivores, and insects are considered their natural diet. Financial, environmental, and social aspects are permeated throughout the study, including stakeholder attitudes, legislation, and market factors. The aim has led to the research question below:

- *What are the stakeholders´ perceptions of using insects in feed for pigs and poultry production?*
- *What are the key aspects that influence the implementation of using insects in feed for pigs and poultry?*

The aim and the research question were the foundation of the interview guide and survey questions, with chosen critical stakeholders in this study. Furthermore, the process and development of this study are presented in the next paragraph.

1.4 Outline

This section outlines the study and processes to provide an overview for the reader, illustrated in Figure 3 below.

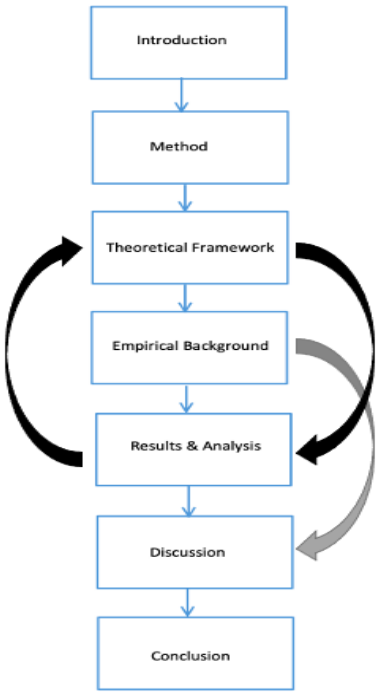

Figure 3. A presentation of the outline and the process of the development of this study, where theoretical framework and results and analysis where intertwined, and empirical background used as a basis for the discussion.

Figure 3 provides an overview of the study's structure, where the study started with an introduction (chapter 1). It included a description of the background, problem area, aim, and research questions. In chapter 2, the flexible research design and chosen methodology, case study, are presented, including data collection, content analysis, and quality assurance. The theoretical framework is presented in chapter 3, where four chosen theories are presented, which also will be integrated in the

results and analysis chapter. This is followed by a conceptual framework where the four theories' critical components were presented in a table to analyze the data. The empirical background derived of previous studies is found in chapter 4, with bovine spongiform encephalopathic, legislation, perceived drawbacks, and benefits with BSF and yellow mealworm followed by acceptance toward insects as feed. The results and analysis of this study will be presented in chapter 5, where the results will be analyzed with the conceptual framework's help. A discussion is conducted in chapter 6, where our analysis is compared to the empirical background. Lastly, conclusions reconnected to the study's aim, and further studies are found in chapter 7.

2. Method

This section presents the chosen research design and the chosen method, a case study. The case study method is based on multiple ways of collecting data, which presents an all-around portrayal of the contemporary context for food and feed dialogues. Furthermore, data collecting techniques and analytical methods are presented, leading to the results. The section ends with a reflection of the chosen methods, including quality assurance of the research process.

2.1 Flexible research design and Case Study

A flexible research design was used in this project since data collection could not be thoroughly planned. Data collection was made in a continuous learning process with ambitions to create qualitative data that serve as a contemporary representation of current views and understandings of a phenomenon that Robson (2011, 132) refers to as an iterative process, which can be seen in Figure 3. Case studies aim to investigate complex social structures of different variables, which can be presumed to understand the phenomenon, according to Merriam (1994, 47) and Robson and McCartan (2016, 37). There are several definitions of what a case study embodies, but the decision was to follow the definition by Yin (2009, 2):

> *A case study is a research strategy that includes an empirical investigation of a particular contemporary case within its real-life context using multiple data sources.*

A case study as a method focuses on cases where researchers want to investigate questions; *how* or *why* events occur instead of *who* and *where* (Yin, 2009, 2). Furthermore, the case was something contemporary and something we had no control over, making the case study a suitable method to use. The case study's orientation was exploratory since there is not much knowledge about the case in the Swedish context. Therefore, we also decided to apply abductive reasoning in the study, which is a process where we alternated between our theories and results, according to Robson and McCartan (2016, 37).

This study's case is on perceptions and understandings of insects' use as feed within animal production. In the continuous analysis, data were divided into categories,

which lead to further division into subcategories of factors that influence the understanding of using insects in the feed.

2.2 Literature review

A literature review was made continuously through the process. According to Robson and McCartan (2016, 52) a literature review is a guide to find relevant literature to the study, identify trends and gaps of the area of interest, and to contribute to that area. The literature in this study was found searching in Google Scholar, through the SLU library and suggestions from Axfoundation, the supervisors and respondents. The literature review consists only of peer-reviewed articles, as they are trustworthy. Since this subject appear to be trending, there are new research constantly published. The most recent research if from December 2020, and all relevant literature for this study is presented in chapter 4, empirical background.

2.3 Choice of case and unit of analysis

As previously mentioned in the aim, the case study was chosen for this study due to investigate: *why the* implementation of insects as feed can be complicated, *how* perceptions of insects as feed can differ, and *what* insects are preferable to use in a large-scale setting. Furthermore, a survey was conducted to understand the attitude regarding insects as feed among consumers. As this study's case is on perceptions and understandings of insects' use as feed within animal production, we managed this as one case but including two different insect species.

We collaborated with Axfoundation who wanted a general overview and a broad perspective and investigate the possibilities to implement insects as feed for poultry and pigs in Sweden, and therefore the case was in the context of Sweden. Pigs and poultry were two species of interest to examine whether BSF and yellow mealworms can be used as feed. Poultries and pigs were chosen since they are omnivores, and BSF and yellow mealworms are the most promising insects to rear as feed and achieve a circular system with food waste due to their versatile qualities (Ojha *et al.*, 2020).

2.3.1 Data collection

This study consisted of data collected mainly through interviews. Based on the stakeholder theory (chapter 3.1.1) we identified some stakeholders which were relevant for the development in the industry. Based on Figure 4, we contacted authorities, customers, business partners and external influencers, which can be seen in Table 1. The data collection of authorities, business partners and external influencers were conducted through interviews, and customers by a survey. The interviews were semi-structured since we wanted to ask additional questions depending on the direction of the discussion. During the interviews, we, together with the respondents, identified critical stakeholders and due to the snowball effect interviewed several of the critical stakeholders. The objectives for the interview guide were to: find out which critical stakeholders is needed for the industry; the environmental, social, or financial benefits with BSF and yellow mealworm compared with current feed; the risk of large-scale production of BSF and yellow mealworm; nutritional value of BSF and yellow mealworm; what substrate BSF and yellow mealworm possibly could have. Furthermore, the interview guide was intertwined and based on the theoretical framework to answer the research questions. At the end of each interview, we asked if the respondent could recommend any relevant contacts for the study. Respondents were chosen based on their occupations, and interviews were foremost chosen to get in-depth knowledge about the case and its complexity. Since it was Swedish stakeholders, the interviews were held in Swedish, and the interview guide can be found in Appendix I.

We allowed a physical meeting, as it is preferable to have face-face interviews in qualitative research not to miss reactions. It was up to the respondents if they wanted to meet in person or not, but since the world is in a pandemic, we decided not to risk physical meetings with all respondents. Instead, we had most video call meetings on Zoom; one interview was held through a phone call, one through email, and two physical meetings. Two respondents requested a physical face-face meeting, and since we took precautions, we decided to agree on a face-face meeting (Table 1).

Table 1. Overview of respondents including the profession linked to stakeholder theory, name, role and what form of interview

Profession	Respondent	Role	Form
Farmer (business partners)	Jeanette Elander	President of Sveriges Grisföretagare	Zoom
Industry (business partners)	Nils Österström	CEO and Co-founder of Tebrito	Phone
Industry (business partners)	Åsa M Carlsson	Product manager at Svenska Foder	Mail
Industry (business partners)	Malin Alm	Project manager at Vreta Kluster	Zoom
Industry (business partners)	Anita Pettersson & Maria Malmström	Head of feed, and manager of production at Swedish Agro	Zoom
Industry (business partners)	Jessica Schenk & James Bonet	Feed and infection control administrator & infection control administrator at the Swedish Board of Agriculture	Zoom
Industry (business partners)	Olof Persson	Head of department for consulting / entrepreneurship in Växa	Zoom
Politician (authorities)	David Ling	Spokesperson in youth wing of Green Party	Zoom
Politician (authorities)	Isak Öhrlund	National board member of SSU	Personal meeting
Politician (authorities)	Lorentz Tovatt	Member of Parliament for the Green Party	Personal meeting
Researcher (external influencer)	Åsa Berggren	SLU Professor	Zoom
Researcher (external influencer)	Anna Jansson	SLU Professor	Zoom
Researcher (external influencer)	Björn Vinnerås	SLU Professor	Zoom
Researcher (external influencer)	Emma Ivarsson	SLU Senior Lecturer	Zoom
Researcher (external influencer)	Ivar Vågsholm	SLU Professor	Zoom
Researcher (external influencer)	Cecilia Lalander	SLU Scientist	Zoom

In Table 1, stakeholders are arranged from top to bottom, depending on their occupations. The interviews were held from 8/10-2020 until the 13/11-2020. The respondents were added gradually due to the snowball effect (Robson & McCartan, 2016, 160), where the respondents were asked to recommend other people who could be relevant for the study.

Besides, a survey was conducted and sent out via Google Forms 14/10-2020, which were sent out on LinkedIn and Facebook. Furthermore, the survey was limited to people living in Sweden at a minimum 18-year-old, since at that age, they are considered adults in Sweden and can make their own decisions. The survey was conducted in English to reach also non-Swedish speaking people in Sweden. A mix of qualitative and quantitative questions (Appendix II) aimed at consumer attitudes towards eating insects directly or as feed for animals.

2.3.2 Content analysis

A content analysis was the secondary method, where categories of the results were made to identify different respondents' themes by the patterns of words used according to Vaismoradi *et al.* (2013). Identify the themes; interviews were recorded, transcribed, and printed to seek patterns of words and meanings. The categories are presented in the results, where an analysis is ongoing throughout chapter 5. As we had a flexible research design, the categories were not pre-set but made simultaneously as the content was processed. Therefore, it created the categories of alternating between the data and analysis, referred to as an iterative process (Robson & McCartan, 2016, 501). The content in a category must be homogenous, and between the categories, it needs to be heterogeneous, which means that there is a clear difference between the categories (Merriam, 1994, 146-147; Robson & McCartan, 2016, 355). Furthermore, the survey's answers were processed and placed in separate categories with a presentation from the results in the form of figures and a generic description of the respondents

2.3.3 Quality assurance and ethical considerations

Research quality is established at every step of the research process, according to Robson & McCartan (2016, 170). Therefore, to establish research quality, we have actively aimed toward having a dense empirical image, as shown in Table 2. We collected and analyzed the data together. A summary of the interview was sent on 21/12-2020 to the respondents after we categorized their answers to receive validation, suggested by Robson & McCartan (2016, 172). Respondents received a GDPR-form to ensure informed consent and research in line with the legislation, saying that the respondents could withdraw the participation at any time. Furthermore, we wanted to establish triangulation in data, observation, methodology, and theory to avoid threats toward validation.

Table 2. Overview of how to reach triangulation and how we met these criteria. Criteria of triangulation inspired by Robson & McCartan (2016, 171)

Type of triangulation	How to reach triangulation	Choices took in our study
Data	Methods to collect data	Interviews, read legislation & reports
		Survey
Observation	Have more than one observer in the project	Had two authors for the interviews and analysis
Methodology	Use of qualitative data	Case-study, content analysis
	Use of quantitative data	Survey
Theory	Use various theories or perspectives	Stakeholder theory & Multi-level perspective
		Cradle-cradle & Circular economy

In Table 2, the different types of triangulation are presented in the left column, which consists of data, observation, methodology and theory to enhance the accuracy of the study. The middle column in the table presents what criteria are needed to achieve triangulation within the different types. To achieve triangulation within data, more than one method of data collection ought to be used according to Robson & McCartan (2016, 171), where we did interviews, a survey, read reports and legislation. To achieve observation triangulation, we were two authors during all interviews and throughout the process. Furthermore, we had flexible research design which consisted of both qualitative and quantitative data which is required to achieve triangulation of methodology (*ibid.*). Four theories were chosen to reach triangulation within theory to use several perspectives (*ibid.*).

2.4 Method reflection

The advantages of using a case study are that the data will be concrete and more vivid instead of theoretical. The data will be based on interviews and the respondents' experience of a contemporary case. Furthermore, the respondents' experience reflects the contextual situation since the case may not be the same if changing the context, which makes generalization hard to achieve (Merriam, 1994, 28-29). However, the different contextual situation might lead to a broader understanding of the case, since experiences of various perspectives and insight might lead to additional information of the case (Merriam, 1994, 28-29). Furthermore, case studies are an excellent method to use when seeking a perspective on the case from different groups, since the researchers decide the groups, which is not the case for traditional science (Merriam, 1994, 28-29). We decided to identify and interview a few critical stakeholders for this case, which all might have different agenda and biases for the use of insects. We as interviewers decided not to interfere, since we wanted to avoid steering the interview towards a certain direction.

When using the survey to gather data, it is good to know that the respondent will reflect the data. Different experience, knowledge, and personality can give different outcomes on a survey (Robson, 2011, 240). Other aspects to consider are the attitudes and beliefs, and that respondents often want to be seen in a good light and can give answers which might not reflect their reality (Robson, 2011, 240). We sent out the surveys, and by doing this, there is a risk of getting a low rate of responses, respondents not taking the survey seriously, and a misunderstanding that was not detected. By having a pilot study with colleagues' and supervisors' feedback, we tried to reduce the risk of a misunderstanding. Also, there were two questions at the start of the survey asking if the respondent lives in Sweden and is over 18 years old, to eliminate answers from other countries, where insects might be more acceptable, and people who do not usually buy groceries. If some respondents answered that they did not live in Sweden or were under 18 years old, they could not continue the survey. By spreading the survey within our network, there was a possibility to spread the survey to a broader network, which is usually called the snowball effect (Robson & McCartan, 2016, 160).

Furthermore, since we sent the survey through our network, the possibility of generalizing the Swedish population got lost. However, the answers were mainly used as an indication and suggestions for future studies. With the survey, it was easier to visualize data. It was a straightforward way to gather many answers about attitudes and got generalizable answers and can be an efficient way to gather data for a low cost in a short period (Robson, 2011, 241).

3. Theoretical framework

In this chapter, four frameworks are presented, starting with Stakeholder Theory and Multi-Level Perspective, followed by the concept of Cradle to Cradle, and lastly, the concept of Circular economy. These concepts and models analyze institutional conditions for a transition in practices as part of a circular economy.

3.1 Stakeholder Theory and Multi-Level Perspective

3.1.1 Stakeholder Theory

The stakeholder theory is being discussed by Freeman (1984) in his book "*Strategic management: A Stakeholder Approach*." Freeman (1984) explains that an organization or industry needs to take both primary and secondary stakeholders into account, affecting, or being affected by the company or industries. According to Freeman (Freeman *et al.,* 2018, 16), a company or industry must include all stakeholder groups, whether they are primary or secondary stakeholders. Primary stakeholders can affect the company or industrial decisions and create value, such as venture capitalists, employees, consumers, *etcetera* (*ibid.*). Secondary stakeholders are "influencers" because they do not create a direct value in a company or industry, but they are interested in the management. Some secondary stakeholders are competitors, media, and non-governmental organizations (Freeman *et al.,* 2018, 17).

Large numbers of well-established companies are currently aware that their reputations and costs are being affected by managing their sustainability issues. These issues include components that are not in the company's direct control, such as social and environmental impacts resulting from their network (Roberts, 2003). Often, the reputation is defined by opinions from companies' stakeholders that have a direct interest in the company. By having a good reputation, companies can develop a strategy that can be very advantageous for them in the market (*ibid.*). Furthermore, Roberts (2003) introduced a new way of thinking regarding the stakeholder theory. Roberts (2003) divided the stakeholders into four categories, and within each category, there are examples of whom these stakeholders are (Figure 4).

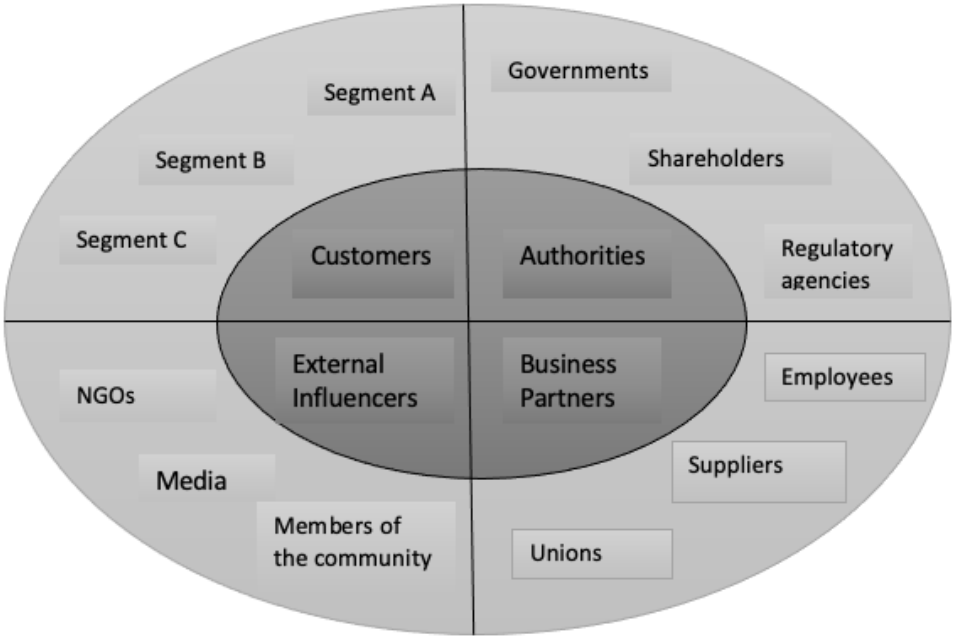

Figure 4. An explanation of the stakeholder theory according to Roberts (2003, 162), with minor modification. The dark gray color illustrates categories within the stakeholder theory and the light gray color illustrates examples of stakeholders within each category.

The stakeholder roles illustrated in Figure 4 are further presented considering this study context. The first stakeholder category is authorities. The authorities should monitor companies' performances and permit companies to operate (Roberts, 2003). Some examples of authorities are government, municipalities, regulatory agencies, a board of directors, *etcetera*. They all have a vast interest in companies and their management (*ibid.*). The second category is business partners. Without these stakeholders, companies would not be able to operate and to survive on the market. The stakeholders in this category are suppliers, unions, employees, *etcetera*. The third category in the stakeholder theory is external influencers, and these are, *e.g.*, NGOs, journalists, and community members. These organizations often have an interest in companies that can influence others in society. This group has a significant impact on corporate management. The fourth and last category is customers. Customers can be divided into several segments depending on their interest in the product/ service that the company provides and, therefore, can have different opinions on the company. Generally, when buying a product/ service, customers want to get a good feeling about it and that the product or service does not harm them, the environment, and the employees (*ibid.*).

How stakeholders are defined depends on which company or industry one is looking at (Escoubés, 1999). According to Escoubés (1999), if stakeholders are defined as having a direct interest in a company or industry, there must be an equal number of performance indicators as stakeholders within the organization and industry. A company or industry needs to; identify the stakeholders, select critical stakeholders for the company or industry, consult the stakeholders to evaluate each stakeholder wants and needs, and evaluate the stakeholders' compatibility with the companies or industries selected strategy to develop the necessary performance indicators. Performance indicators from different stakeholders could differ. Some stakeholders might have environmental performance indicators while other stakeholders might have operational and technical performance indicators (*ibid*.). Lastly, a company or industry needs to interpret information systems to meet the selected company or industry strategy (*ibid.*). This is shown in the figure below (Figure 5).

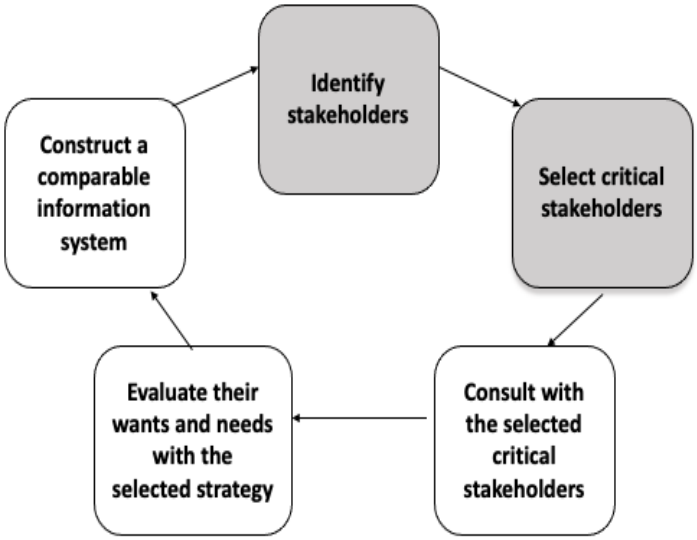

Figure 5. Essential steps to develop performance indicators, according to Escoubés (1999, 63), with minor modifications.

In this study, however, the first two steps were conducted as can be seen in Figure 5. First, we identified stakeholders which is needed for the development of this industry, *e.g.*, researchers (external influencers), politicians (authority), consumers (customers), suppliers (business partners). thereafter we selected critical stakeholder for this industry, which were foremost researchers. The third step 'consultation with a few selected critical stakeholders,' was initiated with the researchers. In the Swedish context, other relevant stakeholders within this industry are municipalities since they are responsible for waste management (Swedish

Waste Management and Recycling Association, 2020). Nevertheless, municipalities and other critical stakeholders were not consulted since the development is a long process. We only had data from the contemporary moment in the initial stages of the process. With stakeholder theory, companies and industries can understand and analyze how they, together with the stakeholders, can develop and exchange value between each other (Freeman, Harrison & Zyglidopoulos, 2018, 1). However, stakeholders will have different values for the company or industry. These values will depend on what the stakeholders believe are important goals for the company or industry to achieve (Escoubés, 1999). The companies and industries need to ensure that the stakeholders can trust each other and build a long-term relationship to get the most out of the stakeholders and create a fair and profitable company (Freeman *et al.*, 2018, 28; Roberts, 2003).

3.1.3 Multi-Level Perspective

The Multi-Level Perspective (**MLP**) theory conceptualizes patterns in a sociotechnical shift (Geels, 2011). MLP reflects a circular process where three heuristic and analytical levels interplay with each other. The three levels are Meso-level (landscape), Micro-level (regime), and lastly, Macro-level (niches - sustainability innovations) (Geels, 2005). In this study, the focus was on the micro-level, which includes technological niches. Usually, technological niches are considered as the starting point for radical innovation. Niches start within a sector where it is hard to change the predominant management, contributing to the novelty's low achievement (Geels, 2005).

Nevertheless, niches are highly valued by some stakeholders as it is a basis that creates processes of new learnings. The processes can arise on various levels: infrastructure, technology, production, regulations, *etcetera* (*ibid.*). As stated above, stakeholders value niches highly and often encourage niches in the hope of changing or removing the existing regime. There are barriers to overcome due to existing regimes being robust in many ways, *e.g.*, culturally, organizationally, institutionally, and economically. These barriers make it difficult for niches to penetrate the market (Geels, 2002; Geels, 2005).

Nevertheless, Geels (2005) believes that niches are essential for a chance to arise and new system innovations. Furthermore, innovation breakthroughs are dependent on the context which occurs from processes on both landscape and regime levels, which is linked with technological niches (Geels, 2002). Figure 6 below briefly shows how the interactions between the three levels are intertwined.

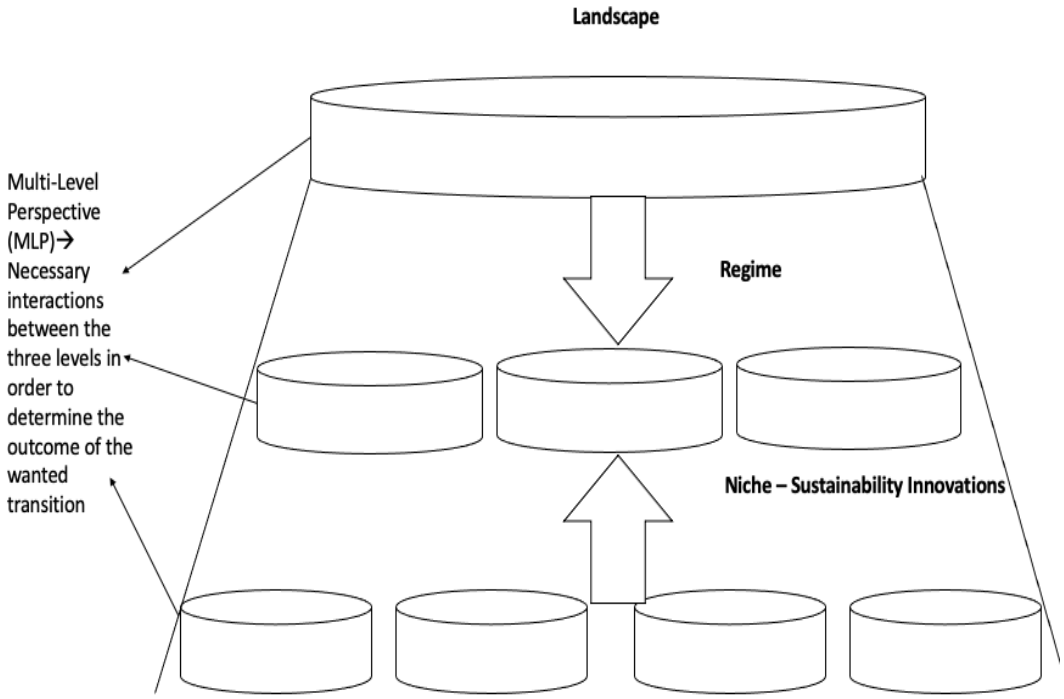

Figure 6. Interactions within a Multi-Level Perspective determines the wanted outcome inspired by Geels (2011, 28), with modifications.

Figure 6 illustrates how the three levels can be perceived and how they are interlinked, whereas the three levels can determine the transition outcome. However, the focus of this study was on niches, especially technological niches and sustainability innovations, which is required in Sweden since it is a novel industry. There are developments and research regarding new niches in the agricultural sector, improving environmental performance (Geels, 2005). However, several technologies within the agricultural sector have not yet been introduced into the market due to, *e.g.*, financial factors. As stated above, factors such as; cultural, regulative, social, and infrastructural also have a significant influence on why some innovative technologies and niches have not been introduced to the market (Geels, 2002). Current systems in the agricultural sector are robust, which is an obstacle that needs to be overcome and thus makes it difficult to change (Geels, 2005). Nevertheless, robust systems and management can be overcome if stakeholders understand how to overcome the obstacles (Geels, 2002). Therefore, Geels (2005) states that the primary focus should be on how the systems function rather than how they can be changed.

3.2 Cradle-cradle and the concept of circular economy

3.2.2 Cradle-cradle

Cradle-cradle is a principle where systems should be designed without waste and mimic nature where materials are kept circulating (Ellen MacArthur Foundation, n.d.). According to McDonough and Braungart (2002, 37), manufactured products not composed for human and ecological health are regarded as *crude* products. It is necessary to move towards a circular system worldwide to control waste treatment, reduce toxic waste, and achieve an eco-efficient industry. An eco-efficient industry aims to: reduce toxic emissions to the air, soil, and water; meet the requirements of numerous different legislation; and prevent putting valuable products in landfills (McDonough & Braungart, 2002, 62). In Sweden, some waste goes to landfill, but it is forbidden to put organic waste in landfills since it causes methane gas, which strongly affects the climate (Swedish Environmental Protection Agency, 2020a).

The concept' triple *bottom* line' by Elkington (1999) helps incorporate sustainability in a company. The concept advises companies to operate in economic or environmental values and ethical and political values (Elkington, 1999). According to McDonough & Braungart (2002, 153), the prime target is on the economy and does not consider the ecological and social aspects equally high. However, within the cradle-cradle concept, there is a triple *top* line where all aspects are equally considered *before* producing a product and requires the designer to recognize all aspects and create value from them. The outcome should lead to products strengthening humans' health and the environment and creating economic profit (McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020). This thinking is particularly important when converting food loss and waste into feed for insects, since it needs to be safe for human health to use, before released into the market.

3.2.3 Circular economy concept

Circular economy (**CE)** concept is based on cradle-cradle, where a system should be designed without waste, but also contribute to societal benefits, reduce pollution, and have renewable energy sources (Ellen Macarthur Foundation, *n.d.*). The CE concept was introduced when the linear economy's consequences appeared throughout the whole supply chain (Sillanpää, 2019, 282). The CE received increased attention in several discourses, and much of the increased attention derives from that it contributes to sustainable development. Resources need to be managed efficiently according to CE and create added value throughout the supply chain for the concept to be competitive (Sillanpää, 2019, 20). If using insects as

waste managers, food loss and food waste would be managed efficiently and create added value of the decreased environmental impacts. Furthermore, CE will provide an advantage for companies if economic growth is integrated sustainably (Sillanpää, 2019, 26). When a business model integrates into a circular economy, environmental management is needed within an immense network, including the environment, stakeholders, management, and decision making (Sillanpää, 2019, 291).

Companies often have a linear business model, where natural resources are being exploited, which are transformed into services and products for consumers (Rockström, 2015, 137). Circular thinking must be applied for small and large industries, locally and globally, for organizations and individuals (Ellen Macarthur Foundation, *n.d.*). Considerations in financial, social, natural, and manufactured capital are required to generate recirculated products and services (Rockström, 2015, 137). Financial development will have a new pathway that contributes to further prosperity without exceeding the planetary boundaries (*ibid.*). To achieve a circular system and CE, the waste that occurs throughout the food supply chain needs to reach reuse or recycle levels in the waste hierarchy (The Swedish Board of Agriculture, 2020, 6).

In the European Union (**EU**), the circular economy is believed to reduce emissions by almost 50%, create monetary value, and two million additional jobs until 2030 (European Commission, 2014). The goal is to make sustainable products affordable, attractive, and accessible to consumers since the decision-making is influenced by various factors like other people's behavior; what way information and advice is given; the cost and benefit of the product (European Commission, 2014). The EU has already initiated circular thinking by implementing a waste hierarchy and prioritizing recycling and reducing waste (European Commission, 2014).

3.3 A conceptual framework

Stakeholders tend to hold a company accountable for their way of managing sustainable issues, even those who are not in their direct control (Roberts, 2003). Therefore, it is important to identify and selects critical stakeholders for the specific industry (Escoubés, 1999). Suppose the company or industry fails to manage the sustainability issues accurately. In that case, there is a risk that they will gain a bad reputation, which will be a disadvantage for them in the market they are in (*ibid.*).

MLP conceptualizes patterns that are in a sociotechnical shift, and one of the patterns includes innovations. Innovative technologies in the agricultural sector are

currently under research and development and may improve performance. Many new technologies in this sector have not yet been introduced into the market due to several factors, where the most common factor is financial (Geels, 2005). In a robust and multi-level dimension system, as the agricultural sector is, there are difficulties in entering technology innovations to change it. According to Geels (2002), to change the robust and multi-level system, a stakeholder needs to understand how the system functions and how to overcome the obstacles.

Furthermore, the cradle-cradle theory was used together with the CE to analyze whether BSF and yellow mealworms potentially can be designed without waste, have triple-top line in mind, contribute to less emissions, are attractive, affordable, and accessible products to use as feed. Therefore, it was analyzed if BSF and yellow mealworm as feed could fulfill these factors. It is currently not legal to give insects as feed for poultry and pigs. Therefore, this study's focus was not to investigate if the product would meet legislation requirements, instead investigate the attractiveness *if* it was legal. The triple top line concept within the cradle-cradle was used to investigate whether the respondents thought about all aspects. CE was used to analyze whether the industry of BSF and yellow mealworms have the potential to reduce pollution, considered to be designed without waste, and have renewable energy sources. Table 3 presents the key components and questions used in the empirical findings and analysis (chapter 5).

Table 3. Overview of the conceptual framework and critical question used in the analysis

Theory	Key component	Key questions used in the analysis
Stakeholder Theory	- Include critical stakeholders in the industry. Trust between actors - Managing sustainable issues correctly to avoid a bad reputation	- Which critical stakeholders were accounted for? - Which risks exist to threaten an industry with BSF and yellow mealworm?
Multi-Level Perspective	- Factors that hinder innovative technologies to enter robust systems - Niches - How the system works instead of solely focus on system changes	- Which factors hindered insects as feed to be implemented? - What focus did critical stakeholders have - understanding the food system or changing specific stages within the food system? - How were niches mentioned?
Cradle-Cradle	- Triple top line - Products contribute to reduced pollution, designed without waste, and use renewable energy. - Affordable, attractive, and accessible products to stakeholders	- Which aspects of sustainability are mentioned by the critical stakeholder? - What environmental impacts do BSF and yellow mealworm have the potential to reduce? - How can the system be designed without waste and use renewable energy? - What makes the feed affordable, attractive, and accessible toward stakeholders?
CE		

The four concepts of Stakeholder theory, MLP; Cradle-cradle, and CE, are presented in the left column. Since cradle-cradle and CE are closely linked to each other, both theories are intertwined in the table. The middle column's critical components contain selected components from each theory used in the analysis. The right column includes key questions based on the key components to help us cover all theories in the analysis. The next chapter presents previous studies that were compared to the analysis.

4. Empirical background

The chapter consists of previous studies which has been divided into three sub-chapters; Bovine Spongiform Encephalopathic (BSE) and development of legislation, and perceived benefits and drawbacks with BSF and yellow mealworm, and lastly acceptance towards insects as feed. The first sub-chapters have a historical description of BSE, which caused legislation changes in both the EU and Sweden—followed with previous research of perceived benefits and drawbacks with insects as feed.

4.1 Bovine Spongiform Encephalopathic (BSE) and development of legislation

According to Fernandez-Cassi *et al.* (2018), prions are one primary concern regarding food safety and the animals' health. *Bovine Spongiform Encephalopathic* (**BSE**), commonly known as the mad cow disease, is a deadly and extremely contagious disease that affects some animals' nerve system (The Swedish Board of Agriculture, 2018). It can be transmitted to humans if consuming infected BSE meat and causing Creutzfeldt-Jakob's disease (**CJD**) (Public Health Authority of Sweden, 2019). BSE is the main reason why the EU has forbidden bone and meat flour to animals. Typical symptoms from BSE are not often visible from the start. Throughout weeks or months, the animal's health can worsen (The Swedish Board of Agriculture, 2018). In 1996 several BSE cases appeared in Great Britain. The connection is clear between BSE and CJD, which has led to increased surveillance in the EU of *transmissible spongiform encephalopathic* (**TSE**). TSE is a collective name of animals' prion disease, which can cause BSE (Public Health Authority of Sweden, 2019; Zafar *et al.*, 2018). However, there have not been any recorded cases in Sweden where CJD has infected a human through infected BSE meat (*ibid.*). One reason was that Sweden acted immediately when BSE was first detected in 1980 when the cause for BSE was still unknown (The Swedish Board of Agriculture, 2012).

Before BSE, food waste was given to pigs and poultry as feed, which is currently forbidden according to the EU and Swedish legislation. This is due to the risk of animal residues in the waste, which increases the BSE risk and prevents cannibalism within the same species (Swedish Board of Agriculture., 2020, 11:13). Animal residuals are regulated in the EU regulations (1774/ 2002 Article 22 & 1069/ 2009 Article 11) that include '*whole or parts of an animal; products that*

have its origin from animals; or other types of products taken from an animal not intended for human consumption' (*ibid.*). Sweden has complementary legislation regarding animal by-products regulated in SFS 2006:814 (The Swedish Board of Agriculture., 2020, 14). Nevertheless, there are exceptions within this legislation, and some animal residuals can be used as feed where exceptions are found in EU regulation 1069/2009 together with the Swedish legislation SFS 2006:814 (*ibid.*).

Furthermore, at all stages, companies within the feed industry need to follow the stated EU regulations 183/2005 Article 3 to ensure that feed given to livestock meets the requirements to resist hazards and establish good quality for the feed intended for livestock. A precondition is to ensure animals' good health, especially if the purpose is to provide meat for human consumption. The Swedish feed legislation has a similar definition of feed and how it should be implemented to the market (SFS 2006:805). Hence, if a feed contains animal by-products, companies need to simultaneously follow feed and animal by-product legislation (*ibid.*). Other legislation that needs to be taken into considerations can be seen in the Figure below (Figure 7).

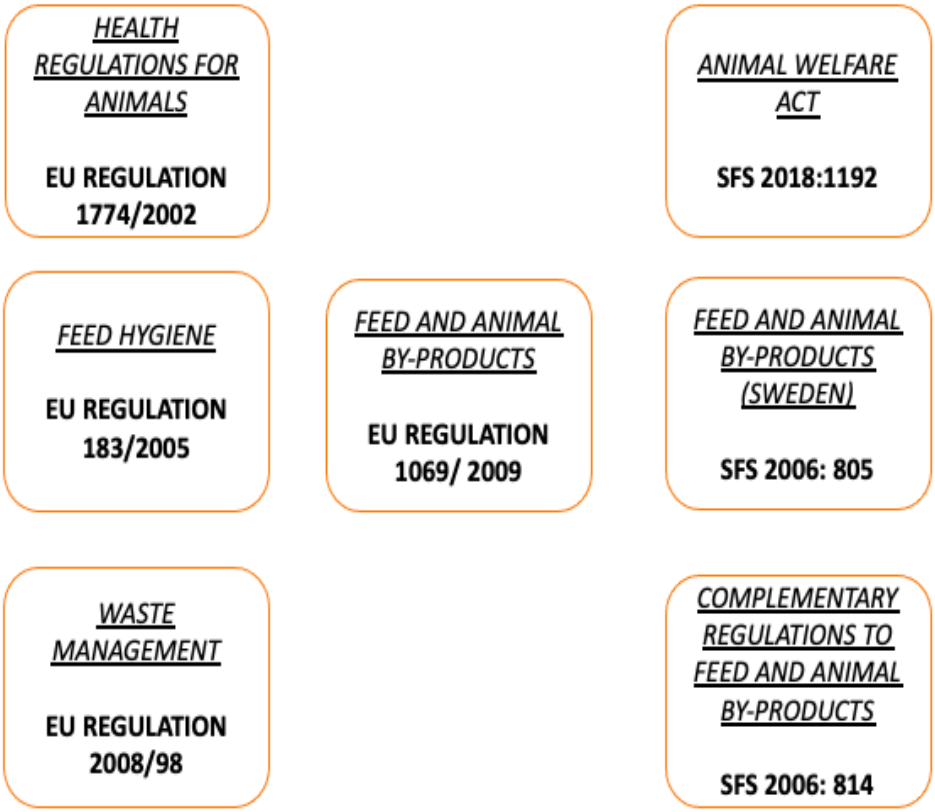

Figure 7. Different legislations that are required to be taken into consideration concerning feed in Sweden. The left and middle column presents EU regulations while the right column presents Swedish legislation.

As illustrated in Figure 7, the EU regulation, together with other legislation, needs to be considered before having a new product on the market. Ojha *et al.* (2020) further raised different challenges with pursuing insects as feed, where' regulatory guidelines' were one of the challenges. Van Huis (2015) states that the insects were not a part of the definition of food and feed when the legislation was established. However, usually, insects are included in the definition "animal". Therefore, insects are being included in legislation regarding food and feed. In July 2017, the EU new legislation (EU 2017/893 EC, 2017) made it possible to give seven types of insects as feed in the aquaculture sector, where BSF and yellow mealworm were included (Dicke, 2018; Macobe *et al.*, 2019). The Ministry of the Environment in Sweden published in July 2020 how to promote a circular economy. Food waste is one prioritized flow that is included in one of the four focus areas. The assumption of the prioritization is to lower GHG emissions and to enhance local production. However, Sweden is reliant on the export and trading between other member states in the EU. According to the Ministry of Environment and the EU-commission, changes in the EU-regulations will be necessary to achieve a circular economy (*ibid.*). When different regulations and legislation have been established can be seen in the Figure below (Figure 8).

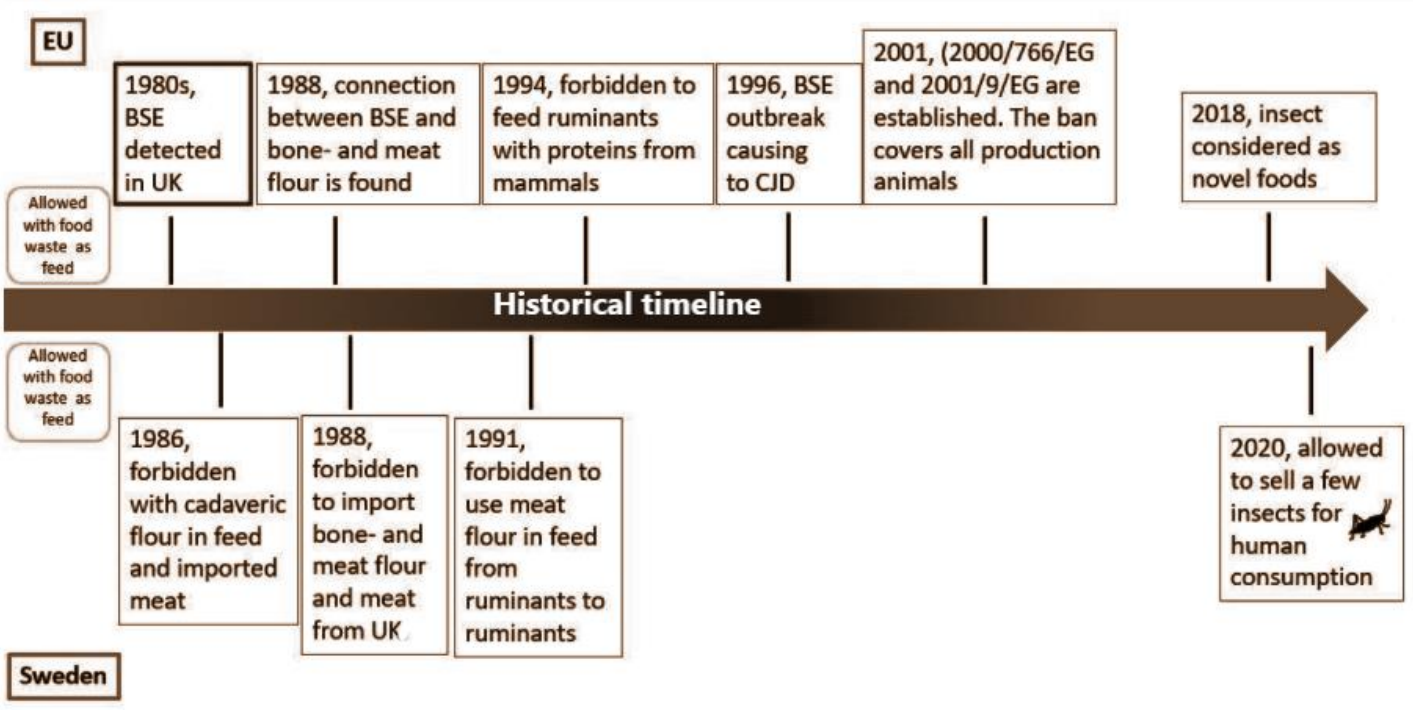

Figure 8. A timeline of significant events lays as the basis of the EU-legislation. Timeline inspired by Winberg (2000).

The timeline in Figure 8 consists of separated actions taken in the EU (the uppermost part) simultaneously as actions were taken in Sweden (the part below) after the detected BSE outbreak in the UK.

4.2 Perceived benefits and drawbacks from previous studies

With the simultaneously increasing population and prosperity, insects as feed can be considered an alternative to reducing environmental impacts (van Zanten *et al.*, 2014; Lalander *et al.*, 2018). Historically, there is a correlation between increased prosperity and demand for animal products, which results in an increased need for feed (Thornton, 2010; Lalander *et al.*, 2018). Recent years have provided two trends: growing demand for poultry products and an increased interest in animal welfare (Schipmann-Schwarze & Hamm, 2020). As this demand has increased, two other meat options have stagnated: beef and pork (*ibid.*). The study by Schipmann-Schwarze & Hamm (2020) concluded that those who prefer organic poultry are less price-sensitive than those who buy conventional poultry. Furthermore, there seems to be potential in organic poultry production as the demand for organic poultry has grown (*ibid.*)

Several researchers have seen benefits in using insects as a food waste manager, and this concept has gained attention these last couple of years (Ojha *et al.*, 2020). The gained attention originates from insects having the qualities to make food waste into high-quality products. Furthermore, it is a natural diet for many animals, *e.g.*, fish, poultry, and pigs (Ojha *et al.*, 2020). Many insect requirements need to be fulfilled when using them as food waste managers, *e.g.*, largemouth to masticating food, soft bodies to move through various substrates, be nourished on food waste, and turn it into high-quality products (*ibid.*). Another study by Van Huis and Oonincx (2017) described risks with having insects in large-scale production. They state that if an insect is not domestic, or if it survives escaping from industry and would harm humans, nature, and plants, then the insect preferably would be prohibited and controlled by regulating imports.

The current most popular insect for industrial rearing is BSF. They can eat various waste streams as food waste, human feces, and abattoir and a mixture of abattoir waste (Lalander *et al.*, 2018; Ojha *et al.*, 2020). However, variability in substrates can affect the growth rates, nutritional value, and BSF developmental time. These waste stream variabilities entail challenges with operation and process control (Ojha *et al.*, 2020). Van Huis and Oonincx (2017) stated that insect-fed meat could be more sustainable than current meat production, but some advanced techniques and processes need to be developed. Large-scale production is needed if insects

should convert to feed to deliver consistent large quantities and high-quality feed, which will be required from consumers (Macobe *et al.*, 2019). van Zanten *et al.* (2014) discussed whether waste-fed insects have environmental benefits due to the high energy requirements.

van Zanten *et al.* (2014) highlighted one problem with feeding insects with food waste. Food waste is frequently used to generate bioenergy, which needs to be replaced with another food waste source as feed for insects. This can cause acceleration in the conflict between food-fuel competition (*ibid.*). According to Lalander *et al.* (2018), different locations might value food waste differently, depending on revenues and demand. Some location around the world might value biogas higher than animal feed as it would be more profitable to convert the feed into biogas. On the other hand, other locations in the world might value animal feed higher than biogas (*ibid.*). Figure 9 below presents a preferred waste hierarchy.

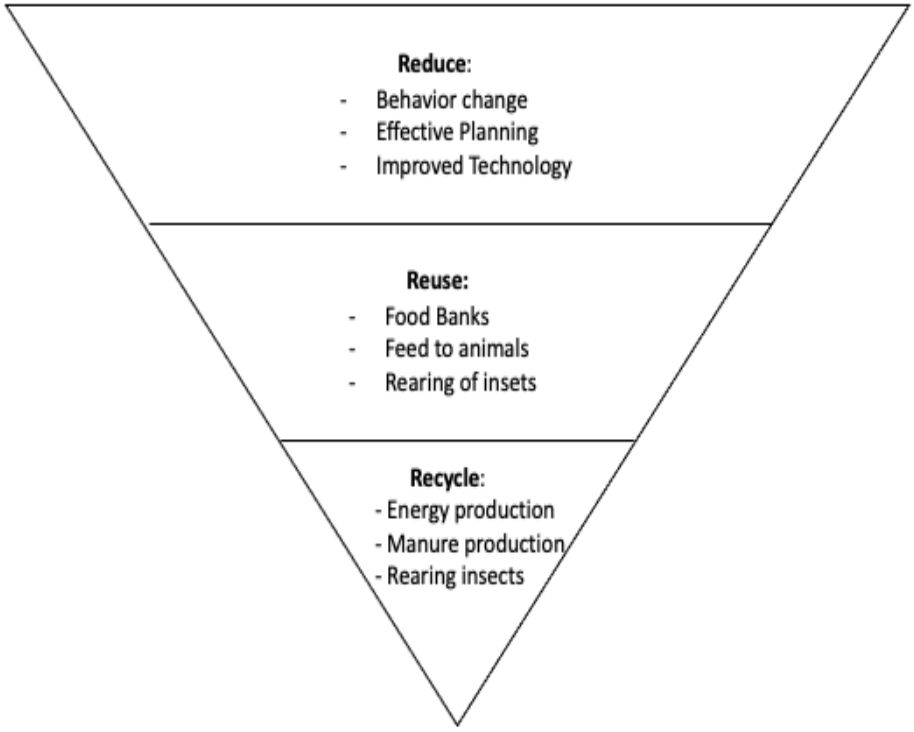

Figure 9. The top three most preferred stages of the waste hierarchy to reduce food waste. Based on Ojha et al. (2020, 602).

Figure 9 shows the first three stages of the waste hierarchy which are most preferable to reach (The Swedish Agricultural Agency, 2020, 6; Ojha *et al.*, 2020). As mentioned in the problem background, the waste hierarchy is essential to consider since a higher level will reduce food waste (Swedish Board of Agriculture,

2020, 6). In the study by Ojha *et al.* (2020), prevention to reduce food waste is mentioned. The most preferred action is behavior change, effective planning, and improved technology, as shown in the Figure above. The future strategies must consider the global food supply chain and consider the local waste streams, which will be combined into a *glocal* strategy (Ojha *et al.*, 2020).

Other than BSF, yellow mealworm is, according to some studies, another insect to rear. According to Bordiean *et al.* (2020a) and Bordiean *et al.* (2020b), yellow mealworm is reared most in Europe and can nourish many different substrates from agricultural production. Furthermore, it is beneficial since it is easy to handle and has rapid growth (Bordiean *et al.*, 2020b). Bordiean *et al.* (2020a) further stated that yellow mealworm is believed to be a part of industrial production soon. That yellow mealworm has been confirmed to be resistant to many harmful compounds like pesticides and heavy metals (*ibid.*).

Apart from the potential environmental benefits, insects' nutritional value is high and is comparable with soy and fishmeal (van Zanten *et al*., 2014; Moon & Lee, 2015). However, the amino acids level (*e.g.*, methionine and lysine) in BSF and yellow mealworm is higher compared with the amino acids in soybean but is not as equivalent as in fishmeal (Fanatico *et al.*, 2018; Dicke, 2018; Mukhtar *et al.*, 2017; Abd El-Hack *et al.*, 2020). Furthermore, essential fatty acids are necessary to consider when making a feed (Abd El-Hack *et al.*, 2020). If the feed does not have the required levels of essential fatty acid, which is lacking in BSF, it will impact poultry health and productivity (*ibid.*). The essential fatty acids will not further be analyzed in this study, but it is crucial to consider the future. In table 4, the amino acids level of lysine and methionine will be presented.

Table 4. Dry wight in percentages of Lysine and Methionine content in fishmeal, soy, BSF and yellow mealworm. Numbers derived from Fanatico et al. (2018), Abd El-Hack et al. (2020) & Mukhtar et al. (2017)

Dry weight %	*Fishmeal*	*Soy*	*Black Soldier Fly*	*Yellow mealworm*
Lysine	4,72	1	3,07	3,44
Methionine	1,81	0,63	0,87	0,82

Table 4 presents a comparison of the amount of lysine and methionine between fishmeal, soy, BSF, and yellow mealworm. 'Fishmeal' is a generic term, but the amino acids can vary depending on what species one is considering. In Sweden, fishmeal is mostly used in organic poultry production since it is forbidden to feed fish with pure amino acids (Spörndly *et al.*, 2019). Instead, poultry in organic production is naturally given amino acids from fishmeal (*ibid.*). Furthermore, some studies present different numbers of the percentage of amino acids, especially for

BSF. The cause can be that the studies accounted for different parts and weight of BSF. The requirements on the amount of protein and amino acids in feed depend on the type of species one is focusing on and the life stage the targeted animal is in (PROteINSECT, 2015, 24).

4.3 Acceptance towards insects as feed

In a study by Verbeke *et al.* (2015), various stakeholders were included. However, farmers and consumers were distinguished to be less favorable towards insects as feed. The foremost cause from farmers was the perceived risks with insects as feed, instead of beneficial possibilities, as the market is uncertain (Verbeke *et al.*, 2015; Moon & Lee, 2015.). One main challenge Verbeke *et al.* (2015) acknowledged is the reactions when insect-fed meat is released to the market. Relevant marketing strategies and well-formulated communication throughout the whole supply chain are expected of future companies to cope with these challenges (*ibid.*). The farmers are in a fragile position with price volatility, uncertainties, economic pressure, and other factors. As a result of the fragile position, reluctance increases toward behavior changes and risk-taking, *e.g.,* alternative feed, such as insects (*ibid.*). This was the primary factor towards less positive acceptance from consumers, regardless of environmental benefits (Verbeke *et al.*, 2015.). The other stakeholders were more positive to give insects as feed to poultry, fish, and pigs since it is a part of their natural diet (*ibid.*). One way to increase acceptance is, according to van Huis (2015), to develop strategies on how to overcome cultural and psychological obstacles, *e.g.*, informing people about novel food that is a sustainably better alternative as food and feed; increase awareness and knowledge connected to the benefits with insects and to make edible insects more available in the society; make the insect feed and food appealing (van Huis, 2015).

5. Results and Analysis

This chapter presents the results from the interviews and survey, which were analyzed with the selected theories. The findings have been sorted into categories based on content analysis. Each category includes commonly mentioned themes extracted from the transcriptions and results from the survey. Furthermore, the analysis was based on the conceptual framework and is presented in separate paragraphs.

5.1 Pros and cons with domestic insects vs. tropical insects

Most of the respondents from the interviews and survey recognized positive environmental benefits of having insects as feed. They mentioned several possible added values if insects would replace traditional feed as soy and fishmeal, shown in Figure 10.

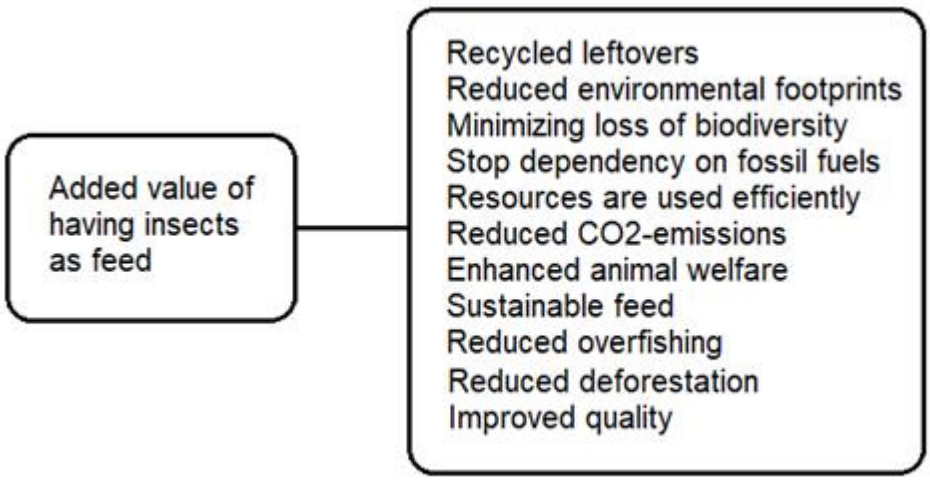

Figure 10. Possible added value if having insects as feed instead of soy and fishmeal, by the respondents from the interviews and survey.

Compared with traditional feed as soy and fishmeal, Figure 10 provides environmental benefits with converting insects as feed, such as reduced deforestation, reduced overfishing, and minimizing biodiversity loss, *etcetera*.

However, some of the respondents stated that caution should be taken into what BSF and yellow mealworm is nourished on, since this can decide how sustainable the industry might be. According to most of the respondents from the interviews, BSF and yellow mealworm use substrate and residual products, which cannot be utilized otherwise. According to Cecilia Lalander (Pers.com., 2020), with insects as BSF, it is possible to shorten the supply chain by having fewer stages, resulting in reduced losses, and becoming more efficient.

Björn Vinnerås (Pers.com., 2020) considers yellow mealworm to be an insect-trend since they nourish substrate humans can consume directly and are therefore not waste managers. Cecilia Lalander (Pers.com., 2020) claimed that yellow mealworm usually is nourished on wheat bran, which is classified as a residual product in Sweden. However, it does not necessarily need to be classified as residual because wheat bran can be used in baking. Everything depends on what is considered food waste (*ibid.*). Furthermore, it was not clear which insect would be best to use as feed, bringing environmental benefits. A discussion was raised about whether to have domestic flies, though they are considered vectors and therefore not suited to use as feed (Pers.com., Jansson, 2020; Pers.com., Lalander, 2020).

Anna Jansson (Pers.com., 2020) and Björn Vinnerås (Pers.com., 2020) claimed that one of the biggest reasons to use insects as feed is to break the infection barriers and lower the risk for a human to be infected by a disease. Processing the insects as flour might reduce the risks even further, according to Ivar Vågsholm (Pers.com., 2020). However, some of the respondents stated it all depends on what BSF and yellow mealworm have been nourished. Furthermore, some respondents mentioned there is a risk that if BSF would escape from the industry, they could establish themselves and become invasive. However, many respondents claim that the BSF would not be able to reproduce since Sweden does not have the required temperature they need, and therefore BSF cannot become an invasive species. Cecilia Lalander (Pers.com., 2020) stated that it is more likely that BSF spreads consequently to climate change.

Moreover, compared to other animals, insects are swift to adapt, and there is ongoing research about adaptation when entering a new environment (*ibid.*). Although there are several environmental benefits, it is not enough to replace the feed with insects, according to Cecilia Lalander (Pers.com., 2020). She believed that society needs to change since meat consumption in society is at a high rate. Therefore, it would require behavior changes within society (*ibid.*).

The results compared to the theoretical framework provided that CE, cradle-cradle, and MLP is considered. As in CE, one aspect is to lower the environmental impacts

of products (Ellen Macarthur Foundation, *n.d.*) compared to the environmental impacts of soy and fishmeal. The majority recognized several positive environmental benefits of using insects as feed (Figure 10). Lowering the risk of infected diseases towards humans could make insects feed an attractive product (European Commission, 2014). This is one aspect that is important to take into consideration before introducing the product on the market according to the concept cradle-cradle (McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020). Furthermore, according to McDonough and Braungart (2002, 37), products should be manufactured regarding human health and nature's health. Using insects, which will work as an infection barrier, the product will be safer to use for humans.

BSF might reduce environmental impacts if nourished on food waste and be a part of a circular system since the concept of CE and cradle-cradle must be designed without waste (Ellen Macarthur Foundation, *n.d.*). Depending on how food waste is defined, yellow mealworms might not be considered as a waste manager. Furthermore, MLP provides identifying factors as to why innovations were not implemented (Geels, 2005). One factor that hinders innovation might be the uncertainty of which insect to use. Developments and research are needed in the agricultural sector on innovations (niches) and technologies to improve environmental performance within the sector (*ibid.*).

5.2 It is all about the flows

Many of the respondents raised the concern of the feed being a risk of harming humans' health and the environment, if not thoroughly planned. Consequently, the economy could be affected if consumers would get sick when consuming meat that has been fed with insects (Pers.com., Anita Pettersson & Maria Malmström, 2020). The circular systems are considered an expensive path since every step of the process is accounted for, which might discourage stakeholders from moving towards a circular system (Pers.com., Lalander, 2020). In a circular system, it would be harder to identify and eliminate outbreaks of zoonoses, in comparison to a linear system, since an outbreak in a circulating system is at risk of accumulating dangerous substances (Pers.com., Lalander, 2020; Pers.com., Vågsholm, 2020). It is not thoroughly researched if BSF larvae can accumulate prions and if it has qualities as a species barrier (Pers.com., Lalander, 2020; Pers.com., Vågsholm, 2020). However, there is evidence that poultry and fish do not accumulate prions, and one reason could be the short lifespan (Pers.com., Lalander, 2020). However, if heavy metals accumulate in BSF and mealworms, the heavy metals will not disappear even though processed (Pers.com., Vågsholm, 2020). Moreover, there is a challenge with quality assurance in a circular system since it includes new

interactions and various stakeholders in every step (Pers.com., Vinnerås, 2020). These are some critical stakeholders needed in a circular system, identified by the respondents (Figure 11):

Figure 11. Required critical stakeholders for the development of the industry, according to the respondents from the interviews.

According to the respondents from the interviews, Figure 11 illustrates some selected critical stakeholders, *e.g.*, researchers, consumers, politicians and authorities, agricultural actors, feed industries, *etcetera.* If waste-fed insects were to be converted to feed, one challenge Björn Vinnerås (Pers.com., 2020) raised is that industries operating within that market must be aware of the seasonal changes in the food waste. Seasonal changes can be challenging since the flows need to be separated, as it is not homogenous and still has a functional process. One challenge with insects as feed, stated by Emma Ivarsson (Pers.com., 2020), is that it is preferable to have similar quantities and qualities throughout a year to a competitive price. This will be possible due to a large-scale production, which will be advantageous for the feed industry (Pers.com., Pettersson & Malmström, 2020). However, another challenge with having biosecurity on a larger scale is the increased risk of zoonoses erupting when gathered in a small area (Pers.com., Vågsholm, 2020). Nevertheless, if having a large-scale production, there might be side flow to consider if having an industry with insects, depending on how the product is processed (Pers.com., Ivarsson, 2020). Emma Ivarsson (Pers.com., 2020) and Malin Alm (Pers.com., 2020) further explained that non-processed insects have a short shelf life if using them as feed, and the supply chain needs to be rapid, in the sense of fast deliveries and distribution.

According to Cecilia Lalander (Pers.com., 2020), it is crucial to investigate the local flows and create innovative solutions, as there are no one-fits-all solutions. Local food waste flows within Sweden are, to a varying extent, taken advantage of since the pigs' diet consists of a considerable amount of vegetable residuals, according to

Jeanette Elander (Pers.com., 2020). One way to increase collaboration between industries is by feeding waste-fed insects to fish and feeding pigs with the fish industry residuals (*ibid.*). Cecilia Lalander (Pers.com., 2020) concurs that fishmeal does not per se have to be wrong, and it does not have to be excluded in all feed because there are multiple flows in fish farming that could be taken advantage of by the industry. There are some technical innovations under development specifically for BSF in the USA. However, according to Anna Jansson, these companies are very secretive and try to get a patent (Pers.com., 2020). Anna Jansson (Pers.com., 2020) raised that the technical solutions will not function for all domestic insects; there is no copy-paste where specific insects will require specific systems (*ibid.*).

The results compared to the theoretical framework in this category, the results provided that CE, cradle-cradle, stakeholder theory, and MLP are considered. The triple top line stated that products need to be designed to recognize all aspects of sustainability (McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020). The outcome should lead to a product strengthening the health of humans and the environment, and at the same time, gain economic profit (*ibid.*). If these criteria are not fulfilled, it will be regarded as a *crude* product (McDonough and Braungart, 2002, 37). Since many respondents feared that the end-product might affect humans, we interpreted them as trying to avoid it becoming a crude product.

If insects were to be processed, they would be easier to distribute without the time-pressure, making them more accessible and attractive, and safer with longer shelf life. These qualities are in line with cradle-cradle, where products should be safe in regards to human health (McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020) and CE, where products in a circular system should be attractive, accessible and affordable, according to the European Commission (2014). Using existing unutilized residuals might lead to a system designed without waste according to cradle-cradle and CE, and reduced environmental impact, since fishmeal will not be imported, the current pressure on exploitation will decrease (Ellen Macarthur Foundation, *n.d.*). One outcome by effectively using the existing resources could increase the competitiveness within the industry (Sillanpää, 2019, 20).

According to stakeholder theory, critical stakeholders need to be consulted and further matched with the companies' or industries' goals and strategies (Escoubés, 1999). New knowledge is needed to create processes where a niche industry might be required in the agricultural sector (Geels, 2005). These processes can arise on various levels, such as technology, regulations, and production (*ibid.*). Niches are also encouraged by some stakeholders since they can change the existing sector

(*ibid.*). However, if the USA has patents on BSF technical solutions, these solutions might not be as accessible for Swedish feed industries and, consequently, less attractive in line with CE (European Commission, 2014).

5.3 Politics and interests

Isak Öhrlund (Pers.com., 2020) and David Ling (Pers.com., 2020) stated that feed is rarely discussed within politics, whereas the focus is on the transition toward a plant-based diet. Some respondents claimed that politicians must be interested in insects as feed to end up on the political agenda. This is something that Isak Öhrlund (Pers.com., 2020) has noticed engaging in politics. Isak Öhrlund (Pers.com., 2020) further expressed what politicians could do to influence the population since their function is to disseminate information, *i.e.*, increase knowledge at conferences or billboards. However, currently, there is a knowledge gap in politics, according to Isak Öhrlund (Pers.com., 2020) and Anita Pettersson & Maria Malmström (Pers.com., 2020). David Ling (Pers.com., 2020), Isak Öhrlund (Pers.com., 2020), and Lorentz Tovatt (Pers.com., 2020) stated that it is the politicians' responsibility to steer financially and legally towards the most sustainable feed production. Furthermore, they stated that economic instruments are most effective for system change, such as bonus malus. This means that the feed contributing to a higher GHG emission should get a higher tax, while feed not contributing to increased GHG emission should get a financial release instead (*ibid.*). However, retailers often lead consumers the way since they decide what products to implement and remove from the market (Pers.com., Anita Pettersson & Maria Malmström, 2020).

This category is analyzed with stakeholder theory, MLP, cradle-cradle, and CE. One of the most mentioned critical stakeholders within this study and stakeholder theory is authorities (Roberts, 2003). According to the stakeholder theory, the authorities' responsibility is to monitor a company's performance or industry and give permission to operate in the market (*ibid.*). As earlier mentioned, MLP identifies factors to why innovation is hindered, and one factor is the knowledge gap that seems to exist among politicians and that their interest lies within changing diets (Geels, 2005). Implementing bonus malus within the agricultural sector might be an effective way to nudge farmers to shift their feed, making it affordable, attractive, and accessible, in line with cradle-cradle and CE, as it could lead to a behavior change within the sector (European Commission, 2014). Nevertheless, even if there is an increased attractiveness among consumers and farmers, it might become inaccessible if retailers decide not to introduce a new product (European Commission, 2014). Products need to be accessible for the consumers, according to CE (*ibid.*).

5.4 Amino acid

If the amino acids are optimized, the protein content could be reduced in the feed (Pers.com., Anita Pettersson & Maria Malmström, 2020). Poultry has a great need for specific amino acids, mainly methionine, which is added into conventional feed, but this is prohibited in the organic feed (Pers.com., Alm, 2020). The consequence of hens not getting enough methionine is problems with feathers and changed behaviors (*ibid.*). BSF larvae have a higher methionine content than soy but not as high as fishmeal. The problem then becomes that there are no equivalent alternative protein sources to meet the high need for these specific amino acids (Pers.com., Alm, 2020). The feed companies are the ones who continuously optimize the ingredients and decide what should be included in the feed (Pers.com., Alm, 2020; Pers.com., Anita Pettersson & Maria Malmström, 2020). The decision of what ingredients to use might depend on the food industry since several respondents expressed concern about how consumers perceive the product. Using insects as waste management might be attractive to communities to reach a higher level on the waste hierarchy, as it would be considered direct reuse of amino acids (Pers.com., Lalander, 2020).

This category is in line with CE, cradle-cradle, and stakeholder theory. Trying to reach the higher levels of the waste hierarchy is in line with the EU since they have started implementing a waste hierarchy by prioritizing recycling and reducing food waste (European Commission, 2014). However, there must be an equivalent alternative protein source with the required amino acids level to make it an attractive product and move away from fishmeal and soy. This is in line with both CE and cradle-cradle for the consumers and achieves a circular system (European Commission, 2014; McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020). In this study, one influential critical stakeholder was interpreted as the food industry since they are interested in what is produced in the feed industry. They are also considered one of the feed industry's biggest consumers (Freeman *et al.*, 2018, 28; Roberts, 2003).

5.5 It is too expensive

One common obstacle that most of the respondents have touched upon is the cost of penetrating the market. Anita Pettersson & Maria Malmström (Pers.com., 2020) has been in several meetings regarding insects as feed. The discussions repeatedly ended up with a remark that it is possible but too expensive in the market today (*ibid.*). Malin Alm (Pers.com., 2020) states that large-scale production is needed to reduce the price. However, no one is willing to invest if there is no apparent

demand. Neither will the consumer purchase the end-product if it is too expensive (Pers.com., Anita Pettersson & Maria Malmström, 2020). According to many respondents, a technique for an automated system is needed to reduce the end-product cost, which is currently novel and not yet invented. An automated system would reduce the labor cost, which is relatively expensive in Sweden (Pers.com., Alm, 2020). However, Åsa Berggren (Pers.com., 2020) recognized the financial benefit of having an insect industry in Sweden. She believed the industry could provide job opportunities (*ibid.*). Furthermore, Anna Jansson (Pers.com., 2020) believed that there would not be any problems to invent the required technique as Sweden is a developed country.

Ivar Vågsholm (Pers.com., 2020) mentioned that infrastructure construction would take a few years to complete. He continued stating that factors like energy, buildings, collection and transport need to be closely looked into to have a functioning infrastructure. Moreover, many respondents raised the need for extra energy input since BSF needs a warmer climate to reproduce, which Sweden cannot provide naturally. However, Björn Vinnerås (Pers.com., 2020) stated that biological treatment generates much heat; one of the problems in composting with BSF larvae is the risk of getting it too hot. Nevertheless, extra energy will be needed if the temperature gets far below zero degrees (*ibid.*). Therefore, it would be preferable to place the production where there is access to residual heat from another production type (Pers.com., Alm, 2020; Pers.com., Lalander, 2020).

This category was analyzed with cradle-cradle and CE from the theoretical framework. The financial aspect was considered the most crucial aspect of decision making according to the respondents; however, all aspects need to be equally valued in the triple top line (McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020). The social aspect was considered since an industry would benefit from increased wealth in the society (McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020). This would need to be considered before an industry begins operating and might lead to all aspects being considered in line with the triple top line (*ibid.*)

Moreover, according to CE and cradle-cradle, it needs to be affordable, accessible, and attractive (European Commission, 2014; McDonough & Braungart, 2002, 154; McDonough & Braungart, 2020). However, this is not yet reached since the end-product attractiveness is uncertain and seemingly not affordable, which leads to it being less accessible (*ibid.*). In addition to a design without waste in a CE and cradle-cradle, it also needs to be built on renewable energy sources and reduce pollution, which seems possible to achieve in Sweden if residual heat is utilized

(Ellen Macarthur Foundation, *n.d.*). Only when these three elements are considered will a circular system be fulfilled (*ibid.*).

5.6 Survey of consumer knowledge and attitude

As consumers were one of the critical stakeholders, a survey was conducted to indicate their knowledge about environmental challenges related to feeding and attitude towards insects as feed. There were 152 respondents in the survey, and the respondents consisted of different sexes and ages. The ages of the respondents were between 18 - 60+. According to the survey, the many of the survey respondents favored eating meat fed on insects, as shown in Figure 12 below.

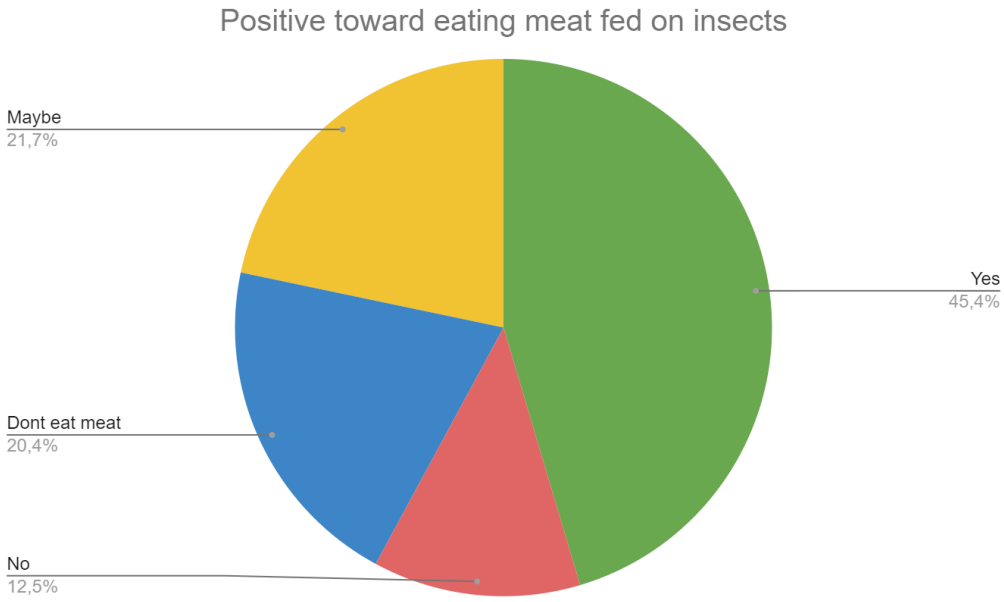

Figure 12. The 152 respondents' opinions towards eating meat fed on insects in the ages between 18 - 60+.

As shown in Figure 12 nearly half of the respondents from the survey would eat meat fed on insects and where a quarter stated they might eat meat fed on insects. However, since this was our secondary data, and this provided us with an indication. Most respondents stated they eat everything, but vegetarians, vegans, and flexitarians participated in this survey. More than half (60%) of the respondents believed that insects would be a part of the future food system. Furthermore, the majority stated they followed food trends sometimes, but there was also a large amount stating they do not follow food trends. See detailed information of the

respondents in Appendix III. On a scale of 1-5, the respondents rated their opinion towards feeding animals with insects, as shown in Figure 13.

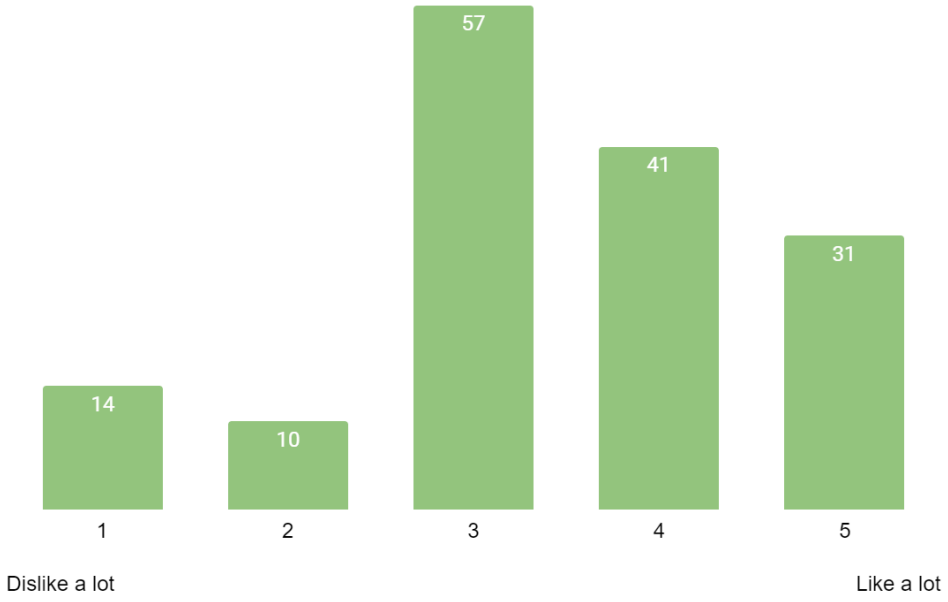

Figure 13. Opinions on using insects as a feed from the survey respondents, on a scale 1 -5.

As seen in Figure 13, the survey respondents rated their opinion on using insects as feed. Several of the respondents were neither positive nor negative towards feeding the animals with insects as they rated their opinion as a three. Nevertheless, the respondents were mostly positive in providing insects as feed to the animals, as they rated their opinion with a four and a five. There was a follow-up question about whether their opinions were based on which animal species it was concerning. If the respondents answered no to that question, they moved on to another question. At the same time, those who responded yes got an additional question asking the respondents which animals they preferred to be fed with insects. According to the survey respondents, Figure 14 below presents which animals it is preferable to give insects as feed.

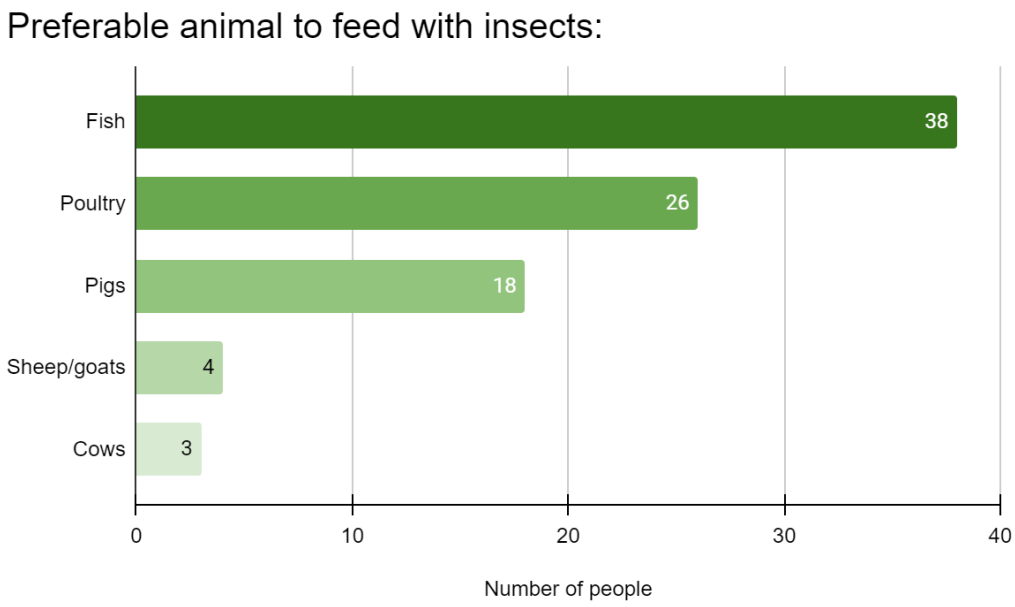

Figure 14. Preferable species to give insects as feed, according to 45 respondents of the survey. Several animals could be chosen.

Forty-five respondents answered this question, and it indicated that these 45 respondents preferred insects as feed foremost to fish, then poultry and pigs, which is illustrated in Figure 14. However, most survey respondents did not express any opinion on which animal species to feed with insects if considering all respondents.

Since consumers are critical stakeholders, the survey provided two possible indications (Escoubés, 1999). First, it might indicate which animals should be provided insects as feed. Second, it might indicate that consumers do not care since two-thirds did not express their opinions on the subject. For an industry to succeed in the market, consumers must accept products to sell them. However, the retailers must see a demand from the consumers to put the products on the shelves. Trust between the retailers, consumers, and feed industry must be in place to ensure that affordable and accessible products are available (Freeman *et al.*, 2018, 28; Roberts, 2003; European Commission, 2014). Consumers tend to hold companies accountable for the social and environmental impacts; therefore, it is vital to establish a good and a long-term relationship with the consumers (Freeman *et al.*, 2018, 28; Roberts, 2003). According to Roberts (2003), companies should integrate corporate social responsibility reports in their management to have transparency, which also helps avoid a bad reputation.

6. Discussion

In this chapter, a discussion is structured with the help of the research questions. It concludes aspects that are considered necessary by different stakeholders, and if they differ between different stakeholders. Furthermore, feeding insects' perceived pros and cons to pigs and poultry are discussed related to the empirical background, problem background, and introduction.

6.1 Perceptions of using insects in feed for pigs and poultry production

One cannot overlook that a change within the agricultural sector is needed to stay within the planetary boundaries (Rockström, 2015). Over the years, researchers have seen benefits with using insects, such as BSF and yellow mealworm, as feed to different animals, *e.g.*, pigs, poultry, and fish (Ojha *et al.*, 2020). The increased attention of insects as feed originated when discovering insects' qualities and the ability to make food waste into high-quality products. It is also considered the natural diet of fish, poultry, and pigs (*ibid.*). The analysis implied that in order to have insects as feed, there must be a legislation change and a well-grounded risk assessment before it enters the market. However, the EU has strict legislation to prevent TSE diseases from being spread out in Europe to animals and humans. Therefore, it can be difficult for this novel feed to enter the market (Public Health Authority of Sweden, 2019; Zafar *et al.*, 2018). Nevertheless, as stated in the analysis by van Zanten *et al.* (2014) and Lalander *et al.* (2018), insects as feed can reduce the environmental impacts from this sector.

To compete with conventional feed, the nutritional value in insect feed needs to be equivalent (van Zanten *et al.*, 2014; Moon & Lee, 2015). However, the amino acids' levels, *e.g.*, lysine and methionine, are higher in BSF and yellow mealworm than soy. However, the amino acid levels in fishmeal are higher than BSF and yellow mealworm, making it hard to compete with (Fanatico *et al.*, 2018; Dicke, 2018; Mukhtar *et al.*, 2017; Abd El-Hack *et al.*, 2020). In Sweden, fishmeal is mostly used in organic poultry production since it is forbidden to feed them with pure amino acids (Spörndly *et al.*, 2019). The feed given to poultry must have the required amino acids (methionine); otherwise, the consequence could be behavior change and problems connected to their feathers (Pers.com., Alm, 2020). As stated by some respondents in the analysis, it is necessary to find an alternative protein source with an equivalent level of amino acids in order to be able to move away from using

fishmeal in the feed. However, some of the respondents contradicted this statement by implying that fish residuals are a huge unutilized waste stream in Sweden, meaning that fishmeal is not always bad, and consideration to local flows is needed. This is mentioned in a previous study by Ojha *et al.* (2020), where the global food supply chain should be taken into consideration and the local streams.

One of the benefits with insects, such as BSF and yellow mealworm, is that they are considered waste managers, which means that they could be given unutilized substrate and residuals (Bordiean *et al.*, 2020a; Bordiean *et al.*, 2020b; Lalander *et al.*, 2018; Ojha *et al.*, 2020). Both in previous studies and analysis, it is believed that using insects as feed could help the industry to reach a higher level of the waste hierarchy as the results would be a decreased level of food waste (Swedish Board of Agriculture, 2020; Pers.com., Lalander, 2020). However, in the analysis, it has been discussed whether yellow mealworm is to be considered a waste manager. A respondent claimed they are considered an "insect-trend", whereas other respondents claimed it all depends on what kind of substrate is given to yellow mealworms and how food waste is defined.

Bordiean *et al.* (2020a) and Bordiean *et al.* (2020b) claimed in their research that yellow mealworms could be fed with various substrates, *e.g.*, brewing, agriculture, and baking. It has been proven that yellow mealworms are resistant to toxic substances, such as pesticides and heavy metals (Bordiean *et al.*, 2020a). Meanwhile, in the analysis and previous studies, the BSF was the most popular insect as it could convert food waste into high-quality products and human feces and abattoir (Lalander *et al.*, 2018; Ojha *et al.*, 2020). Nevertheless, it is preferable to have similar substrates throughout the year, as it could otherwise affect the BSF's growth rate, nutritional value, and development time (Ojha *et al.*, 2020). However, food waste is not always similar, and this might affect the BSF. By using residuals and other substrates to feed the insects might lead to a lower environmental impact and a part of a circular system (Ellen Macarthur Foundation, *n.d.*).

As recognized in the analysis, there is uncertainty about which insect species is best to use in large-scale rearing. Van Huis and Oonincx (2017) stated that it is preferable to prohibit tropical insects if it cannot be ensured that insects will not survive an escape from the premises and if the tropical insects will be harmful to both humans and nature. Furthermore, deducted from the analysis is that there are divided opinions about using BSF as feed-in Sweden. It has been expressed that BSF should be prohibited since it is not considered as a domestic insect species, while others expressed that BSF would not survive Swedish conditions and therefore would not be considered a risk. It was further stated that it is more likely that BSF will spread due to global warming.

The fear of accumulation of prions in the system is a drawback connected to waste-fed BSF, affecting humans (Fernandez-Cassi *et al.* 2018). All researchers expressed this fear, which stressed the importance of the industry being safe before a potential feed would be released onto the market. Due to the fear of prions accumulating, legislation has been developed to reduce the risks, *e.g.*, EU regulation 1774/2002 Article 22 and EU regulation 1069/2009 Article 11. The analysis showed that insects, such as BSF and yellow mealworms, would work as a species barrier, which would reduce the risks of prions accumulating and thereby lower the risks of affecting the health of animals and humans. However, the analysis has also expressed that it is not stated whether the larvae of BSF can accumulate prions. It is favored by various stakeholders to feed fish and poultry with insects rather than providing insect feed to pigs (Verbeke *et al.*, 2015). The results of the analysis have also confirmed this.

6.2 Key aspects that influence an implementation of using insects in feed for pigs and poultry

The analysis expressed that replacing conventional feed with a more environmentally friendly feed would not be enough. A comprehensive behavior change is required from all stakeholders in order to have an effective conversion. This is supported by Ojha *et al.* (2020) since the research has stated that reducing, reuse, and recycling at the highest level of waste hierarchy includes behavior change. Furthermore, effective planning and improved technology are needed to reach the highest level (*ibid.*). According to van Zanten *et al.* (2014), innovations are required in the pursuit of feeding the increasing current and future population and the development of the feed industry. The suggested strategy implied from the analysis is to use the Bonus-Malus in agriculture, which possibly helps relevant stakeholders within the industry toward a behavior change.

Moreover, the analysis displayed the need for legislation to change in order to enhance innovation. The Ministry of the Environment (2020) supports the need for legislation change, as their goal is to move towards a more circular economy, which would require a change in the legislation. However, when minding the case of BSE in retrospect, it has been beneficial to be cautious when there are risks (The Swedish Board of Agriculture, 2012).

According to Ojha *et al.* (2020), stakeholders, *e.g.*, researchers, food industries, authorities, retailers, *etcetera.*, are taking actions to minimize the overall food waste and impacts. The analysis strengthens this statement of required stakeholders within the industry. Furthermore, the development of politicians' strategies is necessary to

inform and spread knowledge about environmentally friendly alternatives in food and feed (van Huis, 2015). This is confirmed in the analysis, seeing that the politicians are responsible for society by being information disseminators and steer toward sustainable feed legally and financially. However, previous studies have not expressed whether additional stakeholders will be required in a circular system. Meanwhile, the analysis provided the complexity of a circular system where waste managers and food industries need to intertwine with abundant legislation.

The cost of the end-product is one concern that has been stated in the analysis. Henceforth, large-scale production is essential in order to reduce costs. Nevertheless, the analysis concludes that the insect industry will commence as a niche, whereas products are more expensive than conventional products. According to Verbeke *et al.* (2015), farmers were more reluctant to use insects as feed to their animals as they were concerned about their reactions. Moon & Lee (2015) and Verbeke *et al.* (2015) believed that farmers often are concerned about the perceived risks rather than the opportunities, as the market is uncertain and that they are in a weak position. It was expressed in the analysis that retailers' impact what will be provided to the consumers as they determine what is on the shelves. Furthermore, whether retailers believe in the product might determine if the product will penetrate the market. According to van Huis (2015), a new development of strategies, *e.g.*, informing the population about novel food which is a sustainably better alternative, increase the awareness and knowledge connected to insects, make the insect feed appealing, *etcetera*, is vital in order to overcome cultural- and psychological obstacles.

Schipmann-Schwarze and Hamm (2020) state that there are two current trends. One trend where there is a growing demand for poultry products and another trend is the increased interest in animal welfare. These two trends have led to a demand for beef and pork has stagnated, and on the other hand, the consumers tend to be less price-sensitive as they are willing to pay more for an end-product if the animal welfare is better (*ibid.*). The analysis showed that most of the respondents were more positive towards giving insects as feed to poultry rather than pigs. This confirms Verbeke *et al.* (2015) statement, where the research showed that it is preferable to feed fish and poultry with insects.

Furthermore, the analysis presented qualities of pigs that might be useful in collaboration between several industries. One example that came up is to use the fish industry's residuals as feed to pigs instead of feeding them with insects. Meanwhile, pork demand has stagnated in the EU, while the demand for organic poultry is increasing (Schipmann-Schwarze & Hamm, 2020). Ultimately, the

stakeholders need to provide information to society and reassure which insect species to use as feed safely to lower the risk of prion accumulation.

7. Conclusions

In this chapter, the study's aim is presented with the help of the chosen theories to explore stakeholders' perceptions of using insects in feed for pigs and poultry production and what key aspects that influence implementation. Furthermore, suggested further studies are presented.

This study was based on various stakeholders' perceptions of BSF and yellow mealworms. From the researchers' point of view, there were different opinions on whether BSF and yellow mealworms were considered an excellent option to be given as feed. On the one hand, some researchers regard BSF as a tropical species which should never be introduced in the Swedish environment. On the other hand, some researchers state that BSF will not survive if it escapes the premises because they are not suited for Swedish conditions. Those who believe that they will not survive if escaping believes it is more likely BSF will spread to Sweden with climate change and then adapt to the environment. Yellow mealworm is the most used insect in the EU; however, previous studies seem to prefer BSF. Some view yellow mealworms as a favorable insect to use as they have a short generation time and do not accumulate heavy metals and other harmful substances. At the same time, it is still unknown whether BSF accumulates heavy metals and prions. Nevertheless, one conclusion is that the stakeholders were mostly favorable towards using insects as feed to poultry and pigs as it would potentially reduce the environmental impacts.

A circular system includes more interactions between stakeholders in comparison to a linear system. Each stakeholder has different requirements and interests that need to be considered for the collaboration to be established. As previously stated, environmental, social, and financial aspects need to be valued equally in a circular system. One conclusion based on this study results is that the social, environmental, and financial aspects are considered together; however, the social and environmental aspects are often deprioritized as the financial aspect is valued as the most important. This is because the insect feed will not be able to compete with traditional feed, such as soy and fishmeal, if the end-product will cost substantially more, resulting in difficulties to be introduced into the market. Furthermore, according to the results and previous research, it is vital to have a well-grounded risk assessment before implementing products to the market to ensure the health of both animals and humans. Therefore, some key aspects that might influence using insects in feed for pigs and poultry are: having the triple top line in mind (where

social, financial, and environmental aspects are equally considered and to ensure the health of humans and animals with a well-grounded risk assessment); the end-product need to have a comparable price to traditional feed to be ably competing in the market; lastly, a collaboration between stakeholders is needed to establish a circular system.

As presented in both previous studies and the survey, insects are considered a natural diet for the poultry, enhancing stakeholders' willingness to convert insects into a feed. Furthermore, as the demand for pork has stagnated in the EU, while the demand for organic poultry increases, one conclusion might be that it is foremost desirable to feed insects to poultry and fishes. To increase interest and achieve the 12 SDG, politicians must lead consumers' way by steering toward the most sustainable feed both legally and financially. Since population growth and increased prosperity are on the horizon, and poultry is prospected to be highly demanded, it can be beneficial to invest in poultry production to release pressure on future generations.

7.1 Further Studies

Some suggested research for future studies in order to achieve in-depth knowledge on how to develop the feed industry and a circular system:

- Since one of the study's conclusions is the crucial role of politicians, and where there is currently a knowledge-gap and little interest in the subject. Sweden aims at a circulating system with food waste, and one future study could be toward subsidies for needed facilities and what scale the facility should have.

- The industry's location is essential to take into consideration since it will be more environmentally friendly to place it close-by to residual heat. Further studies can be focused on what residual heats exists in Sweden and how the heat can be facilitated in the insect industry.

- This study did not cover all critical stakeholders. Further studies would be needed to cover critical stakeholders' perspectives and consult them, evaluate wants and needs, and construct a comparable information system. Municipalities in Sweden are needed to take into consideration since they are responsible for waste management in Sweden. Furthermore, additional non-critical stakeholders are needed to be defined since they will be affected by the critical stakeholders.

- Yellow mealworms could potentially nourish on substrate humans can eat directly, and BSF can nourish on a substrate that is almost rotten. Therefore, further studies must investigate what substrate would be most useful to feed to yellow mealworm and BSF without any alternative use. It is also essential to consider both amino acids and essential fatty acids in substrates since too low levels will impact both the health and productivity of poultry.

- The primary data in this study were not gathered from the survey. Therefore, further research based on consumer attitudes with statistically significant results might increase insects' importance as feed.

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Personal Messages

Alm, Malin
Project Manager, Vreta Kluster
Zoom interview, (2020-11-05)

Berggren, Åsa

Professor, SLU
Zoom interview, (2020-10-14)

Carlsson, Åsa
Product Manager, Svenska Foder
Email, (2020-11-04)

Elander, Jeanette
Farmer and President, Svenska Grisföretagare
Zoom interview, (2020-11-04)

Hanssen, Christin
Project Manager, Axfoundation
Zoom meeting, (2020-10-12)

Ivarsson, Emma
Senior Lecturer, SLU
Zoom interview, (2020-10-27)

Lalander, Cecilia
Scientist, SLU
Zoom interview, (2020-11-03)

Ling, David
Spokesperson, Youth wing of the Swedish Green Party
Zoom interview, (2020-10-12)

Persson, Olof
Head of department for consulting/ entrepreneurship, Växa
Zoom interview, (2020-10-19)

Petterson, Anita and Malmström, Maria
Head of feed & Manager of production, Swedish Agro
Zoom interview, (2020-11-09)

Schenk, Jessica and Bonet, James
Feed and infection control administrators, The Swedish Board of Agriculture
Zoom interview, (2020-10-26)

Tovatt, Lorentz
Member of Parliament, The Swedish Green Party
Personal interview, (2020-10-16)

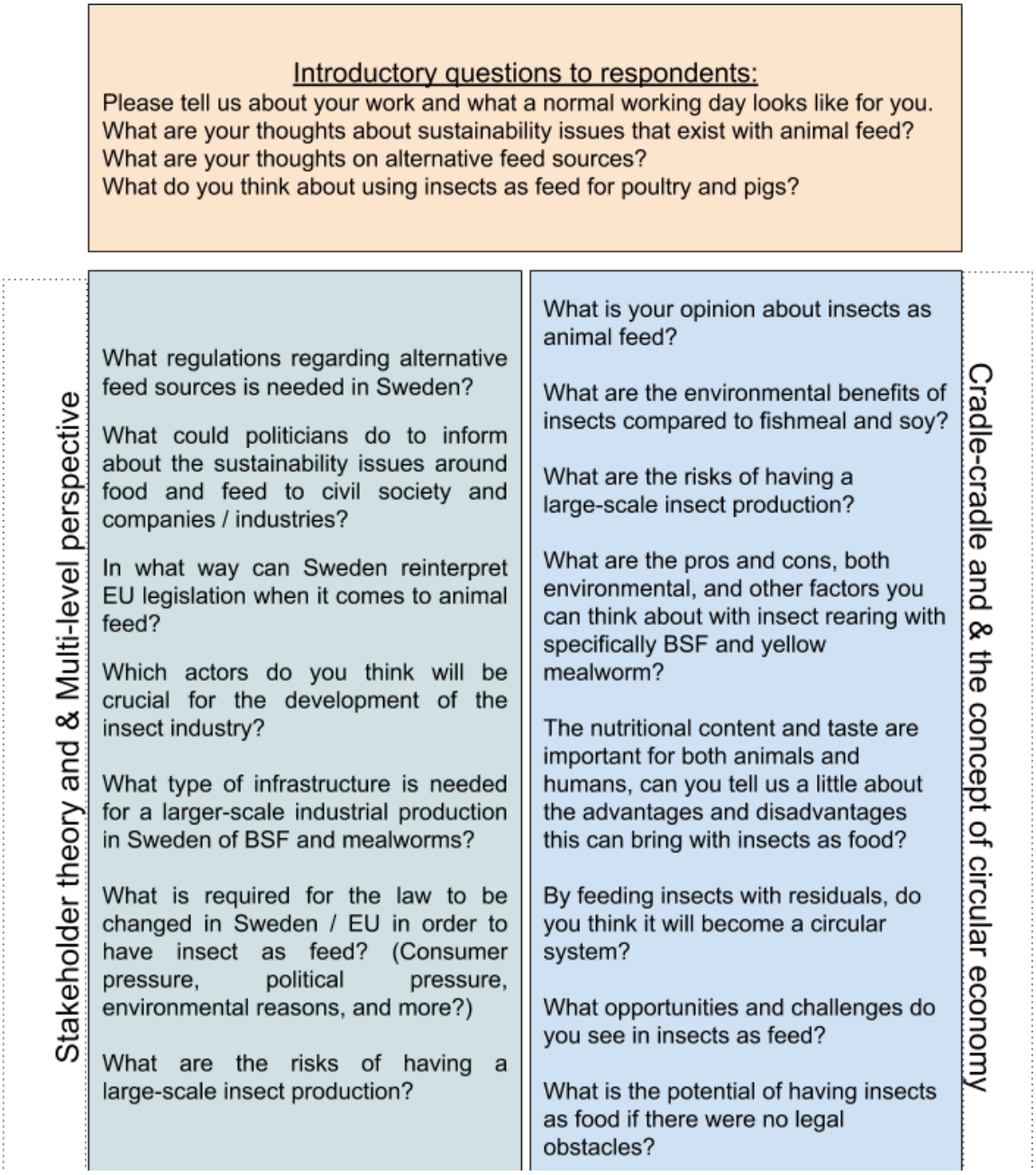
Öhrlund, Isak
National Board Member, Swedish Social Democratic Youth League (SSU)

Personal interview, (2020-10-15)

Österström, Nils
CEO and Co-founder, Tebrito
Phone interview, (2020-10-8)

Appendix I - Interview guide

These are the prepared questions for our semi-structured interviews. Some respondents were mostly asked questions from the stakeholder theory & multi-level perspective, while some stakeholders were asked mostly questions from cradle-cradle & circular economy. Additional questions which were not prepared were also asked during the interview dependent on which direction the interview went.



Interview questions are also available in Swedish and can be found here!

Appendix II - Survey questions

Do you live in Sweden?

- Yes
- No

How old are you? *

- Under 18
- 18-30
- 31-40
- 41-50
- 51-60
- 60+

Gender *

- Female
- Male
- Prefer not to say
- Other

Do you live in a...

- ◯ City with more than 300 000 inhabitants
- ◯ City with 300 000 - 100 000 inhabitants
- ◯ City less than 100 000 inhabitants
- ◯ On the countryside

In which county do you live in? *

- ◯ Blekinge County
- ◯ Dalarna County
- ◯ Gotland County
- ◯ Gävleborg County
- ◯ Halland County
- ◯ Jämtland County
- ◯ Jönköping County
- ◯ Kalmar County
- ◯ Kronoberg County
- ◯ Norrbotten County
- ◯ Skåne County
- ◯ Stockholm county

- ◯ Södermanland County
- ◯ Uppsala County
- ◯ Värmland County
- ◯ Västerbotten County
- ◯ Västernorrland County
- ◯ Västmanland County
- ◯ Västra Götaland County
- ◯ Örebro County
- ◯ Östergötland County

Education level *

- ◯ Elementary school
- ◯ High school
- ◯ Higher education
- ◯ Vocational training

Food preferences *

- ◯ I eat everything
- ◯ Vegetarian
- ◯ Vegan
- ◯ Flexitarian

Do you follow food trends? (examples: banana bread, coconut water, kombucha etc) *

- ◯ Yes
- ◯ No
- ◯ Sometimes

Are you familiar with some environmental challenges regarding food? *

- ◯ Yes
- ◯ No

What kind of environmental challenges related to food do you know of?

Kort svarstext

On a scale from 1-5, what is your opinion about feeding farm animals with insects? *

	1	2	3	4	5	
Dislike alot	◯	◯	◯	◯	◯	Like alot

Does the previous question depend on which farm animal its regarding?

- ◯ Yes
- ◯ No

Please choose which are more preferable to feed with insects, according to you?

- ☐ Cows
- ☐ Pigs
- ☐ Poultry
- ☐ Sheep/goats
- ☐ Fish

Would you eat meat fed on insects?

- Yes
- No
- Maybe
- I do not eat meat

Would you eat an insect?

- Yes
- No
- Maybe
- I have already tried

Imagine a scenario where you are eating with a group of friends or collegues during your lunch break, and you have brought a lunchbox with insects. You are the only one in the company with this type of food. How would that make you feel?

Kort svarstext

Do you believe insects will be a part of the food system in the future?

- Yes
- No
- Maybe

Appendix III - Detailed information of respondents in the survey.

	#	Educational level				Food preferences				Follow food trends			Positive toward eating meat fed on insects				Positive towards eating insects			
Age	Men	Elementary school	High school	Higher education	Vocational training	Omnivore	Vegetarian	Vegan	Flexitarian	Yes	No	Sometimes	Yes	No	Dont eat meat	Maybe	Yes	No	Maybe	Already tried
18-30	28	1	3	22	2	24	3		1	4	11	13	14	4	1	9	11	6	9	1
31-40	11		3	8		7		2	2	4	4	3	7	3		1		6	3	2
41-50	6	1	1	4		6					4	2	2	2		2		5	1	
51-60	8		1	7		8				1	1	6	6	2			1	2	5	
60+	4	1		3		3		1		1	2	1	3	1				1	3	

	#	Educational level				Food preferences				Follow food trends			Positive toward eating meat fed on insects				Positive towards eating insects			
Age	Women	Elementary school	High school	Higher education	Vocational training	Omnivore	Vegetarian	Vegan	Flexitarian	Yes	No	Sometimes	Yes	No	Dont Eat meat	Maybe	Yes	No	Maybe	Already tried
18-30	58		4	53	1	25	14	4	15	4	17	37	23	2	15	18	8	22	20	8
31-40	14			14		5	6	1	2	3	4	8	6	2	3	3	1	5	7	1
41-50	8			8		6	1		1	1	3	4	3	1	3			5	3	
51-60	8		5	3		7			1	2	1	5	2	1	5			2	6	
60+	5			5		4			1		3	2	2		3		1	1	3	

	#	Educational level				Food preferences				Follow food trends			Positive toward eating meat fed on insects				Positive towards eating insects			
Age	Other/PNT	Elementary school	High school	Higher education	Vocational training	Omnivore	Vegetarian	Vegan	Flexitarian	Yes	No	Sometimes	Yes	No	Dont eat meat	Maybe	Yes	No	Maybe	Already tried
18-30	1			1					1			1			1			1		
31-40																				
41-50																				
51-60																				
60+	2		2				1	1			2		1	1			1		1	

	#	Educational level				Food preferences				Follow food trends			Positive toward eating meat fed on insects				Positive towards eating insects			
Age	All groups	Elementary school	High school	Higher education	Vocational training	Omnivore	Vegetarian	Vegan	Flexitarian	Yes	No	Sometimes	Yes	No	Dont eat meat	Maybe	Yes	No	Maybe	Already Tried
18-30	87	1	7	76	3	49	17	4	17	8	28	51	37	6	17	27	19	29	29	9
31-40	25	0	3	22	0	12	6	3	4	7	8	11	13	5	3	4	1	11	10	3
41-50	14	1	1	12	0	12	1	0	1	1	7	6	5	3	3	2	0	10	4	0
51-60	16	0	6	10	0	15	0	0	1	3	2	11	8	3	5	0	1	4	11	0
60+	11	1	2	8	0	7	1	2	1	1	7	3	6	2	3	0	2	2	7	0
Total:	153	3	19	128	3	95	25	9	24	20	52	82	69	19	31	33	23	56	61	12